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The Donald C. Hellmann Task Force Program

### A MULTI-PERSPECTIVE ANALYSIS OF RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA:

A Ghana Case Study



# AFRICAN ENERGY INTERVENTION: GHANA CASE STUDY

Task Force Report

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# GLOSSARY

**1V-1D** One Village, One Dam  
**3SIL** Strategic Security Systems International  
**ACET** Africa Centre for Economic Transformation  
**AfDB** African Development Bank  
**BAG** Biogas Association of Ghana  
**BPA** Bui Power Authority  
**BSE** Black Star Energy  
**CBFM** Community-Based Forest Management  
**CEESD** Centre for Energy Environment and Sustainable Development  
**CFMP** Community Forest Management Project  
**COPD** Heinrich Obstructive Pulmonary Disease  
**CSOs** Civil Society Organizations  
**DER** Distributed Energy Sources  
**ECG** Electricity Company of Ghana  
**EPA** Environmental Protection Agency  
**ESI** Electricity Supply Industry  
**EU** European Union  
**FLEGT** Forest Law Enforcement Governance and Trade  
**GEDAP** Ghana Energy Development and Access Project  
**GIPC** Ghana Investment Promotion Centre  
**GoG** Government of Ghana  
**GSS** Ghana Statistical Service  
**GWh** Gigawatt hours  
**HAP** Household Air Pollution  
**IDO**s International Development Organizations  
**IPP** Independent Power Producer  
**kW** Kilowatt  
**LPG** Liquid Petroleum Gas  
**MCC** Millennium Challenge Corporation  
**MFI** Microfinance Institutions  
**MMDAs** Metropolitan, Municipal, and District Assemblies  
**MW** Megawatts  
**MWh** Megawatt hour  
**MWp** Megawatt peak  
**NDC** National Democratic Congress  
**NEDCo** Northern Electricity Distribution Company  
**NEPAD** New Partnership for Africa's Development  
**NES** National Electrification Scheme

**NGOs** Non-Governmental Organizations  
**NITS** National Interconnected Transmission Grid  
**NPP** National Patriotic Party  
**ODA** Official Development Assistance  
**OECD** Organization for Economic Co-operation and Development  
**PDS** Power Distribution Services  
**PPA** Power Purchasing Agreement  
**PPP** Public-Private Partnership  
**PURC** Public Utilities Regulatory Commission  
**PUWU** Public Utility Workers Union  
**PV** Photovoltaic  
**REDD+** Reduced Emissions from Deforestation and Forest Degradation  
**REMP** Renewable Energy Masterplan  
**RETs** Renewable Energy Technologies  
**RETT** Renewable Energy Technology Transfer  
**REP** Rural Enterprises Programme  
**RPR** Residue to Product Ratio  
**SHEP** Self-Help Electrification Program  
**SHP** Small Hydropower Project  
**SHS** Solar Home System  
**SMFEs** Small and Medium forest Enterprises  
**SPS** Strategic Power Solutions  
**SSA** Sub-Saharan Africa  
**TLAS** Timber Legality Assurance System  
**TTA** Trama Techno Ambiental  
**TUC** Trade Union Congress  
**TWh** Terawatt-Hours  
**UNDP** United Nations Development Programme  
**UNEP** United Nations Environment Programme  
**UNFCCC** United Nations Framework Convention on Climate Change  
**UNT** Universal National Tariff  
**USAID** United States Agency for International Development  
**USTDA** United States Trade and Development Agency  
**VPA** Voluntary Partnership Agreement  
**VRA** Volta River Authority  
**WAPP** West African Power Pool



## EXECUTIVE SUMMARY

Limited access to reliable electricity in sub-Saharan Africa (SSA) is one of the most pressing global dilemmas today. With the incredibly diversifying and growing economy and population of youth, it is critical to address the need to transition to a future in which electricity is readily available and accessible with consideration to the social, political, and environmental implications at stake.

This report centers Ghana and its current energy landscape in regard to renewable sources because it is the ideal country to begin exploring this future through navigating regional issues concerning electrification and their prospective solutions. This report begins with a look into the substance of biogas, not in lieu of, but within biomass energy, which includes the present use of wood fuel and charcoal in mainly rural communities across Ghana. We then examine the substantial prevalence of hydropower and its climate-related limitations, which call for an expansion of the energy portfolio to include wind sources. Our third section addresses the considerable potential of solar energy as an increasingly reliable source especially for non- and low-electrified areas. Each of these renewable energy sources will be analyzed with political, economic, and social implications in mind.

While we recognize that complex and systemic problems underpin the roadblocks in achieving reliable, utilitarian, and accessible electricity, change can be implemented from the top-down to ensure progression in energy expansion with the benefit of Ghana and the needs of its people in mind. Our recommendations of improved infrastructure, social engagement, local and foreign investment, and government and policy changes include investor-funded education pathways, multi-sector coordination efforts, increased presence in foreign funded projects, and expansion of the Self-Help Electrification Program (SHEP).



# INTRODUCTION

Access to reliable energy and electrification is imperative to the development of any nation, state, or region. The ability to produce and supply consistent energy and electrification is directly linked to the economic, political, social prosperity, and an overall better quality of life for every nation and its people. Understanding the need for generating energy and accessible electrification, however, is not the same as providing them. As people's dependence on technology and global populations continue to rise, the need for countries to increase their energy generation and production of reliable and affordable electricity also continues to rise. Currently, the world is in an era of accelerating change that demands an urgent shift to limit the effects of climate change whilst achieving sustainable growth, all of which have strengthened the global energy transformation. Fully electrified countries are shifting towards a more integrated use of environmentally-friendly energy sources such as solar, wind, and biomass technology to maintain their full-scale electrification. However, we must acknowledge that reliable access to energy has not reached the coveted state of universality wished upon it by the world. In addition, the anthropogenic impacts of long term fossil fuel use and greenhouse emissions have created further complications and barriers that disproportionately affect regions like sub-Saharan Africa (SSA). The global movement towards environmentally-friendly energy generation, although commendable, places pressure on the countries of SSA who are still actively working toward providing affordable and reliable electricity to their populations.

## ***The Sub-Saharan Case of Energy and Electrification***

While some regions such as East Asia have managed to significantly catch up to the 150 year head start of countries within Europe and the United States, other regions such as SSA still lag behind in regard to energy generation and consistent, and affordable provision of electricity to its inhabitants. This lag results in a region in which approximately only two-fifths of the population has access to electricity and nearly 600 million people in SSA live without it.<sup>1</sup> Even with the many strides being made in the region, according to the International Energy Agency (IEA), these efforts still fall short. The IEA, a Paris-based autonomous intergovernmental organization established in the framework of the Organization for Economic Co-operation and Development (OECD) reports in its 2019 African Energy Outlook analysis, that only 45% of the region which

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<sup>1</sup> International Energy Agency, "Africa Energy Outlook 2019 – Energy Access." IRENA 2019.

includes 46 countries has access to electricity- comparatively low when taking into account other parts of the world.<sup>2</sup> The goal of this report is to not only understand why this problem persists, but to work towards feasible solutions that can meet the demands of the region while keeping in mind determinants such as population growth, foreign investments, the overall energy potential of SSA, and socio-economic factors including the rural-urban divide. Although numerous studies and scholars have written a disparaging narrative of SSA and its efforts towards electrification, the region is very much within a position of achieving its electrification goals. As Grimaldi puts it, Africa does not have the same fossil-fuel dependency as many other continents and countries do, which grants it the opportunity to greatly diversify its energy mix to include renewable energy technologies and even further decrease its limited use of fossil fuels.<sup>3</sup>

### ***Breakdown of Sub-Saharan Africa's Renewable Energy Potential***

The renewable energy landscape of SSA includes hydro, solar, wind, biomass, and geothermal sources. For the sake of this report we look at the breakdown of SSA's renewable energy potential across biomass, wind, solar, and hydro. Much of the total renewable energy of SSA is derived from hydropower, with a potential capacity of 35.7 GW and less than 13.8 GW derived from non-hydro sources such as solar, wind and geothermal energy.<sup>4</sup> In terms of solar, although solar irradiation in Africa is one of the highest levels globally, the installed capacity in SSA for solar is around 2GW, representing less than 1% of the world's solar capacity.<sup>5</sup> In SSA, a majority of areas experience in excess of 2000 kWh of solar radiation annually. Of the estimated 300 GW of hydropower capacity, only 8% of this is currently utilized, representing 84% of all non-fossil fuel energy use.<sup>6</sup>

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<sup>2</sup> Ibid.

<sup>3</sup> Jordan Grimaldi, "Models of Growth and Colonial Implications in the Renewable Energy Sector in Africa" 2018 Claremont Colleges Library Undergraduate Research Award. 6. [https://scholarship.claremont.edu/cclura\\_2018/6](https://scholarship.claremont.edu/cclura_2018/6), 1.

<sup>4</sup> International Renewable Energy Agency, "Planning and Prospects for Renewable Power: West Africa-Hydropower," 8.

<sup>5</sup> General Electric Company, "Re-Imagining the Future of Power in Sub-Saharan Africa" (2019) Accessed February 28, 2020 Digital.Pdf. [www.ge.com/content/dam/gepower-pw/global/en\\_US/documents/regions/africa/Re-imagining%20the%20future%20of%20power%20in%20Sub-Saharan%20Africa\\_Digital.pdf](http://www.ge.com/content/dam/gepower-pw/global/en_US/documents/regions/africa/Re-imagining%20the%20future%20of%20power%20in%20Sub-Saharan%20Africa_Digital.pdf). Accessed 28 Feb. 2020.

<sup>6</sup> Ibid.

A 2011 report on the potential of biomass energy for electricity generation in SSA, estimated energy generation potential of SSA at 15000 megawatts (MW) which could generate 100 terawatt-hours (TWh), equivalent to 15% of current generation in SSA.<sup>7</sup> In regards to the energy potential of wind the Global Wind Energy Council assessed in a 2019 report that SSA possesses 100 GW of wind energy potential.<sup>8</sup> Installed onshore wind farms currently generate only 5 GW of that 100 GW potential, meaning wind energy production accounts for only 1% of the African energy mix. Overall the renewable energy potential within SSA is enormous. However, these resources are grossly underutilized. These various sectors are in need of a holistic method of diversifying their energy portfolios that will integrate aspects of these sectors within the region and easing reliance on other means of energy generation like petroleum.

### ***Global Interests in Sub-Saharan Africa***

For decades, SSA has been the subject of foreign interests often exploitative in nature and to the detriment of its own interests. In recent years this interest has drawn new actors into SSA, in particular China which has increased its presence within the region. Additionally, development banks like World Bank and the African Development Bank continue to promote energy infrastructure projects with the support of most developed nations. With China's new role as a global economic superpower, it has begun funding development projects across Africa in many different infrastructure industries, typically under the framework of its Belt and Road Initiative. In Ghana, as in other areas of West and Central Africa with abundant hydrology resources, the Chinese government has funded various hydro-sector initiatives with the hope that new hydropower projects serve as a catalyst for further infrastructural development consistent with China's international goals.<sup>9</sup> The Chinese government's "Belt and Road" initiative which expands their influence into other energy sources such as crude oil, solar, and wind is an example of these international goals. As we look to the future of renewables as a source of energy generation in SSA, it is imperative that the relationships between SSA countries and foreign actors be scrutinized for the sake of identifying foreign partnership that are in the best interests of SSA countries.

<sup>7</sup> S Dasappa, Abstract to "Potential of biomass energy for electricity generation in sub-Saharan Africa." *Energy for Sustainable Development* 15, no. 3 (2011): 203. 2011, 209. <https://doi.org/10.1016/j.esd.2011.07.006>

<sup>8</sup> Global Wind Energy Council, "Market to watch: Africa," (2019). Accessed February 29, 2020. <https://gwec.net/winds-of-change-are-blowing-in-africa/>

<sup>9</sup> See for example French, *China's Second Continent: How a Million Migrants Are Building a New Empire in Africa.*

### ***The Rural Urban Divide***

It is without question that the continent of Africa has immense potential for energy generation with both fossil and renewable energy resources. With this knowledge, countries such as Tanzania have developed progressive policies and partnerships for harnessing these energy sources and increasing their electrification capacity. One example of how Tanzania is doing so is through the collaborative effort between the Tanzanian government and United States Agency for International Development (USAID)-Power Africa program to reform its national utility TANESCO. This partnership has resulted in 2,379,775 new off-grid connections, increasing the number of households with electricity,<sup>10</sup> a significant increase within the last 10 years where only 868,953 households had access to electricity prior to this partnership.<sup>11</sup> Nevertheless, the countries of sub-Saharan Africa must remain diligent and strategic if they wish to meet their goals of energy generation and electrification that address the specific needs of their individual countries. When examining the case of energy generation and electrification in SSA one must recognize the disparities not only between countries of the region but within. As is common for most places in the world, electrification in urban areas such as state capitals and other large cities/metropolises have greater access to some form of reliable energy and electricity while rural areas account for a larger portion of the data depicting the gross lack of electrification across SSA. The distribution of energy and electricity is a serious element that must be addressed if these countries want to achieve equity across their populations. There is a need for the creation of infrastructures, policies, and regulatory frameworks that prioritize equity of energy distribution. With the exception of Kenya, Ghana, and South Africa, most of the rural populations within SSA countries have only achieved rural electrification of 48 percent or less, a disparity that is prevalent throughout our research and present within our report.

### ***Why Ghana?***

Despite Ghana's comparatively high rate of electrification, the country still experiences a shortage of energy generation which results in power outages and blackouts. This energy inefficiency at its

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<sup>10</sup> U.S. Agency for International Development. *Power Africa in Tanzania | Power Africa | Fact Sheet 2019*.

<sup>11</sup> Energypedia. "Tanzania Energy Situation". Accessed March 2, 2020.  
[https://energypedia.info/wiki/Tanzania\\_Energy\\_Situation#References](https://energypedia.info/wiki/Tanzania_Energy_Situation#References)

peak resulted in what became known as the ‘dumsor’ phenomenon, an Ashanti word meaning “off/on” and the street term used to describe the constant, irregular, and unpredictable blackouts in Ghana. Although Ghana rates high among SSA countries in accessible electricity, these numbers do not reflect the power outages that frequently disrupt access, nor does it note the disparities in the accessibility between rural and urban communities- which is imperative to the process of providing universal electricity to Ghana.

In response, a task force of experts from the Ghanaian Ministry of Energy wrote the 2019 Renewable Energy Master Plan (REMP) to significantly increase the capacity of Ghana’s energy grid by 2030 with specific targets and action plans for solar, hydropower, wind, and biomass. Examples include implementing solar solutions such as solar crop dryers with an increase in research and development to mitigate high startup and maintenance costs with the hope of generating interests within the agriculture sector.<sup>12</sup> The REMP’s goal of electrification to 1000 off-grid areas partially stems from previous initiatives, including the Ghana Poverty Reduction Strategy of 2003 and the 1995 “Vision 2020”, that include energy resource development as a way to decrease reliance on the forest for wood fuel, implement rural energy programs, and recommend the expansion of the electricity supply in Ghana to decrease poverty and increase the accessibility of electricity. The plan focuses on providing a framework to invest in the development of renewable energy sources to create sustainable economic growth, contribute to improved social life, and reduce adverse climate change effects. This document also takes into account the resource availability and opportunities for energy resource development in Ghana and makes recommendations for interventions for the promotion and development of these resources. In addition to other goals, some strategies included in the REMP involve improving and sustaining the creation of Renewable Energy Technologies (RETs) in which Ghana has a competitive advantage promoting local participation to guarantee a local market. Overall, the REMP lays the foundation for the potential for Ghana to transform and expand its energy grid using RETs to increase self-sufficiency, while simultaneously developing as potential exporter of energy. According to the REMP in 2015, Ghana’s energy supply is largely dependent on petroleum along

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<sup>12</sup> Energy Commission of Ghana. “REMP.” United Nations Development Programme, 2019. Accessed January 29, 2020.  
[https://www.undp.org/content/dam/ghana/docs/Reports/UNDP\\_GH\\_SUS\\_DEV\\_REN\\_MASTER\\_PLAN\\_2019.pdf](https://www.undp.org/content/dam/ghana/docs/Reports/UNDP_GH_SUS_DEV_REN_MASTER_PLAN_2019.pdf)

with biomass and hydro. Petroleum was said to have contributed approximately 44.48% to the primary energy supply in 2015. Including energy imports and excluding energy exports, the energy mix was made up of 44.48% oil, 37.48% biomass, 5.27% hydroelectricity, and 12.38% natural gas.<sup>13</sup> In comparison, petroleum products accounted for 47% and biomass in the form of firewood, charcoal, and agricultural residue made up 40% of Ghana's final energy consumed, which measures the amount of energy consumed by end users, such as households. It is important to note that electricity generation from hydropower can fluctuate every year; in 2007 and 2015, electricity generation from this source was significantly lower due to low rainfall in the Volta basin.<sup>14</sup> With its strong lead in utilizing renewable energy sources through investing in research and strategies such as the REMP, Ghana is uniquely positioned to surpass other countries in SSA and the Global North in developing renewable energy technologies, providing rural communities with access to electricity, and tackling the issue of climate change through a focus on sustainability.

### ***The Structure of This Report***

This task force through extensive research into the present energy context of Ghana as it pertains to renewables, the infrastructures for this energy sources, political, social, and foreign actors, and generation and allocation of funds aims to present effective measures in preparation of this growth of renewables. Divided into three sections, we begin our report focusing on biomass as a current source of energy generation via wood fuel and charcoal. The social, political, economic, and environmental implications of this use are all analyzed for the purpose of developing a case for the inclusion of biogas within the biomass sector of energy and the renewable energy portfolio of Ghana as a whole. The second section delves into the considerable presence of hydropower in Ghana's energy mix, as well as the potential for diversification with other sources, such as wind, to supplement the shortcomings of hydropower due to extreme weather patterns. We look into existing Ghanaian projects in hydropower and wind and a comparison of utility scale and small scale systems to better maximize the generation capacity of each source, respectively. We then address current economic and political roadblocks to success in hydropower and wind electrification which we acknowledge as barriers that intersect with the colonial history of Ghana. The third section details the current landscape of solar energy in the region, including access to

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<sup>13</sup> Ibid, 3.

<sup>14</sup> Energy Commission of Ghana. "REMP." 2020.

electricity, suppliers, and methods to meet Ghana's energy needs through solar power. We follow this with an exploration of the potential use of solar in agriculture and consider the political factors that affect the development of this technology. We also discuss the benefits of solar energy, methods of financing, and future access. To conclude, we explore the capabilities of microgrids, examine operational challenges, and review the role of the local government in addressing the energy needs of Ghana through solar power.

## I. BIOMASS

Ghana is heavily reliant on biomass, particularly wood fuel used for cooking and heating, to meet its energy needs.<sup>15</sup> Organic material as a source of energy generation can be traced back to the earliest instance of man using fire, but technologies now exist that allow the energy potential of biomass to be converted to distributable electricity. It is clear biomass will continue to play a major role in the daily life of Ghanaians for decades to come, but the potential of newer biomass technologies has not been fully capitalized on.

As Ghana's demand for energy continues to grow, a diversification of existing energy production methods is necessary to ensure strong and reliable power for years to come. Although expanding the national grid to serve distant customers is important to achieving full electrification in Ghana, the existing system is riddled with distribution and reliability issues.<sup>16</sup> Ghana's energy sector needs to work towards lessening the strain on existing power generation systems and to foster solutions that are viable in remote communities. Biogas--which relies on human, animal, and agricultural waste-- and biomass gasification-- which relies on agricultural residues-- have both shown huge promise in the biomass energy sector. Even better both technologies are naturally suited for off-grid communities of varying sizes. Biomass energy is already commonplace throughout the continent for cooking and heating, but the potential of its more sustainable variations to generate electricity in Ghanaian off-grid communities has not been fully realized.<sup>17</sup>

### ***Context: Charcoal and Wood fuel***

Wood fuel and charcoal production has been a major source of energy in Africa for many years. The industry itself supports the economies of local communities at the domestic level by providing an accessible, low-cost source of energy as well as poverty alleviation as it allows to tap into a

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<sup>15</sup>Abubakari Ahmed, Benjamin Bety Campion, and Alexandros Gasparatos, "Biofuel Development in Ghana." *Renewable and Sustainable Energy Reviews* 70 (2017): 133, <http://www.sciencedirect.com/science/article/pii/S1364032116309856>

<sup>16</sup>Ebenezer Nyarko Kumi, "The Electricity Situation in Ghana: Challenges and Opportunities." *Washington, DC: Center for Global Development. CGD Policy Paper*, no.109 (2017) <https://www.cgdev.org/publication/electricity-situation-ghana-challenges-and-opportunities>. 8-10.

<sup>17</sup> Ahmed, Campion, and Gasparatos, "Biofuel Development in Ghana.", 133.

widely available source at very low capital costs.<sup>18</sup> In spite of the world's collective shift towards renewable energy sources, it is important to note the reality in SSA regarding this shift. Many sources of renewable energy are not feasible for many years to come, and in practice their capacity for energy production is a fraction relative to their potential maximum output.<sup>19</sup> Therefore, despite the pursuit of renewable energy methods, the development of more sustainable energy production concerning wood fuel and charcoal is vital. Sustainability in regard to the charcoal and wood fuel production processes will mitigate their negative effects on global climate change. In its current state, the production process includes the carbonization of wood and other bio-substances which leads to pyrolysis, and results in producing charcoal.<sup>20</sup> This process is time consuming and efficiency depends on multiple factors, including the type of kiln used, the dryness of the wood being burned, among others. This needs to be taken into consideration when implementing recommendations in regard to charcoal and wood fuel, given that as an energy source they are widely used, and impact the daily lives of millions of people. The charcoal and wood fuel industry spans worldwide, providing an accessible and reliable energy source for many regions. Today this energy source is relied upon primarily by countries in the Global South. Domestic and household use comprise much of the demand for wood fuel, which represents “60 to 80 percent of total wood consumption in these nations; wood fuels often accounts for 50 to 90 percent of all energy used.”<sup>21</sup> Though domestic use is not the only method of use for wood fuel and charcoal, it is the focus of this report.

### ***Implications of Charcoal and Wood fuel Production and Use***

#### ***Economic***

In examining the current economic landscape of the charcoal and wood fuel industries, it is clear that despite its widely perpetuated negative impact, its importance as an energy source across the world is remarkable. In regions such as South East Asia, Latin America and sub-Saharan Africa (SSA), these methods are actively growing, providing employment opportunities, and generating

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<sup>18</sup> Leo C Zulu, and Robert B. Richardson, "Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa." *Energy for Sustainable Development* 17, no. 2 (2013): 127-137.

<sup>19</sup> Scott Montgomery, "African Energy Presentation." Lecture, University of Washington, January 20, 2020.

<sup>20</sup> Peiter van Beukering et al., "Optimization of the Charcoal Chain in Tanzania," Institute for Environmental Studies (IVM), May 2007, 2.

<sup>21</sup> Energy Sector Management Assistance Program. "*Commercial Wood fuel Production: Experience from Three Locally Controlled Wood Production Models*". World Bank, October 2012, 1.

income and ultimately contributing to poverty alleviation.<sup>22</sup> Charcoal and fuelwood as sources of energy production will continue to be prevalent for years to come because of their accessibility to smaller communities and supplementation in household incomes year round. Charcoal is a commonly utilized source of heat and cooking fuel that is preferred in many cases over ‘modern’ sources of energy because it is inexpensive, readily available, and part of a stable supply market.<sup>23</sup> According to Arnold et al., charcoal production fosters economic growth while decreasing the dependence of poorer developing countries on non-cost effective methods of energy import. This is achieved through mostly domestic enterprises referred to as small and medium forest enterprises (SMFEs) in which a high percentage of Ghana’s population participates.<sup>24</sup>

This report focuses on the region of SSA, but specifically examines Ghana’s domestic energy production. In regard to charcoal and wood fuel, this leads to the examination of SMFEs. Despite the fact that large-scale export business comprises most of the regulated, formal forest sector in Ghana, SMFEs constitute the informal, domestic sector and promote not only the accumulation of wealth but the empowerment of local entrepreneurship.<sup>25</sup> SMFEs represent the sector of business that the charcoal and fuelwood supply chain falls under, which is defined as “forestry related enterprises that employ one person or few people” and are “characterized by having minimal capital and employing informally trained workers.”<sup>26</sup> This displays domestic enterprise potential, especially in rural areas where professional training is not always accessible to the entire population. In Ghana, the majority of domestic enterprises and SMFE’s already established fall under the category of sole proprietorship businesses in which both men and women are engaged.<sup>27</sup> Despite key challenges faced in this industry, there are clear opportunities for income generation, poverty alleviation, and expansion of local entrepreneurship through SMFE’s.

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<sup>22</sup> Keith Openshaw, “Biomass Energy: Employment Generation and Its Contribution to Poverty Alleviation.” *Biomass and Bioenergy* 34, no. 3 (2010): 365–78.

<sup>23</sup> Zulu, and Richardson, “Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa.” 127–37.

<sup>24</sup> J.e. Arnold Michael, Gunnar Köhlin, and Reidar Persson, “Wood fuels, Livelihoods, and Policy Interventions: Changing Perspectives.” *World Development* 34, no. 3 (2006): 596–611.

<sup>25</sup> Reem Hajjar, “Advancing Small-Scale Forestry under FLEGT and REDD in Ghana.” *Forest Policy and Economics* 58 (2015): 12–20.

<sup>26</sup> Paul Osei-Tutu et al., “*Small and Medium Forest Enterprises in Ghana: Sourcebook on Enterprise Characteristics, Activity Centres, Product Markets, Support Institutions and Service Providers*,” IIED Small and Medium Forest Enterprise Series No. 28, v.

<sup>27</sup> Ibid.

Around the world, the charcoal and fuelwood markets provide income generation opportunities throughout their value chains, including directly involved positions such as producers, transporters, traders and consumers, and additional indirect actors.<sup>28</sup> When seasonal and full time employment in regional value chains are generated, they cover large scale commercial production, casual production, wholesale trade, and retail sale.<sup>29</sup> The aforementioned direct actors and the entities that mediate each specific portion of the wood fuel and charcoal production chain illustrate the wide reach that charcoal production has on Ghanaian society at all levels of involvement (Figure 1.1).

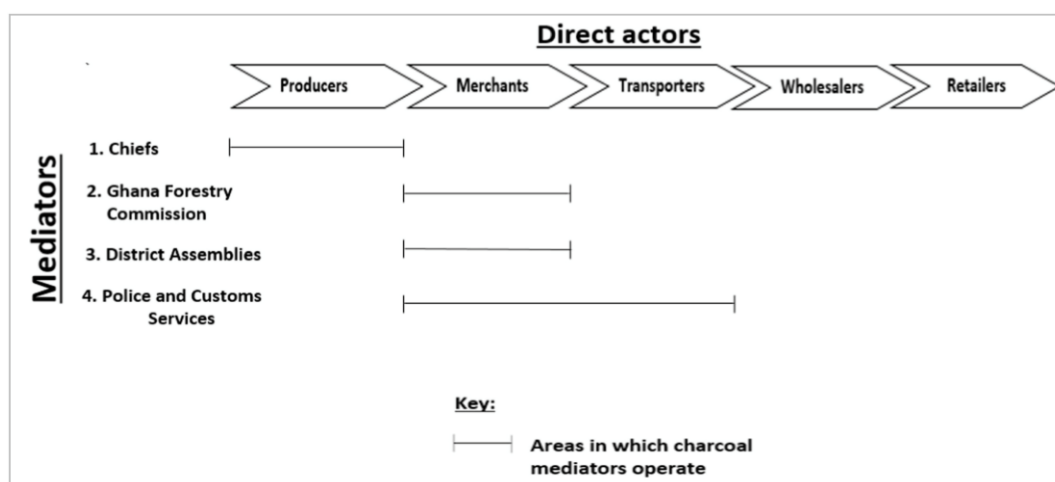


Figure 1.1. The direct actors and mediators and their involvement in the wood fuel and charcoal production chain. Agyei et al., "Profit and Profit Distribution along Ghana's Charcoal Commodity Chain," (chart), *Energy for Sustainable Development* 47, (December 2018), 63.

In Ghana, the income generation of the charcoal and wood fuel market is distributed along the production chain above. A study completed in Ghana, specifically the cities of Kumasi, Takoradi, and Accra, reports that the highest annual income of individuals participating in this market is higher than the average national income.<sup>30</sup> The positions along the production chain earn differing income amounts, and in Ghana, the highest earning position is the merchant due to their control

<sup>28</sup> Patrick Kambewa, "Charcoal--the Reality: a Study of Charcoal Consumption, Trade, and Production in Malawi," London: International Institute for Environment and Development, 2007, 15.

<sup>29</sup> Zulu, and Richardson, "Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa." 127–37.

<sup>30</sup> Ibid.

over the market price of the charcoal itself. However, depending on market climate, the wages of each position along the production chain do fluctuate. This is partially due to the involvement of these different actors in a diverse array of income generation, including participation in other markets such as agriculture and other forms of trade.

Economic challenges arise in regard to the charcoal and wood fuel market and SMFEs in general. These include “lack of tenure security, excessive bureaucracy, unfavorable policies and legislation, poor market access and information, lack of access to credit, weak bargaining power, and insufficient business training.”<sup>31</sup> This presents economic challenges for the government and in upholding the respective economies that rely on this market. For example, this affects the potential revenue payable to the government from effective charcoal production and trade and consequently results in lost revenue. The informal nature of this sector also limits its ability to provide long-term stable income, promoting ‘short-termism’ resulting in over-exploitation of resources.<sup>32</sup> Furthermore, the lack of regulation leaves the participating population vulnerable to corruption at transportation checkpoints and the undercutting of producer net incomes/ government revenues that could have been used for poverty reduction.<sup>33</sup> Generally speaking, significant challenges arise in the charcoal and fuelwood production chain, however, this sector is continuously growing as a result of its income generation benefits and accessibility to the populations most in need.

### *Political*

The current political landscape includes fluctuating attitudes towards the production and use of charcoal and fuelwood as sources of energy. To provide context, in the 1970s and 1980s, talk of an impending fuelwood crisis contributed significantly to a negative perception of charcoal production. As Bergmann, Roden and Nusser put it, “population growth coupled with inefficient techniques of wood energy production and consumption was expected to cause almost complete deforestation in wood fuel-dependent countries by the turn of the 21st century.”<sup>34</sup> This narrative

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<sup>31</sup>Hajjar, Reem. “Advancing Small-Scale Forestry under FLEGT and REDD in Ghana.” *Forest Policy and Economics* 58 (2015): 12–20. <https://doi.org/10.1016/j.forpol.2014.09.014>.

<sup>32</sup> “Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania,” World Bank, 2.

<sup>33</sup> Zulu, and Richardson, “Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa.” 127–37.

<sup>34</sup> Christoph Bergmann, Paul Roden, and Marcus Nüsser, “Contested Fuelscapes: Producing Charcoal in Sub-Saharan Drylands.” *Area* 51, no. 1 (2017): 55–63.

discouraged governments from developing comprehensive policy regarding charcoal during the time, and consequently set the tone for increased emphasis on other sources of energy. In recent history, concepts such as the transition theory and energy ladder have contributed to the stigmatization of charcoal and wood fuel as a fuel source. Focusing on wood fuel and charcoal production policy in Ghana provides the population with accessible, affordable forms of energy and increased sustainable practices resulting in the mitigation of climate change from their production chains.

The aforementioned energy transition theory was initially theorized by the Global North in response to the fuelwood crisis. It was established based upon key societal and economic observations: positive correlation of economic growth and usage of modern fuel, regional developments in improving ‘modern’ fuel access and household incomes, and the transition from traditional biomass fuel methods to modern fuel methods. This was historically seen as a marker of development and economic prosperity because of its association with urbanization and industrialization and still today displays those effects. The shifted focus from ‘traditional’ to ‘modern’ fuel methods speaks to the inherent assumption of the inferiority of underdevelopment, because “in the poorest developing countries biomass fuels account for 60-95% of total energy use, in middle income countries for 25-60% and in high-income, industrialized countries - with minor exceptions - for less than 5%.”<sup>35</sup> The use of charcoal, wood fuel, as well as any other long-established forms of energy are therefore equated with the negative characteristics of ‘underdevelopment.’ This is detrimental to any countries in which these energy sources are important, because the energy transition theory and its consequent stigmatization of traditional energy was imposed upon developing countries in combination with expectations of accelerated modernization. The effects of this lie in the rapid shift in focus from charcoal and wood fuel energy sources to renewable energy sources. While this is important for the future of energy, it is essential to further expand upon potential sustainable policy in regard to charcoal and wood fuel. Related to the energy transition theory is the concept of the ‘energy ladder’ which refers to certain methods of fuel being more highly regarded in social context than others.<sup>36</sup> This ladder is hypothetical but

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<sup>35</sup> Gerald Leach, “The Energy Transition.” *Energy Policy* 20, no. 2 (February 1992): 116–23.  
[https://doi.org/https://doi.org/10.1016/0301-4215\(92\)90105-B](https://doi.org/https://doi.org/10.1016/0301-4215(92)90105-B).

<sup>36</sup> *Ibid.*

represents real effects on the general population, especially in household settings which collectively tend to be the largest consumers of energy in developing countries.<sup>37</sup> Considering the ‘energy ladder,’ residential energy consumers are presumed to have an inherent ranked preference for different fuels based on physical characteristics including cleanliness, ease of use, cooking speed and efficiency with biofuels at the bottom and electricity at the top.<sup>38</sup> This concept is still relevant, also contributing to the stigma surrounding charcoal and wood fuel. However, despite these concepts and their negative impacts, within the last 20 years there have been significant additions to charcoal and wood fuel policy, in which Ghana has participated.

Ghana has taken steps to mitigate the impact of the charcoal and wood fuel industry on climate change, including not only domestic (explained in later sections), but international policies that partner with entities such as the European Union (EU). The Forest Law Enforcement, Governance and Trade policy (FLEGT), in addition to the Voluntary Partnership Agreement (VPA) display this effort. Initially adopted in the European Union in 2003, this action plan aims to combat illegal logging and the trade of illegal timber products in global markets consequently addressing deforestation.<sup>39</sup> Ghana is one of six African countries involved in this agreement with the EU, which is overseen by a committee comprised of representatives (government agencies, civil society, and private sector) originating from each respective country. The voluntary partnership agreements are a key element of the FLEGT, characterized as bilateral negotiations that “define what ‘legal timber’ is in the country of origin and outlines a Timber Legality Assurance System (TLAS) which is subsequently put in place to verify and certify legality.”<sup>40</sup> It is reported that the implementation of the FLEGT initiative has led to a multitude of benefits, including: providing an effective platform for non-governmental organizations (NGOs) and other domestic stakeholders to raise problems, improve accountability, and track systems that aid in more sustainable forest management practices.<sup>41</sup> This is an example of policy that has been enacted in an effort to improve

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<sup>37</sup> Ibid.

<sup>38</sup> R.h Hosier, and W. Kipondya, “Urban Household Energy Use in Tanzania.” *Energy Policy* 21, no. 5 (1993): 454–73.

<sup>39</sup> Christian P Hansen, Rebecca Rutt, and Emmanuel Acheampong, “‘Experimental’ or Business as Usual? Implementing the European Union Forest Law Enforcement, Governance and Trade (FLEGT) Voluntary Partnership Agreement in Ghana.” *Forest Policy and Economics* 96 (2018): 75–82.

<sup>40</sup> Ibid.

<sup>41</sup> Ibid.

forest governance, and represents Ghana's willingness to move forward with more sustainable practices related to charcoal and wood fuel. Improving forest governance such as this is vital to the development of the wood fuel and charcoal industry, however certain barriers arise and impede these efforts. In SSA, the barriers to sustainable charcoal production are displayed "in a lack of coherent energy policies specifically addressing residential energy needs and in biases toward industrial energy resources, as well as outdated forest policies that put control of forest resources in the hands of centralized agencies, which rarely recognize energy as an important forest product."<sup>42</sup> The above policy, amid a very complex issue of political and governmental involvement in forest related industry seems to provide the structure that Ghana aims to achieve. However, it is very clear that without implementation and regulation of these policies as a priority, their success will be limited.

### *Environmental*

The charcoal and wood fuel production chain represents a complex dynamic in which its effects on society are both positive and negative. Ghana has generally been described as being ahead of other countries in SSA, for "progressive policies, comprehensive laws, relatively well-developed institutions and a handful of well trained professional foresters and policy analysts."<sup>43</sup> However in regards to the environment, it is well known that the impact charcoal and wood fuel has on climate change is unavoidable, and needs to be addressed. Wood fuel and charcoal not only leave natural resources depleted but contribute heavily to total household greenhouse gas emissions and endanger the health of the general population and biota. There are many negative consequences to the use of charcoal and wood fuel, some of which include unsustainable deforestation practices, forest degradation, emissions, and harmful effects on biodiversity. It is widely understood that these negative impacts are due largely to unsustainable forest management and inefficient charcoal manufacture and wood fuel combustion.<sup>44</sup> This not only results in the negative impacts mentioned

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<sup>42</sup> R. Bailis, "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa." *Science* 308, no. 5718 (January 2005): 98–103. <https://doi.org/10.1126/science.1106881>.

<sup>43</sup> Albert A Arhin, and Mohammed-Anwar Sadat Adam, "Protecting the Environment for the Present and Future Generations: REDD+ and the Reversal of Deforestation in Ghana." *Ghana Studies* 17 (2014): 131-156.

<sup>44</sup> Jinke Van Dam, *Charcoal Transition: Greening the Charcoal Value Chain to Mitigate Climate Change and Improve Local Livelihoods*. Food and Agriculture Organization (FAO), 2017, 3.

above, but also in the loss of a large percentage of fuel energy.<sup>45</sup> Moving forward, it is clear that some of the detrimental nature of this fuel source around the world is due to infrastructural issues and lack of thorough implementation of already existing policy. Focusing and regulating sustainable policies that currently exist in Ghana, in addition to the efforts already taking place would cause a dramatic decrease in the contribution of wood fuel and charcoal to global climate change.

The impact of traditional fuelwood and charcoal production is measured using many factors, one of which is the combustion process which releases carbon dioxide CO<sub>2</sub>, black and organic carbon, aerosols and methane (CH<sub>4</sub>).<sup>46</sup> Charcoal sourcing from earth based kilns in which the environment is oxygen poor results in incomplete combustion, and therefore increases the contribution to climate change through the additional release of CH<sub>4</sub> and other organic carbon compounds.<sup>47</sup> The above chemicals are emitted annually in the production and use of fuelwood and charcoal, and comprise 2–7 percent of the total global anthropogenic emissions.<sup>48</sup> The loss of biodiversity is threatened through the charcoal and wood fuel production process due to unsustainable practices. The health concerns related to solid fuels (including charcoal and firewood among other sources) are directly connected to their applications within the home. The extremely common use of charcoal and wood fuel in Ghanaian households exposes the population to hazardous pollutants, including but not limited to sulfur, nitrogen oxides, and particulate matter due to inefficient and incomplete combustion.<sup>49</sup> This results in the occurrence of household air pollution (HAP) which is the number one environmental risk factor for death in the world, of which women and children are disproportionately affected.<sup>50</sup> Consequently, air pollution represents the third leading risk factor constituting 6.4% of the global disability-adjusted life years (DALYs) among children under

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<sup>45</sup> Eva Rehfuss, Sumi Mehta, and Annette Prüss-Üstün. "Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals." *Environmental Health Perspectives* 114, no. 3 (2006): 373–78. <https://doi.org/10.1289/ehp.8603>.

<sup>46</sup> Rob Bailis et al., "Getting the Numbers Right: Revisiting Wood fuel Sustainability in the Developing World." (2017)

<sup>47</sup> R. Bailis, "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa." *Science* 308.

<sup>48</sup> Jinke Van Dam, "Charcoal Transition: Greening the Charcoal Value Chain to Mitigate Climate Change and Improve Local Livelihoods," 1.

<sup>49</sup> F. Johnson et al., "What wood fuels can do to mitigate climate change. *FAO Forestry Paper*." (2010). 43.

<sup>50</sup> Kirk R. Smith et al., "Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution." *Annual Review of Public Health* 35, no. 1 (2014): 185–206. <https://doi.org/10.1146/annurev-publhealth-032013-182356>.

5 years, and the second leading risk factor in disease burden for women globally.<sup>51</sup> Combustion of these fuel sources dramatically increases the prevalence of chronic disease in individuals after consistent exposure, this includes diseases such as pneumonia (among other acute lower respiratory infections), chronic obstructive pulmonary disease (COPD), and lung cancer.<sup>52</sup> Additionally, unsustainable deforestation practices in the making of wood fuel and charcoal contributes largely to climate change.

Most charcoal production in Africa constitutes unsustainable forest mining of existing natural woodland stocks which creates a negative perspective on this source of energy.<sup>53</sup> A study conducted in Ghana displays deforestation at a rate that “may adversely influence the rainfall pattern of the study area since the amount of rainfall attracted to the area due to the presence of trees is likely to decrease and this may adversely affect agriculture.”<sup>54</sup> This study shows the concerning effects that deforestation can have, especially in areas heavily reliant on agriculture, such as Ghana. Further into the process of wood fuel and charcoal production, soil quality is negatively impacted. Initially, the soil is disrupted when the trees are harvested referred to as ‘low impact.’ However, the combustion that occurs in charcoal production as a result of the digging and carbonization processes considered to have ‘high impact’ effects on the soil namely land degradation.<sup>55</sup> This disrupts the ecosystem, which “ultimately undermines ecosystem services including elements of agricultural productivity and increases the vulnerability of poor farmers to food and livelihood insecurity.”<sup>56</sup> Overall the effects of the wood fuel and charcoal production chain are detrimental to the environment, and disproportionately affect the most vulnerable populations. This issue displays the need for an approach to charcoal and wood fuel production that is more sustainable, in addition to an increase in regulation of the market chain, which would

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<sup>51</sup> J David Spence, “Faculty of 1000 Evaluation for a Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990-2010: a Systematic Analysis for the Global Burden of Disease Study 2010.” F1000 - Post-Publication Peer Review of the Biomedical Literature, 2017. <https://doi.org/10.3410/f.719894684.793533485>. 2247.

<sup>52</sup> Rehfuess, Mehta, and Prüss-Üstün, “Assessing Household Solid Fuel Use.” 373-78.

<sup>53</sup> Zulu, and Richardson. “Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa.” 127–37.

<sup>54</sup> Selase K Adanu, T. Schneider, B. Stimm, and R. Mosandl. “Journal of Food, Agriculture and Environment.” *Journal of Food, Agriculture and Environment*, 2009, 241-247.

<sup>55</sup> Johnson et al., “What wood fuels can do to mitigate climate change.” 35.

<sup>56</sup> Zulu and Richardson, “Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa.” 127–37.

improve these negative effects and mitigate their impact on climate change. In Ghana, there are policies being developed that aim to mitigate the effects of charcoal and wood fuel production and use.

The Reduced Emissions from Deforestation and Forest Degradation (REDD+) strategy is, for example, a program that commenced in 2008 with the support of the chief executive of the forestry commission. It is a ‘voluntary mechanism’ under the United Nations Framework Convention on Climate Change (UNFCCC) that “incentivizes forested developing countries employing new strategies to reduce forest loss in order to cut the carbon emissions associated with such loss.”<sup>57</sup> The effort aims to significantly decrease the level of emissions related to deforestation and forest degradation over the next twenty years, whilst at the same time addressing threats that undermine ecosystem services and environmental integrity in order to maximize co-benefits from forests. Another measure Ghana has taken to mitigate the effects of wood fuel and charcoal on climate change is incorporating Community Based Forest Management (CBFM) into the Forestry Commission of Ghana. This was launched in 2003 under the Community Forest Management Project (CFMP), and funded by the African Development Bank (AfDB). It originally was “designed to rehabilitate degraded forest reserves while increasing production of Agricultural, wood and non-wood forest products and strengthening the capacity of relevant institutions.”<sup>58</sup> This strategy focused on the reserves of Ashanti, Brong Ahafo, Eastern and Western and aided in forest conservation efforts, responding to the overharvesting of forests.<sup>59</sup> CBFM efforts such as this have been shown to result in “rural livelihood improvement, poverty reduction, strengthening of civil society institutions, and decentralized democratic governance.”<sup>60</sup> It is clear from these efforts that Ghana has taken steps to improve the charcoal and wood fuel sector, in its continual growth. However, further development of sustainable policies in Ghana is vital to continue mitigating the effects of charcoal and fuelwood production.

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<sup>57</sup> Abdul-Razak Saeed, Constance Mcdermott, and Emily Boyd. “Examining Equity in Ghana's National REDD Process.” *Forest Policy and Economics* 90 (2018): 48–58. <https://doi.org/10.1016/j.forpol.2018.01.006>.

<sup>58</sup> Forest and Wildlife Sector Programmes. The Forestry Commission of Ghana. Accessed February 24, 2020. <https://www.fcghana.org/page.php?page=266&ion&typ=1>.

<sup>59</sup> Ibid.

<sup>60</sup> Energy Sector Management Assistance Program “*Commercial Wood fuel Production: Experience from Three Locally Controlled Wood Production Models*,” 2.

### *Social*

The intricacy of social involvement in the wood fuel and charcoal market spans the entirety of the production chain. From producers to retailers, there are social impacts of charcoal and wood fuel in areas such as on gender relations, health, and overall livelihood. This section focuses on the social implications of the role of gender in the charcoal production chain, and the disproportionate effects that charcoal and wood fuel use has on women and children. One report regarding gender inequalities displays that “access and control over productive resources, decision-making power and social and political capital, have all been found to limit women's equitable participation and beneficiation in value chains.”<sup>61</sup> In SSA studies have been done examining the involvement of gender in regards to charcoal and wood fuel production chains, which report that even though there is often a focus on male participation due to the physical nature of harvesting, women are involved in multiple stages of production. However, this involvement can lead to the overburdening of labor on women, due to their dual role as caretaker of the home and position within the charcoal supply chain.<sup>62</sup> A 2002 study on the progress of the United Nations’ Millennium Development Goals examined wood fuel use by the poor that “focused on the perceived burden fuelwood places on women and children by reducing the time they might have for education or more remunerative activities.”<sup>63</sup> This displays the opportunity cost women face in order to participate in the wood fuel market. In addition to the aforementioned health issues that arise from indoor air pollution and their disproportionate effects on women and children, other challenges arise because of their involvement in the wood fuel and charcoal production chain, such as social stigma. Participation in charcoal and wood fuel production is perceived as “men’s work,” “dirty,” and “inappropriate for women.”<sup>64</sup> In the cases of women-run households, this stigma can result in low salaries often received, as well as job insecurity, and casual labor contracts.<sup>65</sup> These sociocultural contexts feed into the complexity of the charcoal and wood fuel production processes, which encompasses all factors of daily life faced by millions of people around the world.

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<sup>61</sup> Markus Ihalainen, Jolien Schure, and Phosiso Sola. “Where Are the Women? A Review and Conceptual Framework for Addressing Gender Equity in Charcoal Value Chains in Sub-Saharan Africa.” *Energy for Sustainable Development* 55 (2020): 1–12. <https://doi.org/10.1016/j.esd.2019.11.003>.

<sup>62</sup> Zulu, and Richardson, “Charcoal, Livelihoods, and Poverty Reduction: Evidence from Sub-Saharan Africa.” 127–37.

<sup>63</sup> Michael, Köhlin, and Persson, “Wood fuels, Livelihoods, and Policy Interventions: Changing Perspectives.” 596–611.

<sup>64</sup> Ihalainen, Schure, and Sola, “Where Are the Women?” 1–12.

<sup>65</sup> *Ibid.*

It is imperative to recognize the importance of charcoal and wood fuel in Ghana's current energy landscape, and investment in programs such as community-based forest management will aid in a transition to more sustainable wood fuel and charcoal use. However, it is of vital importance to also focus on increasingly sustainable forms of biomass production to ensure the longevity of electrification schemes in Ghana, as encouraging more renewable fuel methods is necessary for Ghana's energy landscape long-term. While working towards more sustainable practices in the wood fuel industry, it is important to also look towards biogas and biomass gasification as viable renewable solutions for energy production in Ghana. Biogas, as an emerging technology, exists as a largely untapped energy source in Ghana. Since biogas can be produced from human, animal, and agricultural waste, it possesses the potential to greatly aid in energy production and waste management in rural and semi-urban areas of Ghana. Although biogas technology is still developing, many successful case studies exist throughout the world, including in Ghana. As Ghana moves towards sustainable electrification, biogas is an important and practical renewable energy source that should be considered.

### ***What is Biogas?***

Biogas is the product of the decomposition of waste through anaerobic digestion, a process that occurs naturally and can be mimicked in order to produce energy for human consumption. It is often cited as a "waste-to-energy" technology that mimics nature's ability to recycle waste into energy, causing it to be considered a clean and renewable energy source that prevents waste from entering landfills and does not rely on fossil fuel extraction.<sup>66</sup> When biogas is produced as energy for the purpose of human consumption, it is manufactured through a biodigester, utilizing inputs ranging from agricultural waste to sewage. Instead of allowing methane gas to be released from waste into the atmosphere, digesters provide a system that processes the waste into gas through anaerobic digestion and harnesses the biogas so that it can be productively used. Organic matter is input into the digester where it decomposes and is then submerged in water to produce an anaerobic environment. This environment is free of oxygen and allows microorganisms to break down the

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<sup>66</sup> "What Is Biogas? A Beginners Guide," Homebiogas | Household Biogas Digester System, accessed February 1, 2020, [https://www.homebiogas.com/Blog/142/What\\_is\\_Biogas%7Cfq%7C\\_A\\_Beginners\\_Guide](https://www.homebiogas.com/Blog/142/What_is_Biogas%7Cfq%7C_A_Beginners_Guide).

organic material and produce biogas.<sup>67</sup> Several types of biogas digesters are currently manufactured, including the fixed-dome, floating-drum, and puxin models, and each model varies in cost, size, input, and output (Table 1.1).

Table 1.1. Pros and cons of different types of biogas digesters.

Type	Pros	Cons
Fixed-dome	Relatively low initial costs; Long useful life-span; No moving parts involved; Simple design.	Air tight is highly required; Gas leaks occur quite frequently; Inconsistent gas pressure makes gas use complicated; Amount of gas produced is not immediately noticed; Experienced biogas technician required.
Floating drum	Easy to understand and operate; Gas is provided at constant pressure; Volume of gas stored is easily notice by the position of the drum;	Relatively expensive steel drum; It is maintenance intensive; Rust removal and painting has to be done regularly.
Puxin	Easy and quick to build; Durable and easy to maintain; Rate of gas production is high.	Digested slurry consists of about 90% water
ABR	Low operating cost; Resistant to organic and hydraulic shock load; High BOD reduction; Low sludge production; Moderate area needed.	Expert required for the design and construction; Low pathogen and nutrients reduction; Effluent and sludge needs further treatment and/or proper discharge.

Source: “Biogas Technology Diffusion and Shortfalls in the Central and Greater Accra Regions of Ghana,” (table), *Water Practice and Technology*; London 13, no. 4 (December 2018), 936, <http://dx.doi.org/10.2166/wpt.2018.100>.<sup>68</sup>

Biogas is often referenced as a technology with untapped potential, especially in regions such as West and East Africa that have largely agricultural-based economies that naturally produce biomass byproducts.<sup>69</sup> Biogas has the potential to serve as a fuel for cooking and heating as well as augment existing electrification structures as an energy source for generators. Byproducts from the production of biogas can also be utilized as sources of fertilizer for agriculture if treated properly.

While biogas implementation has been successful in providing energy to many agricultural-driven areas of the world-- namely China and India-- in the past few decades, most of SSA has yet to implement biogas production on a large scale.<sup>70</sup> East African nations such as Tanzania and Kenya

<sup>67</sup> Ibid.

<sup>68</sup> M. Osei-Marfo et al., “Biogas Technology Diffusion and Shortfalls in the Central and Greater Accra Regions of Ghana,” (table), *Water Practice and Technology*; London 13, no. 4 (December 2018), 936, <http://dx.doi.org/10.2166/wpt.2018.100>.

<sup>69</sup> Wilson Parawira, *Reviews in Environmental Science and Bio/Technology* 8, no. 2 (June 1, 2009): , <https://doi.org/10.1007/s11157-009-9148-0>.

<sup>70</sup> Ibid.

have seen the most growth in the biogas sector, with thousands of small scale biogas digesters installed in either country.<sup>71</sup> Although some large and small scale biomass production plants have been introduced in parts of SSA, few of these plants have been met with success due to poor installation and/or lack of understanding towards the maintenance and use of the technology after installation.<sup>72</sup> Barriers to further development in biogas technology in SSA include a lack of regional research about the technology, minimal public awareness surrounding biogas, and a subsequent lack of investment in the biogas sector.<sup>73</sup>

### ***Biogas in Ghana***

According to the Biogas Association of Ghana (BAG)--a network of companies, practitioners, researchers, civil society organizations (CSOs), NGOs, artisanal associations and international development organizations (IDOs) “promoting anaerobic digestion as a preferred solution for sustainable waste management, energy, agriculture and climate change mitigation”-- at least 400 biogas digesters have been installed in Ghana.<sup>74</sup> The fixed-dome biogas digester is the most popular design in Ghana-- constituting approximately 80% of biogas plants-- due to its low cost in comparison to other digester types.<sup>75</sup> Biogas production in Ghana has been introduced in institutions, communities, and individual homes in varying capacities (Figures 1.2 and 1.3). Biogas implementation in Ghana has been met with variable success, as problems such as high investment costs, poor maintenance, lack of sustainable feedstock, and gaps in education have arisen. The REMP states that the Ghanaian government first introduced biogas energy solutions as early as 1987, with the first large scale project being the Appolonia Biogas Project as a result of a cooperative agreement between Ghana and China. The project, designed to bring biogas electricity to the rural community of Appolonia, was met with many challenges. The challenges included unreliable feedstock supply for the biodigester, maintenance, and socio-cultural attitudes towards biogas based on a lack of knowledge surrounding the technology, particularly at such a large

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<sup>71</sup> Edem Bensah, “Biogas Technology Dissemination in Ghana: History, Current Status, Future Prospects, and Policy Significance,” *International Journal of Energy and Environment* 1 (March 1, 2010).

<sup>72</sup> Parawira, “Biogas Technology in Sub-Saharan Africa: Status, Prospects and Constraints,” 187–200.

<sup>73</sup> Ibid.

<sup>74</sup> “Welcome to Biogas Ghana,” accessed January 24, 2020, <https://www.biogasghana.org/>.

<sup>75</sup> Richard Arthur, Martina Francisca Baidoo, and Edward Antwi, “Biogas as a Potential Renewable Energy Source: A Ghanaian Case Study,” *Renewable Energy* 36, no. 5 (May 1, 2011): 1510–16, <https://doi.org/10.1016/j.renene.2010.11.012>.

scale.<sup>76</sup> Ultimately these challenges led to the discontinuation of the project entirely. Since the failure of the Appolonia project the government has been hesitant to invest in biogas energy solutions.<sup>77</sup> The REMP ultimately concludes that, “existing biogas technologies are not sustainable to provide community-based electrification but may be an ideal technology for sanitation management in relevant institutions.”<sup>78</sup>

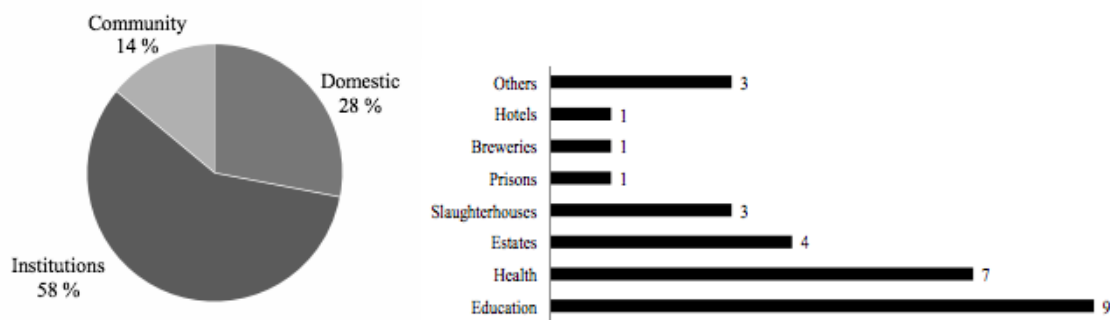


Figure 1.2. Biogas installations in Ghana categorized as institutional, community, and domestic plants.

Figure 1.3: Types of institutions utilizing biogas technology in Ghana.

Edem Cudjoe Bensah and Abeeke Brew-Hammond, “Biogas Technology Dissemination in Ghana: History, Current Status, Future Prospects, and Policy Significance,” (charts) *International Journal of Energy and Environment* 1 (March 1, 2010), 282.

The REMP lists challenges to biogas production as lack of awareness and regulation, inadequate data on current biogas production, and high installation costs. Also indicated are opportunities for biogas in Ghana that may have been overlooked in the Appolonia project, including the opportunity of waste treatment with energy spill over, opportunities to “build capacity of local artisans in design, construction, operation and maintenance of biogas systems,” and the possibility of collaborating with other institutions and groups that are interested in biogas production.<sup>79</sup> The REMP indicates that existing and future biogas digesters must be improved upon in order to best deal with sanitation management. Furthermore, it leaves the possibility of improving upon biogas technology for future implementation. If challenge areas are addressed, biogas has the potential to augment electrification schemes, serve as a sustainable alternative to current cooking fuels, and provide a waste-to-energy solution that solves both waste and energy management issues. Although initial investment costs can be high for biogas technologies and installations are at risk for mismanagement, the technology requires little maintenance when proper training is provided,

<sup>76</sup>Energy Commission of Ghana, “Renewable Energy Masterplan,” (2019).

<sup>77</sup> Bensah.

<sup>78</sup> Energy Commission of Ghana, “Renewable Energy Master Plan.” 2019.

<sup>79</sup> Ibid.

and provides numerous social, economic, and environmental benefits if communities are properly educated on the installation and upkeep of biodigesters. Although biogas is likely not the answer to grid-scale electrification, great potential lies within the technology as an integrated approach to waste treatment and energy production.

### *Opportunities and Challenges Associated with Biogas*

As an emerging technology, much of the conversation surrounding biogas focuses on its challenges and its opportunities. The opportunities and challenges present in the expansion of biogas in Ghana are outlined below in three overarching opportunity categories: economic, social, and environmental. It is important to note that each of these categories are not mutually exclusive, and rather are deeply connected in the goal of sustainable development.

#### *Economic Implications*

As mentioned in the Ghana REMP, investment in biogas has the potential to build the capacity of local laborers in a variety of technical skills and thus create opportunities for income-generation and employment. The REMP elaborates on the economic benefits of renewable energy technology: “Manufacturing and assembling of renewable energy technologies is pivotal to the overall growth of the industry. This will not only stimulate sustainable growth of the sector, but also contribute to the overall development of the West African renewable energy market.”<sup>80</sup> A study conducted in 2011 concluded that Ghana possesses the technical potential to establish at least 278,000 biogas plants, creating the opportunity of both unskilled and skilled employment in design, manufacturing, research, and maintenance.<sup>81</sup> Ghana currently is host to some private development in the biogas sector, in which the technology has been a source of employment for Ghanaians. One such example of a private biogas company in Ghana is DAS Biogas, which provides biogas installation for both institutions and communities. DAS Biogas is a part of BAG, indicating that there is existing collaboration between public and private stakeholders in the biogas industry. Although it is unclear how successful the Biogas Association of Ghana and its members have been in promoting collaboration across the industry, the existence of such an association poses the

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<sup>80</sup>Energy Commission of Ghana, “REMP.”

<sup>81</sup> Arthur, Baidoo, and Antwi.

possibility of expansion and coordination in terms of further job creation, training, and investment in both the public and private sector.

Aside from the opportunity of job creation, biogas also possesses the capability to lower costs of electricity, particularly in settings where abundant feedstock (waste) is present, such as on farms or in university and industry settings. Although biogas is currently not suitable to serve as a grid-scale energy solution, it is able to combine with existing energy infrastructure and reduce stress on grid-power through powering generators, particularly when it is coupled with other renewable energy sources. A feasibility study conducted in 2015 in Kenya concluded that locally-produced biogas (in this case, animal manure) can be an environmentally-friendly and cost-effective substitute for diesel in a hybrid generation system that also uses solar and wind energy. The results of the study proved that “the hybrid system integrated with the biogas engine as backup can be a better solution than using a diesel engine as backup.”<sup>82</sup> The economic analysis of the study concluded that “the LCOE (Levelized Cost of Electricity) of generated electricity by this hybrid system (\$0.25/kWh) is about 20% cheaper than that with a diesel engine as backup (\$0.31/kWh), while the capital cost and the total NPC (Net Present Cost) are about 30% and 18% lower, respectively.”<sup>83</sup> Furthermore, the study concluded that switching to a biogas engine over a diesel engine saved 17 tons of CO<sub>2</sub> a year.<sup>84</sup> Biogas used as a substitute for diesel in generators is primarily a small scale solution, but its potential to expand is largely dependent on the availability of biomass inputs.

Despite the potential for economic growth associated with biogas, there remain concerns associated with the investment and maintenance costs of biogas technology. Research by Osei-Marfo, Awuah, and de Vries acknowledges that “since the construction of a digester is essential for biogas technology, the investment cost cannot be ignored.”<sup>85</sup> Digesters are typically made of brick and/or concrete. Although raw materials are abundant, the initial investment costs can be high. Osei-Marfo et al. estimate the average investment costs for household digesters (6m<sup>3</sup>) at

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<sup>82</sup> Sara Ghaem Sigarchian et al., “Feasibility Study of Using a Biogas Engine as Backup in a Decentralized Hybrid (PV/Wind/Battery) Power Generation System – Case Study Kenya,” *Energy* 90 (October 1, 2015): 1830–41, <https://doi.org/10.1016/j.energy.2015.07.008>.

<sup>83</sup> Ibid.

<sup>84</sup> Ibid.

<sup>85</sup> Osei-Marfo, et al., 933.

between \$889 and \$1,333 and at \$15,556 to \$20,000 for larger, institutional digesters (100 m<sup>3</sup>), with costs varying by site.<sup>86</sup> Furthermore, “some biogas service providers accuse other providers of collapsing the biogas business because of a lack of qualifications. They feel that those without training build digesters/plants that are unsustainable, affecting negatively those with qualifications (sustainable digesters/ plants) in securing contracts.”<sup>87</sup> It is clear that there are disparities in the economic viability of digesters, depending on whether or not those installing and maintaining the digesters are doing so properly and ensuring that the investment costs are paid off through sustainable energy production. Therefore training individuals on biogas technology is imperative to its success. Typical maintenance activities for digesters include “daily feeding, cleaning of stoves and other appliances, checking of gas leakages especially at pipe joints and gas valves, and inspection of balloon gasholders.”<sup>88</sup> While daily maintenance can be performed by any individual who has received the proper training, more technical repairs require specialists. The prospect of training individuals as biogas professionals has opportunities for job creation, and there is also the possibility of training communities on these relatively simple maintenance tasks to promote low-cost, sustainable maintenance. Such training should be a cross-sectoral effort, with NGOs, private companies, and the government collaborating to establish standards of biogas production and maintenance that ensures consistency and sustainability across the sector. The Biogas Association of Ghana, as an existing network of biogas stakeholders, is a potential starting point for establishing regulatory standards for the industry.

Furthermore, many of the problems associated with construction and maintenance of biogas technology results from a lack of research on biogas and a lack of funding for such research. Parawira writes, “it is important to initiate long-term anaerobic digestion and other renewable energy training and capacity-building programmes... perform scientific work in this field...[and] establish contacts between research and university groups and experienced contractors.”<sup>89</sup> If a long term investment-- resulting from collaboration across the biogas sector-- is made towards research, production and management regulation, and job training, biogas will be able to support local economies and improve livelihoods. One such investment could come in the form of

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<sup>86</sup> Ibid, 941.

<sup>87</sup> Ibid.

<sup>88</sup> Bensah, 289.

<sup>89</sup> Parawira, 187

government subsidies for the construction of biogas digesters, which could promote energy production and economic development in rural farming communities where the initial investment costs are high, but maintenance costs are low when communities are empowered to operate and maintain the digesters.

### *Social Implications*

In addition to opportunities for economic mobilization with biogas, a number of other social benefits coincide with biogas production. One of the social benefits most often attributed to biogas is its inherent opportunities for women, particularly in its role as an alternative cooking fuel source. Research conducted by Arthur et al. describes the benefits to women as follows:

*“[Women are] heavily involved in fuelwood collection and charcoal production. More time required for firewood collection is another problem associated with the use of firewood. At the household level, time saved while not fetching firewood could also be used for educational or other productive activities. This consequently will improve the standard of living, provide additional income and enhance the nutritional and health status of the household.”<sup>90</sup>*

Arthur et al. mention both the timesaving advantage of biogas-- which allows women to invest more time in education or other income generating opportunities-- as well as the improved health outcomes when energy is provided by biogas. Since women traditionally do most of the cooking in Ghanaian households, women and children are put at the greatest risk of smoke borne diseases related to traditional cooking fuels such as wood and charcoal. Using biogas in place of these traditional fuels “noticeably reduces the number of smoke borne diseases for the concerned women or children.”<sup>91</sup> Exposure to toxic byproducts associated with charcoal and wood burning are widespread in Ghana, particularly in communities with one-room homes and little ventilation. Furthermore, widely used Liquid Petroleum Gas (LPG) stoves pose dangers to women and children. In one of our research interviews, Amos Apam, a teacher from Northern Ghana, underscored a common concern with LPG stoves: they have been known to explode and injure or

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<sup>90</sup> Arthur, Baidoo, and Antwi, 1515.

<sup>91</sup> Ibid.

kill those in the home.<sup>92</sup> Such a case recently occurred on January 5th, 2020, with a mother and her three children killed in an LPG explosion in a suburb of Accra.<sup>93</sup>

The social benefits of biogas do not extend to women alone. *Wastelandia*, written by scholar Brenda Chalfin, provides a case study in which she follows a local community leader (whom she calls “M”) in Tema, Ghana as he works to produce a bio-digester toilet as a source of income generation and waste management for his community. M’s development of biogas energy in his community is unique in that he was highly educated and possessed the technical capacity and funding to undergo such a project, but support-- either public or private--for such projects can increase accessibility and community ownership of biogas projects in Ghana. Chalfin’s report elucidates the opportunity for community empowerment and grassroots infrastructural growth that comes with biogas, proving that when communities are involved in development projects they are more easily sustained. What started as a means to provide cooking gas for M’s hostel through processing community waste in a biodigester ended up as a full community development project. Chalfin writes, “With so much output from the heavy toilet traffic, M said he was barely tapping the full potential of the methane gas supply. When I saw him next, he was looking for a generator to convert the gas to electric power. The plan was to use the power for the toilet and hostel’s electrical needs and sell the surplus to others nearby.”<sup>94</sup> Furthermore, access to cheap, renewable power allowed M to provide educational services and more employment opportunities in his hostel.

The *Wastelandia* grassroots model has the potential to grow through community collaboration with NGOs, government actors, and private entities. Ghana is currently host to a number of environmental advocacy NGOs, including KITE, an NGO that has already partnered with the Ghanaian government and outside funding partners to conduct an “integrated biomass project.”<sup>95</sup> The project was supported by The Forestry Commission and Bole Bamboi District Assembly, and

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<sup>92</sup> Amos Apam, phone interview, January 24th, 2020.

<sup>93</sup>“Policewoman, 3 Kids Killed in Gas Explosion Go Home Today,” accessed February 5, 2020, <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Policewoman-3-kids-killed-in-gas-explosion-go-home-today-853930>.

<sup>94</sup> Brenda Chalfin, “‘Wastelandia’: Infrastructure and the Commonwealth of Waste in Urban Ghana: *Ethnos*: Vol 82, No 4,” accessed January 17, 2020, <https://www.tandfonline.com/doi/full/10.1080/00141844.2015.1119174>.

<sup>95</sup>“Integrated Biomass Project – KITE – Innovating Clean Energy Solutions,” accessed January 24, 2020, <https://kiteonline.net/integrated-biomass-project/>.

received funding from the Energy Commission. It promoted community involvement and consisted of three components: establishment of a community owned tree plantation, promotion of an improved charcoal production system, and promotion of improved charcoal cook-stoves.<sup>96</sup> Although the project was not specifically focused on biogas, it shows potential for further partnership between communities, NGOs, and government actors that could contribute to sustainable community development.

Biogas has also been a notable solution to waste management in schools and universities in Ghana, providing support for educational facilities that produce large amounts of waste daily. Combined energy generating and waste management facilities in school and universities can reduce energy costs, decrease greenhouse gas emissions from waste, and treat sewage. A study conducted by Arthur, Baidoo, Brew-Hammond, and Bensah focusing on biogas generation from sewage in four public universities in Ghana presented significant benefits to public health as well as energy production. The article references the strategy of sewage dumping as having an “enormous impact on the communities around the dumping sites considering the fact that raw sewage serves as breeding sites for microbes that cause diseases if not handled properly.”<sup>97</sup> When bio generators intended to operate off of sewage were introduced into the four universities, the digesters were developed using a three-pronged approach: “energy production, waste treatment and fertilizer production.”<sup>98</sup> The benefits of the biodigesters include improved waste treatment and health outcomes of the surrounding community, energy production in the form of cooking gas, and opportunities to use the effluent (treated sewage from the biodigesters) as a sustainable alternative to traditional fertilizers in surrounding farms.<sup>99</sup>

The use of digested human or animal excreta as fertilizer in an agricultural setting has been stigmatized in communities around the world, including those in Ghana. An interview with Frank Baffour-Ata, a PhD student in Ghana, revealed that the root of the stigma surrounding biogas results primarily from the public’s lack of knowledge about the technology. He continued by

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<sup>96</sup> Ibid.

<sup>97</sup> Richard Arthur et al., “Biogas Generation from Sewage in Four Public Universities in Ghana: A Solution to Potential Health Risk,” 3087.

<sup>98</sup> Ibid, 3092.

<sup>99</sup> Ibid.

stating that most Ghanaians would actually be excited by the prospect of a waste-to-energy technology such as biogas if they were provided proper education on the subject.<sup>100</sup> This point was reiterated in a thesis written for the University of Ghana by John Leonard Doghle, in which he outlines steps that need to be taken to garner public support for biogas technology: “This calls for education, knowledge sharing and promotional messages on the multiple benefits of biogas technology in Ghana. These multiple benefits should highlight on sanitation and hygiene, lower cost of energy (LPG, Fuelwood, and Charcoal), environmental protection, soil nutrient improvement from bio-slurry, poverty reduction and employment creation.”<sup>101</sup> The socio-cultural concerns over biogas technology poses a valid concern but one that most likely can be overcome by education efforts driven by Ghanaians well-versed in the technology, either through NGOs, private companies, or government-sponsored programs. Collaboration across the public and private sector poses its own difficulties, but researchers such as Osei-Marfo et al. have recommended that the government provides support to local, community based NGOs such as KITE and Centre for Energy, Environment and Sustainable Development (CEESD) who will then help disseminate the necessary educational, technical, and financial support for individual and community biogas owners.

### *Environmental Implications*

As a renewable energy that does not contribute to greenhouse gas emissions, biogas is considered to be an environmentally conscious energy solution. Beyond its status as a clean energy, biogas can contribute to a number of sustainable practices. As aforementioned in the case of biogas production in Ghanaian universities, biogas presents an opportunity to support sustainable agriculture practices in Ghana. The majority of households in Ghana are reliant on agriculture as a source of income, and most of them rely on fertilizer to ensure the success of their crops.<sup>102</sup> Biogas generators produce an organic byproduct called effluent, which can serve as an alternative to environmentally harmful chemical fertilizers. Arthur et al. describe the benefits of using effluent as a fertilizer in both environmental and economic terms: “The cumulative effect of the use of biogas effluent as organic fertilizer will lead to increased crop production yields. It could

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<sup>100</sup> Frank Baffour-Ata, phone interview, January 29th, 2020.

<sup>101</sup> John Leonard Doghle, “Assessing the cost-efficiency and willingness to adopt biogas as a sustainable source of renewable energy: the case of senior high schools in the greater Accra region,” 66.

<sup>102</sup> Arthur et al.

eventually reduce the importation of chemical fertilizer hence providing some savings for other economic activities which will improve the Ghanaian economy.”<sup>103</sup>

The potential for sustainable agriculture through the production of biogas can be seen in Ejura, Ghana, where a small-scale biodigester has been installed to deal with the waste associated with slaughterhouses. The Ejura District was chosen by the Government of Ghana (GoG) to be the location of a pilot biogas plant as part of a campaign encouraging district capitals to upgrade their infrastructure and standards of living. The Ejura biogas plant “cost \$15,000 to build in 1999/2000, and operational and maintenance costs are low.”<sup>104</sup> The biogas plant provides a model for sustainable agricultural practices, in which each part of the farm system contributes to other parts of the system. In Ejura, the generator treats waste produced by the slaughterhouse, the biogas generated from the waste replaces firewood to singe fur from slaughtered animals, and the organic biomass leftover from the digester is used as a fertilizer for the farm.<sup>105</sup> The Ejura plant has been successful in meeting the needs of the community, as it “has been operational, without breakdown, for 6 years. Its implementation has improved the environment in and around the slaughterhouse to a surprising extent. There has been a conspicuous reduction in noxious smells and in the number of flies, dogs, and vultures.”<sup>106</sup>

In addition to supporting sustainable agricultural practices, the waste management capacity of biodigesters is beneficial to both communities and the environment. Sewage that may otherwise go untreated and contaminate water and release greenhouse gases can be used for biogas production in institutions such as universities. Biogas is not only in and of itself a clean energy production method, but it also contributes to cleaning up existing environmental hazards and preventing the introduction of more.

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<sup>103</sup> Ibid, 1514.

<sup>104</sup> E. D. Aklaku, K. Jones, and K. Obiri-Danso, “Integrated Biological Treatment and Biogas Production in a Small-Scale Slaughterhouse in Rural Ghana,” *Water Environment Research; Alexandria* 78, no. 12 (November 2006): 2335.

<sup>105</sup> Ibid.

<sup>106</sup> Ibid, 2335

One challenge that has arisen in counter to the sustainability of biogas is the fact that it can potentially be difficult to have a sufficient feedstock supply if existing waste is not properly capitalized on. This has led to concerns over the need for agricultural production specifically to provide fuel stock for digesters. Fortunately, such issues can generally be avoided when biogas digesters are introduced in the correct setting. Digesters are ideal for communities or facilities that already produce large amounts of waste, such as farms that produce agricultural byproducts or schools that accrue consistent supplies of waste.

Looking to biogas as a source of power generation is a logical energy intervention in Ghana and SSA as biomass products-- from the agricultural sector, universities, and densely populated areas-- are already plentiful. However, as is common with renewable energy sources, the technology needed to harness the potential of biomass requires significant research, education, technical training and feasible financing options. Should Ghana achieve these successfully through the proper implementation and maintenance of biodigesters, the country can create opportunities for sustainable heat, energy generation, and waste management. The potential of biomass as a part of Ghana's energy mix is not limited to biogas and wood fuel; biomass gasification has also shown to be an effective generation technology because it too relies on renewable inputs. Although biogas and biomass gasification require significant investment in research and infrastructure, each is uniquely suited to serve communities and population centers in need of reliable power.

### ***The Potential of Small-Scale Biomass Gasification in Sub-Saharan Africa***

Ghana's energy sector needs to be further diversified to lessen the strain on existing power generation systems and to foster solutions that are viable in remote communities. Although renewable energies are beginning to serve this purpose in forms such as community solar microgrids and solar home systems, more solutions need to be considered. Biomass gasification has been in use for the better part of a century, but proper application in developing countries has yet to be standardized. Biomass energy is already commonplace throughout the continent for

cooking and heating, but its potential to generate electricity through gasification has not been fully realized.<sup>107</sup>

### *The Technology*

Biomass gasification is a noteworthy technology because it relies on common agricultural residues and is effective at varying production scales. While underutilized, biomass gasifier microgrids have proven to be ideal for powering rural farming communities in South Asia and some parts of Africa. Once constructed onsite, the gasifier system works by heating biomass and combusting it to create a gas (known as producer gas) that can be used as a liquid fuel alternative.<sup>108</sup> By connecting the gasifier directly to a generator set, remote communities can begin producing electricity for a variety of uses. Producer gas is not limited to use in diesel or gas generators though; a biomass gasifier can be combined with a steam turbine, a gas turbine, a fuel cell or a Stirling motor to create electricity that is ready for distribution.<sup>109</sup> Biomass gasifier technology can meet energy needs varying from agricultural irrigation pumps to industrial mills, but its potential to serve domestic power needs is most relevant to Ghana and SSA. To distribute power beyond the immediate vicinity of the gasifier and generator a distribution system is needed. Although microgrids have primarily been paired with solar photovoltaic systems in Africa, these community grids can distribute power from biomass gasifiers too.

### *Environmental Impact and Feasibility*

Although biomass gasifiers have been used sparingly in Africa, they are environmentally viable and prove to have many advantages over other power generation technologies. First, it is important to consider the environment itself in Ghana and how that plays into biomass power generation. Of Ghana's 238,539 km<sup>2</sup> of land area, 57% is used for agricultural activities. Additionally, Ghana's agricultural sector is characterized by small farms with little or no purchased inputs; just 15% of all farms are greater than two hectares. So, while the sector contributes significantly to Ghana's

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<sup>107</sup> Abubakari Ahmed, Benjamin Betey Campion, and Alexandros Gasparatos, "Biofuel Development in Ghana: Policies of Expansion and Drivers of Failure in the Jatropha Sector," *Renewable and Sustainable Energy Reviews* 70 (April 1, 2017): 133–49, <https://doi.org/10.1016/j.rser.2016.11.216>.

<sup>108</sup> Elmar Dimpl, Michael Blunck, and Heike Volkmer, "Part I: Biomass Gasification," n.d., 5.

<sup>109</sup> Dimpl, Blunck, and Volkmer, 5.

GDP (54%) and export earnings (40%), farms are not dominated by big business.<sup>110</sup> Also of relevance, soils in the north of Ghana contain high amounts of nutrients as opposed to those in the south of Ghana which suffer from much less fertile soil.<sup>111</sup> Biomass gasifiers can run on various inputs, but an abundance of agricultural activities makes residues from harvests a particularly attractive input.

Crop residues vary significantly from crop to crop, but Ghana's diverse mix of crops provides varying options for a biomass power scheme. Sorghum, palm, cocoa and maize are the country's most abundant crops, but each has unique characteristics that determine its suitability as biomass inputs. The most important figures are national production, residue to product ratio (RPR), moisture content and energy potential (Table 1.2). National production is an important measure because it narrows down the crops most available to communities in need of electricity. Next, RPR reveals what crops can provide the most residue input. Moisture content should be noted because all residue must be dried before it is suitable for gasification and greater moisture content ensures a longer drying period. Finally, the residues energy potential column shows the energy (terajoules) that can be produced based on total residues, which is especially useful when deciding which crops are the most efficient inputs. The northern rural area of Ghana, which suffers from the lowest electrification rate in the country, produces maize, rice, sorghum and millet in abundance.<sup>112</sup> Compared against the country's most plentiful crops, these staples of the northern regions stand out in RPR and energy potential. Millet, sorghum, rice and maize each rank in the top five in these two critical measures.

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<sup>110</sup> "Ghana at a Glance | FAO in Ghana | Food and Agriculture Organization of the United Nations," accessed February 1, 2020, <http://www.fao.org/ghana/fao-in-ghana/ghana-at-a-glance/en/>.

<sup>111</sup> Wood, "Agricultural Development in the Northern Savannah of Ghana," 4.

<sup>112</sup> Ghana at a Glance | FAO in Ghana | Food and Agriculture Organization of the United Nations."

Table 1.2. Selection of Ghana's most prominent crops and their suitability as biomass feedstock.

Crop	Production (x 1,000 tons)	Residue type	Residue to product ratio (RPR)	Moisture content (%)	Residue (wet tons)	Residue (dry, x 1,000 tons)	Residues energy potential (TJ)
Millet	160	Stalk	3	15	480	408	7.44
Sorghum	350	Stalk	2.62	15	917	779.45	15.59
Coffee	165	Husk	2.1	15	346.5	294.525	0.04
Rice	242	Straw	1.5	15	363	308.55	5.65
Maize	1,100	Stalk	1.5	15	1650	1402.5	25.76
Cocoa	700	Pods, husk	1	15	700	595	10.84
Coconut	316	Shell	0.6	10	189.6	170.64	2.01
Sugarcane	145	Bagasse	0.3	75	43.5	10.875	0.58
Oil palm fruits	1,900	EFB	0.25	60	4750	190	7.37

Source: Moses Hensley Duku, Sai Gu, and Essel Ben Hagan, "A Comprehensive Review of Biomass Resources and Biofuels Potential in Ghana," (table), *Renewable and Sustainable Energy Reviews* 15, no. 1, 408, <https://doi.org/10.1016/j.rser.2010.09.033>.<sup>113</sup>

In areas of Ghana not connected to the national electrical grid, diesel is commonly used to run home-based, commercial and industrial generators. The product of biomass gasification, producer gas, is a suitable alternative for liquid fuels like gasoline and diesel. In diesel engines, producer gas can replace between 75% and 85% of diesel fuel. Despite being far less common in Ghana, gas engines can run on 100% producer gas.<sup>114</sup> Biomass gasifiers are also carbon neutral in that they release about as much carbon dioxide as they use. Duku, Gu and Hagan suggest that 1.6 tons of carbon dioxide is avoided for each megawatt hour (MWh) of biomass power generated. Furthermore, because the residue isn't broken down naturally, the subsequent release of methane is avoided. Both carbon dioxide and methane are prominent greenhouse gases, but methane is far better at trapping heat. In fact, reducing 1 ton of methane is equivalent to reducing 21 tons of carbon dioxide.<sup>115</sup> By relying on existing underused residue, biomass gasification gives rural communities the ability to power their communities and avoid expensive fossil fuels.

<sup>113</sup> Moses Hensley Duku, Sai Gu, and Essel Ben Hagan, "A Comprehensive Review of Biomass Resources and Biofuels Potential in Ghana," (table), *Renewable and Sustainable Energy Reviews* 15, no. 1, 408, <https://doi.org/10.1016/j.rser.2010.09.033>.

<sup>114</sup> Anshu Bharadwaj, "Gasification and Combustion Technologies of Agro -Residues and Their Application to Rural Electric Power Systems in India - ProQuest," accessed February 14, 2020, <https://search.proquest.com/docview/275734405?fromunauthdoc=true&pq-origsite=primo>.

<sup>115</sup> Duku, Gu, and Hagan, "A Comprehensive Review of Biomass Resources and Biofuels Potential in Ghana," 414.

From an environmental perspective, this emerging decentralized power generation system does have notable drawbacks. First, biomass residues already serve an important role in communities agriculturally and domestically. Although the production of biogas creates effluent, a useful fertilizer, the gasification of residues does not. Residues provide valuable nutrients and erosion deterrence for farms, while often serving as cooking fuel in homes. Keeping these uses in mind, Dassappa suggests a 30% allocation of all residues to biomass gasification is sustainable.<sup>116</sup> These residues dedicated to gasifier energy production are best suited to be diverted from agricultural uses. According to a 2018 study on the significance of agricultural residues in sustainable biofuel development, farmers can plant cover cropping and use no-till farming to negate the effects of losing nutrient-packed residues. These strategies maintain soil health and allow some residues to be allocated to biomass feedstock.<sup>117</sup> Next, case studies have revealed improper gasifier cleaning practices can threaten the local environment. Although the gasification process produces minimal tar, cleaning the system with water or not cleaning it regularly will increase the likelihood of toxins soaking into the soil.<sup>118</sup> More depth on this issue will be provided in the analysis of Cambodia's biomass gasification landscape. As Ghana looks to further diversify its energy mix to meet growing demand and to improve reliability, potential negative outcomes needs to be prepared for.

### *Economic Considerations*

To fully understand the feasibility of small-scale biomass systems, the costs and tariff strategies need to be reviewed. In India, the technology has been used at every scale with over 1,700 systems accounting for 42 MW of capacity. Higher capacity systems benefit from economies of scale and see notable reductions in cost as capacity increases, although beyond 100 kilowatt (kW) the cost drop off is much less pronounced (Figure 1.4). Research by Dasappa is primarily focused on India, but case studies in Uganda, South Africa, Mali, and Burundi are also reviewed to examine the costs of biomass power generation across the world.<sup>119</sup> The table below projects the various costs for these gasifiers and provides comparison with 100% diesel-based power generation (Table 1.3).

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<sup>116</sup> Dasappa, "Potential of Biomass Energy for Electricity Generation in Sub-Saharan Africa," 210.

<sup>117</sup> Nurudeen Ishola Mohammed, Nassereldeen Kabbashi, and Abass Alade, "Significance of Agricultural Residues in Sustainable Biofuel Development," *Agricultural Waste and Residues*, 2018, <https://doi.org/10.5772/intechopen.78374>.

<sup>118</sup> Mansvelt, "IFC Gasifier Study," 47.

<sup>119</sup> S. Dasappa, "Potential of Biomass Energy for Electricity Generation in Sub-Saharan Africa," 203–13,

Diesel generators are common in communities not connected to the national grid, so biomass systems have the potential to work as an important next step for these communities. The inputs and costs of Dasappa's analysis are reflective of a system with a maximum capacity of 100 kW. For context, 100 kW of power could serve over 3,000 households.<sup>120</sup> The initial investment required for the biomass system is significant at an estimated \$900 per kW, but this cost is offset over time due to a reduction in fuel costs. While an engine running on diesel alone requires 0.272 kg of fuel per kWh, a dual fuel (70% biomass) mix in the same engine only requires 0.082 kg of diesel per kWh. With the average cost of diesel hovering around \$1.25 per liter and biomass estimated to cost around \$50 a ton, the annual cost for dual fuel system is estimated at \$544 compared to \$2,628 with diesel alone. Under this analysis both systems would produce 6,570 kWh of energy annually, with the biomass system's annualized life cycle cost estimated at \$0.184 per kWh as opposed to \$0.50 per kWh for a 100% diesel system. It should be noted assumptions and generalizations are made in this analysis. The cost of diesel is averaged across SSA and fuel consumption is based on the average of a range of power levels. Despite these assumptions the cost savings of a dual fuel biomass system are undisputable.

Table 1.3. Costs of a typical diesel run engine are compared to a diesel engine run on a dual fuel mix (70% biomass producer gas, 30% diesel) and a gas engine run on 100% biomass producer gas.

	Diesel operation	Dual fuel (70% replacement)	Gas engine
Biomass gasification system cost (excluding the engine) (\$/kW)	Nil	900	900
Engine cost (\$/kW)	300	300	700
Project life (yr)	15	15	15
Engine life (yr)	7.5	7.5	7.5
Discount rate	10	10	10
Diesel cost (\$/liter) <sup>a</sup>	1.25	1.25	Nil
Biomass cost (\$/ton)	Nil	50	50
O&M cost (\$/kWh)	0.04	0.07	0.07
Fuel consumption (kg/kWh)	Diesel : 0.272	Biomass : 0.9 Diesel : 0.082	Biomass : 1.1
SFC (MJ/kWh)	11.4	17.8	17.6
Biomass: 16 MJ/kg; Diesel: 42 MJ/kg			
Plant load factor (%)	75	75	75
Annual Fuel cost (\$)	2628	544	329
Annual O & M cost (\$)	292.0	306.6	438
Cost recovery of gasifier (\$)	Nil	118	118
Cost recovery factor for engine (\$)	58.74	58.74	137.06
Annualized total lifecycle cost (\$)	2979	1028	1022
Annual energy generation (kWh) <sup>b</sup>	6570	6570	6570
Annualized lifecycle cost of energy (\$/kWh)	0.50	0.184	0.183

<sup>a</sup>Diesel cost (\$/kWh) = (Diesel consumption (kg/kWh) / density of diesel (kg/liter)) x

Diesel cost (\$/liter) = ( 0.272/0.85)\*1.25 = 0.4.

<sup>b</sup>Gasification system 15% in house consumption.

Source: Table from Dasappa (2011).<sup>121</sup>

<sup>120</sup> Dimpl, Blunck, and Volkmer, "Part I: Biomass Gasification," 9.

<sup>121</sup> Dasappa, "Potential of Biomass Energy for Electricity Generation in Sub-Saharan Africa," 210.

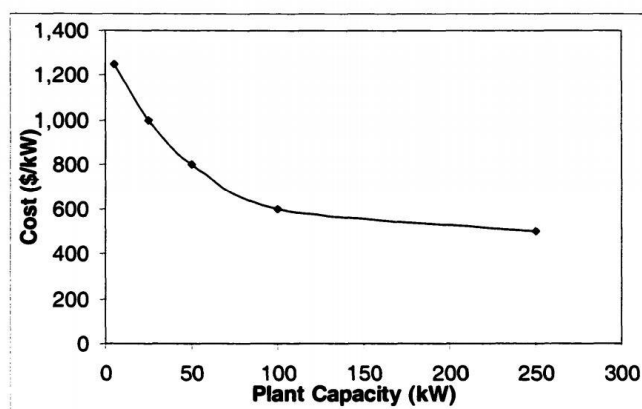


Figure 1.4. The total capital costs are reflective of the installed kW capacity. Gasifier plants with low capacity have very high costs per kW of capacity, but cost drops off as capacity is increased. Once installed capacity reaches 100 kW, cost per kW decreases much less significantly. Bharadwaj, “Gasification and Combustion Technologies of Agro - Residues,” (graph), 18.

## *Financing*

### *Initial Investment*

Although Ghana’s government has stated its preference for a top-down approach to microgrid development, it has always relied heavily on funding from donors and impact funds.<sup>122</sup> The challenge of developing a sustainable business model has also encouraged private companies to pursue outside funding for construction of the gasifier and generator.<sup>123</sup> The investment costs for these pieces of the system vary significantly. In Sri Lanka the cost was about \$162 per kW compared to Europe where costs have surpassed \$3,200 per kW of installed capacity. Systems that are locally built have proven to be cheaper initially in places like Cambodia, but without professional expertise these systems often require more frequent maintenance. Companies such as Husk Power and DESI Power specialize in building gasifiers, but their small-scale systems have yet to reach a point where they are readily available on the world market.<sup>124</sup> The construction of the microgrid itself is far less a financial barrier and community members can assist in building the necessary infrastructure. Community involved development is already encouraged by the GoG

<sup>122</sup> “Off-Grid Solar Market Assessment Ghana,” (USAID & Power Africa, October 2019), 21.

<sup>123</sup> “Off-Grid Solar Market Assessment Ghana,” (USAID & Power Africa, October 2019), 6.

<sup>124</sup> Dimpl, Blunck, and Volkmer, “Part I: Biomass Gasification,” 13.

through its Self-Help Electrification Program (SHEP); communities looking to expedite their connection to the national grid construct low voltage electricity poles and electricity meters while also connecting in at least 30% of households.<sup>125</sup> While this program is specifically paired with the extension of the national power grid, it shows the potential for community involvement in microgrid building as well.

### ***Ownership and Tariff Models***

#### *Public Model*

Under a fully public model the GoG will be responsible for the production and distribution of power at these off-grid sites. This is the GoG's preferred model and stated policy despite there being some private-sector involvement in the development and operation of microgrids. Ghana has remained committed to a Universal National Tariff (UNT), thereby offering rates that are generally equal across the country.<sup>126</sup> This approach maintains national price equity, despite the discrepancy in generation costs between the national power grid and off-grid solutions. Although tariffs have nearly always remained uniform, Ghana's Public Utilities Regulatory Commission (PURC) has ultimate say over what each customer pays. In order to adhere to a UNT, the government distributor must consider cross subsidies (that increase all consumers' prices) or external subsidies. While this ensures pricing equity for customers, the distributors are not incentivized to offer equitable service. Since the government faces uneven production and distribution costs around the country, despite receiving equal revenue from customers, distant communities provide less net income to the government. This could discourage equitable service across regions and ultimately hurt microgrid communities. It is within the bounds of the PURC to adjust tariffs based on location, power source or income, but Ghana's long commitment to a UNT suggests this to be an unlikely outcome. To avoid unequal service under a UNT the Energy Sector Management Assistance Program suggests the use of minimum service level guarantees and 'worst

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<sup>125</sup> Kemausuor and Ackom, "Toward Universal Electrification in Ghana."

<sup>126</sup> Timothy J. Reber et al., "Tariff Considerations for Micro-Grids in Sub-Saharan Africa," February 16, 2018, <https://doi.org/10.2172/1422366>, 2.

customer served’ performance monitoring.<sup>127</sup> While a service level guarantee would set a baseline of service for all customers, a ‘worst customer served’ program would see customers evaluate their service so that power providers could identify their most underserved customers and focus their efforts there.<sup>128</sup> These approaches would allow Ghana to maintain a UNT, while avoiding service inequities.

### *Private Model*

The GoG has refused to adopt regulation or licensing frameworks for private microgrids, but the private sector has and may continue to play a role in the energy landscape. Private operation and distribution will come at a slightly higher cost than a public scheme due to higher capital costs and the economies of scale within Ghana’s energy distributors, Northern Electricity Distribution Company (NEDCo) and Electricity Company of Ghana (ECG).<sup>129</sup> To offset these higher costs, private producers would be inclined to set tariffs according to a sustainable business model rather than the set national rate. Private microgrids can apply for a waiver to avoid the UNT and charge customers a cost-reflective tariff, but only one company, Black Star Energy (BSE), has done so successfully.<sup>130</sup> Although BSE operates 17 microgrids, USAID suggests this is a unique example of private-sector involvement in operation that is not reproducible because of the lack of licensing framework.<sup>131</sup> Privately operated microgrids face similar initial investment barriers as their public counterparts but, the government’s commitment to a national tariff, preference for public operation and nonexistent licensing framework severely impedes a private producer’s chance of success.

### *Public-Private Partnership (PPP)*

There are various ways that both public and private parties can have a stake in a small-scale biomass system. One such scheme would have the GoG own all assets, while giving a private party control over operation and distribution. The funding for construction of these systems has almost entirely relied on donors and impact funds, so it would be unlikely for the GoG to finance such a

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<sup>127</sup> “Ghana: Microgrids for Last-Mile Electrification” (Energy Sector Management Assistance Program, The World Bank, n.d.), [https://www.eca-uk.com/wp-content/uploads/2017/08/ESMAP-Ghana\\_Mini\\_grids\\_for\\_last\\_Mile\\_Electrification\\_Optimized.pdf](https://www.eca-uk.com/wp-content/uploads/2017/08/ESMAP-Ghana_Mini_grids_for_last_Mile_Electrification_Optimized.pdf), 14.

<sup>128</sup> Ibid

<sup>129</sup> “Ghana: Microgrids for Last-Mile Electrification,” 6.

<sup>130</sup> “Off-Grid Solar Market Assessment Ghana,”(USAID & Power Africa, October 2019), 22.

<sup>131</sup> Ibid

project on its own. Depending on the GoG's commitment to a UNT, the private operator and distributor may be permitted to charge cost-reflective tariffs. If the private party is forced to meet the national tariff, the project would likely be unsustainable financially.<sup>132</sup> Another potential PPP model would see a private entity sell power to ECG or NEDCo, who then distribute it. Each party's costs will be reduced compared to a fully public or private model, but the combined costs could be greater. ECG and NEDCo will be required to sell power at the UNT so purchasing the power at a reasonable price will be essential to long-term viability.<sup>133</sup>

### *Political Considerations*

Existing policy on off-grid electrification is limited, but the government has identified policy goals. The most relevant of these include creating a sustainable funding mechanism for rural projects, developing infrastructure for new grid connections in rural areas and addressing conditions that hamper power access for the poor.<sup>134</sup> Ghana's commitment to a uniform national tariff confirms its desire to make electricity affordable no matter the consumer's location. As mentioned previously, a UNT is also bound to create issues because generation and distribution costs depend on a multitude of factors. Adherence to a UNT may discourage private sector participation, but the government can intervene with subsidies or permit limited cost-reflective tariffs. Regional and local governments have played a minimal role in off-grid energy solutions in Ghana up to this point, but Indian case studies show their involvement to be crucial to systems' successes.<sup>135</sup> While the national government has preferred to be the driver of electricity expansion projects in Ghana, regional governments have the best understanding of power needs, accessibility and suitability. The role of lower-level government is currently limited, but greater involvement in tasks such as site selection and tariff setting would allow consumer's needs to be better met.

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<sup>132</sup> Ibid, 22-23

<sup>133</sup> Ibid

<sup>134</sup> Energy Commission of Ghana, *Renewable Energy Masterplan* (2019), 34-38.

<sup>135</sup> Dasappa, "Potential of Biomass Energy for Electricity Generation in Sub-Saharan Africa," 209.

## *Biomass Case Study Analyses*

### *Lucingweni and Thlatlaganya Villages, South Africa*

Biomass gasifier projects that have failed, such as the hybrid microgrid project in Lucingweni village in South Africa reveal that demand for energy and the supply offered are crucial. The project ultimately failed because the cost of power was higher than users were willing to pay, but this is attributable to poor site research. The capacity of the installed system was far too high for the needs of the community it served. In fact, the Lucingweni microgrid produced 75.6% excess electricity compared to a similar South African microgrid that produced 2% excess.<sup>136</sup> Because these systems are designed to run at a set load, systems producing excess power must continue wasting inputs and electricity or face a drop off in efficiency. The microgrid system installed in Thlatlaganya, South Africa provided ample electricity for domestic activities (lighting, cooking, communication), as well as for local enterprises. At 2.4 kWh produced per household, machinery such as a milling machine, water pump, sewing machine and compressor were all powered. The potential for off-grid systems to power more than just domestic activities is significant for economic development. Increased capacity to power local businesses is likely to encourage economic activity and improve living conditions.<sup>137</sup>

### *Cambodia*

Cambodia's first biomass gasification system was installed in 2003, and since then over 150 plants have been constructed. These gasifiers are all medium sized and range in capacity from 100 to 300 kW, generally.<sup>138</sup> Using rice husks as the primary input, these systems throughout the country have shown to save 1 liter of diesel for every 5 kg of rice husk.<sup>139</sup> Despite reduced quantity and price of inputs, many of these systems contributed to environment and health concerns. The use of water cleaning systems, while very effective, led to increased toxic byproducts that "heavily polluted

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<sup>136</sup> Chukwuma Leonard Azimoh et al., "Electricity for Development: Microgrid Solution for Rural Electrification in South Africa," *Energy Conversion and Management* 110 (February 15, 2016): 268–77, <https://doi.org/10.1016/j.enconman.2015.12.015>.

<sup>137</sup> Azimoh et al, 275.

<sup>138</sup> Dimpl, Blunck, and Volkmer, "Part I: Biomass Gasification," 10.

<sup>139</sup> Ramchandra Pode, Boucar Diouf, and Gayatri Pode, "Sustainable Rural Electrification Using Rice Husk Biomass Energy: A Case Study of Cambodia," *Renewable and Sustainable Energy Reviews* 44 (April 1, 2015): 530–42, <https://doi.org/10.1016/j.rser.2015.01.018>.

[the surrounding land] with black tar and waste water.”<sup>140</sup> This can be avoided by using a dry cleaning system and performing routine maintenance.<sup>141</sup> Additionally, the use of inputs with high moisture content increased environmental risks, while decreasing economic efficiency.<sup>142</sup> Cambodia’s experiment with biomass gasification ran into issues, but these tended to result from a lack of professional expertise during installation and improper cleaning techniques.

### *Bihar, India*

Of India’s many biomass systems, a 128 kW gasification plant in Bihar, India provides power to households, businesses and agricultural activities. The gasification plant and distribution system, from Saran Renewable Energy, cost \$170,000 with 90% of that cost attributed to the gasifier itself. The necessary residues to power the plant are bought from local farmers at \$0.04/kg.<sup>143</sup> As opposed to other systems that require all power users to contribute biomass, this system ensures a reliable supply of residues. Tariffs are set at about \$0.15/kWh, which falls nicely in Ghana’s existing tariff range of \$0.08/kWh to \$0.23/kWh.<sup>144</sup> A World Bank report revealed some of the biggest issues with the gasifier to be unreliable after sales service, insufficient training of local operators and inadequate biomass inputs. The report suggests these concerns can be avoided by giving communities a greater management role and requiring the plant manufacturer to train community members and the power distributor.<sup>145</sup>

### *Barriers*

The most significant barriers to effective implementation of an off-grid biomass system generally fall into two categories: technological and market development. The lack of established small-scale biomass gasifier manufacturers means developing this technology specifically for the needs of individual communities will be key to getting the first major projects off the ground. While agriculture is incredibly important to Ghana, the infrastructure in the industry could improve. The World Trade Organization suggests that “Crop production in Ghana is hampered by land

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<sup>140</sup> Rogier van Mansvelt, “IFC Gasifier Study,” March 2, 2011, 49.

<sup>141</sup> Dimpl, Blunck, and Volkmer, “Part I: Biomass Gasification,” 10.

<sup>142</sup> Mansvelt, “IFC Gasifier Study,” 49.

<sup>143</sup> Dimpl, Blunck, and Volkmer, “Part I: Biomass Gasification,” 8.

<sup>144</sup> Reber et al., “Tariff Considerations for Micro-Grids in Sub-Saharan Africa,” 13.

<sup>145</sup> Dimpl, Blunck, and Volkmer, “Part I: Biomass Gasification,” 15.

degradation, improper field development, use of low-yield varieties, lack of organized seed production and distribution systems, and inadequate storage structures.”<sup>146</sup> Considering these existing issues with the agriculture sector in Ghana, biomass gasifiers could create additional strain. Biomass feedstock is dependent on a reliable agricultural system, so ensuring farms are prepared to divert agricultural residues to gasifiers is essential. Next, the lack of qualified technicians will need to be overcome. If the manufacturer can educate the power distributor and the day-to-day operator about the plant and necessary maintenance, power disruptions can be avoided.<sup>147</sup>

Outside of the technical impediments, the market itself is a barrier. First, there is a clear lack of understanding of the technology; rural populations are unaware of the benefits of biomass power and are much more familiar with solar and hydroelectric power.<sup>148</sup> Next, setting proper tariffs will be a challenge in itself, but predicting how demand will change over time will be necessary too. It remains such a new and underused technology that predicting demand-price reactions due to social or political changes will prove difficult.<sup>149</sup>

### ***Conclusion***

National power grids are expanding access to energy in Ghana significantly, but connection to rural areas is not immediately feasible in the short term. Off-grid solutions are a necessity for continued electrification in Ghana, and biomass technologies provide relevant opportunities. Biomass, in its various forms, constitutes 37.87% of Ghana’s total energy supply, with firewood and charcoal as the two largest inputs.<sup>150</sup> The importance of traditional biomass fuel sources such as wood fuel and charcoal should not be ignored when discussing biomass energy, but it is equally important to recognize emerging technologies such as biogas and biomass gasification that provide new opportunities for diversification and sustainability in the sector. Although each aforementioned technology poses a unique set of challenges, strategic planning and

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<sup>146</sup> “Ghana at a Glance | FAO in Ghana | Food and Agriculture Organization of the United Nations.”

<sup>147</sup> Dimpl, Blunck, and Volkmer, “Part I: Biomass Gasification,” 8-15.

<sup>148</sup> Doghle, “Assessing the cost-efficiency and willingness to adopt biogas as a sustainable source of renewable energy: the case of senior high schools in the greater Accra region.”: 66.

<sup>149</sup> Li Jingjing et al., “Biomass Energy in China and Its Potential,” *Energy for Sustainable Development* 5, no. 4 (December 2001): 66–80, [https://doi.org/10.1016/S0973-0826\(08\)60286-0](https://doi.org/10.1016/S0973-0826(08)60286-0).

<sup>150</sup> Energy Commission, “Ghana Renewable Energy Master Plan,” 2019.

implementation can introduce biomass technologies as sustainable and practical renewable energy solutions in rural and semi-urban Ghana.

In the scope of wood fuel and charcoal production, the Master Plan provides solutions to mitigate the negative impacts of charcoal and wood fuel production that Ghana is facing. These suggestions should be further developed in order to acknowledge the complexity of this widely utilized energy source. Although Ghana's use of charcoal and wood fuel for heat and cooking is extensive, biogas and biomass gasification are in contrast underused and undervalued technologies. By making use of existing agricultural residues and other waste products, rural and semi-urban communities can develop biodigesters and gasifiers that serve domestic, industrial, agricultural and commercial needs. Biogas and biomass gasification provide opportunities for sustainable development that transcend social, economic, and environmental sectors, as they provide energy, jobs, and improved health/education outcomes. When communities and individuals are empowered to operate sustainable biomass technologies, little outside maintenance is required, allowing stakeholders to focus on other larger-scale energy solutions without ignoring the immediate energy needs of communities.

## II. WIND/HYDROPOWER

With a constant lack of electricity in the rural areas of Ghana, the famous “dumsor” phenomenon occurring nation-wide, and a growing demand for electricity, existing infrastructure for wind and hydropower energy proves to be complex, and at times inefficient, each for unique reasons. As stated in the Renewable Energy Master Plan, hydropower provided 43.2% of Ghana’s total generating capacity 2015.<sup>151</sup> These energy technologies, however, are not completely sufficient to power Ghana’s heavily centralized electrical grid. Creating consistent and reliable access to electricity for all of Ghana will vastly increase economic potential and strengthen the local and national economies by creating revenue that can be used internally. The diversification of renewable energy technologies will play a key part in the overall solution.

In moving forward towards this solution, it is pertinent to address the Renewable Energy Master Plan (REMP) as it holds a crucial role in shaping and outlining Ghana’s future in renewables. The REMP outlines three basic and over-encompassing priorities: energy diversification, economic growth, and energy to off-grid/rural communities. Currently, the Ghanaian energy mix is heavily dependent petroleum-based sources, non-renewable thermal energy and hydropower. However, considering the impacts of climate change on the future of water supply in the country, as well as historical shortcomings and high costs, it may be beneficial to shift the focus towards other renewable energy technologies, such as wind energy. The REMP mentions a goal of increasing its wind capacity within the next ten years. Ghana must explore the untapped potential of renewable energies while simultaneously improving energy infrastructure to ensure the maximum impact for investment.

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<sup>151</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 32.

## *Existing Ghanaian Projects in Hydropower and Wind*

### *Hydropower*

In independent sub-Saharan Africa (SSA) beginning in the 1950s, but especially into the 1960s, hydropower began to be seen as a symbol for modernity, and as a way for African nations to develop infrastructure and industry necessary for economic growth. In Ghana, hydropower was largely part of the political propaganda of economic modernity and nation building, henceforth producing a newfound interest towards hydropower.

In 2015, 43.2% of Ghana's total electricity generation capacity came from its hydropower projects.<sup>152</sup> However, this substantial contribution to Ghana's energy mix merely represents the maximum *capacity* of the electricity output, not true production. Like many other renewable energy technologies, true production is in fact often far less than the total capacity. It does not take into account inconsistent rainfall, dilapidated infrastructure, and drought, among other issues. For example, droughts in 2001, 2007, and 2013-2014 lowered water tables and resulted in less available energy, causing a "...reduction in power generating capacity by close to 1000 megawatts of power."<sup>153</sup> To put this into perspective, in the drought of 1999-2001, for example, "as a result of the diminished hydroelectric capacity of the dam, electric power output in the nation decreased by over 50 percent."<sup>154</sup> Nevertheless, within the hydropower energy production sector, Ghana predominantly relies on three main medium-to-large scale dams. These three dams make up the near totality of the 43.2% hydropower capacity in Ghana, with two main reservoir dams— Akosombo and Bui Dams— and one large run-of-river dam— Kpong. All of these dams are located in southern Ghana.

The Akosombo Dam, constructed from 1962-1966, was a post-independence feat that symbolized the industrialization of the country, providing a total electricity production capacity of 1,020 MW.<sup>155</sup> The construction of the Akosombo Dam created the world's largest man-made lake, Lake

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<sup>152</sup> Energy Commission of Ghana, Renewable Energy Masterplan, iv.

<sup>153</sup> UNCCD. "Ghana National Drought Plan," N.A.

[https://knowledge.unccd.int/sites/default/files/country\\_profile\\_documents/1%2520FINAL\\_NDP\\_Ghana.pdf](https://knowledge.unccd.int/sites/default/files/country_profile_documents/1%2520FINAL_NDP_Ghana.pdf). 52.

<sup>154</sup> Stephanie Rupp, "Ghana, China, and the Politics of Energy", *African Studies Review* 56, no. 1 (2013)

<sup>155</sup> "Ghana | International Hydropower Association." *International Hydropower Association* (2019)  
<https://www.hydropower.org/country-profiles/ghana>.

Volta, which takes up 3% of Ghana's total land mass through its damming of the Volta River.<sup>156</sup> The project was funded and constructed by a US based company, Kaiser Aluminum and Chemical, now existing in Ghana as Volta Aluminum Company Limited (VALCO), supplying power to the company's oreing operation of Bauxite from which they built up aluminum reserves<sup>157</sup>.

The Kpong dam was constructed in 1982 and is located 15 miles downstream from the Akosombo dam as a run-of-river dam to complement Akosombo.<sup>158</sup> As Akosombo dam releases water from the reservoir, this potential energy is run through Kpong's dam scheme as it continues down the Volta river. It has an electricity production capacity of one-ninth of the Akosombo dam, with 140 MW of power. Throughout the 1980's, the Kpong dam combined with the Akosombo dam supplied 90% of all the nation's energy demand with a total of 1160 MW of electricity generating capacity.<sup>159</sup>

Although the Bui dam was originally planned to be built at the same time as Akosombo in the 1960's, the dam was postponed and finally completed in 2013 mainly due to the increasingly sparse electricity supply in Ghana caused in part by water shortages.<sup>160</sup> The dam, located in the center-west region of Ghana, has a 400 MW power supply and was funded as one of the most recent collaboration projects between the GoG and the Chinese Sinohydro corporation, financially backed by Chinese bank loans.<sup>161</sup> Bui is emblematic of a larger dynamic occurring across sub-Saharan Africa: the presence and unclear motives of Chinese foreign investment and aid in a variety of infrastructure projects. This relationship will be elaborated on in a later section.

In recent years, Ghana has taken interest in the use of mini hydropower dams as a way to mitigate the high social and economic costs of their larger dams. Currently, Ghana only has one completed Small Hydropower Project (SHP), known as the Hohoe District Mini Hydropower Plant or

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<sup>156</sup> P. Gyau-Boakye, "Environmental Impacts of the Akosombo Dam and Effects of Climate Change on the Lake Levels", *Environment, Development, and Sustainability* 3, no. 1 (2001): 25.

<sup>157</sup> T.E. Hilton, "Akosombo Dam and the Volta River Project", *Geography* 51, no. 3 (1966) 251.

<sup>158</sup> Stephan F Miescher and Dzodzi Tsikata, "Hydro- Power and the Promise of Modernity and Development in Ghana: Comparing the Akosombo and the Bui Projects," (2009) 28.

<sup>159</sup> Kwadwo Owusu, Peter Waylen, and Youliang Qiu, "Changing Rainfall Inputs in the Volta Basin." *Geojournal* 71, (2008) 201.

<sup>160</sup> Miescher and Tsikata, "Hydro- Power and the Promise," 28.

<sup>161</sup> Miescher and Tsikata, "Hydro-Power and the Promise," 28.

Tsatsadu Generating Station, created by the domestic Bui Power Authority at a cost of \$400,000 USD.<sup>162</sup> The SHP is also located in the south in the Volta region, built as a run-of-river dam with a production capacity of 45kW, or .045 MW with the possibility to add another turbine to increase its capacity by 45kW.<sup>163</sup> Additionally, the “One village, One dam” initiative, a policy launched and promoted by the current NPP administration, is also a type of small hydro dam in theory. This policy intends to create small dams, mostly for irrigation purposes; however, as elaborated on in the ‘Chinese Strategy in SSA’ section of this paper, it has not been successfully implemented in Ghana.<sup>164</sup>

### *Wind*

With a constant lack of electrification in the rural areas of Ghana, the ever-famous dumsor phenomenon occurring nation-wide, and a growing demand for electricity, existing infrastructure for wind energy proves to be inefficient and costly, due to lack of technology, expertise, investments, research and development, as well as an inadequate and heavily centralized electrical grid. We divide the following section into microgrids wind and utility-scale wind to expand on wind’s existing presence in Ghana’s energy mix, as well as explore Ghana’s potential in further wind development and question the rationale in doing so.

### *Microgrids*

In this section, we question the technological and economic feasibility of microgrid wind. The only small-scale wind project exists through a hybrid wind-solar system, which exists through the support of the Renewable Energy Technology Transfer (RETT) Project, funded by China. It is located on the island of Pediatorkope, and includes a 39.5 kWp solar generator and an 11 kW wind turbine constructed by the Spanish company Trama Techno Ambiental (TTA), which cost \$800,000 USD. This system powers 3 businesses, a clinic, and 110 households, as well as 120

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<sup>162</sup> John Fidelis, “Ghana Commissions a Mini Hydropower Plant in Hohoe.” Construction Review Online, November 21, 2019. <https://constructionreviewonline.com/2019/11/ghana-commissions-a-mini-hydropower-plant-in-hohoe/>.

<sup>163</sup> “BPA Completes GHANA’S First Micro Hydropower Plant.” *Buipower*, October 11, 2019. <https://buipower.com/bpa-completes-first-micro-hydropower-plant/>.

<sup>164</sup> Francis Abugbilla. Personal Interview, February 12, 2020.

streetlights.<sup>165</sup> In contrast, there are five pilot hybrid solar-diesel systems being developed under the Ghana Energy Development and Access Project (GEDAP) and are being funded by the World Bank, striving to provide a total of 200 kW to communities in Kudorkope, Atigagome, Aglakope, Peditorkope, and Wayokope, that are home to about 3,500 residents. These will be managed by the VRA.<sup>166</sup>

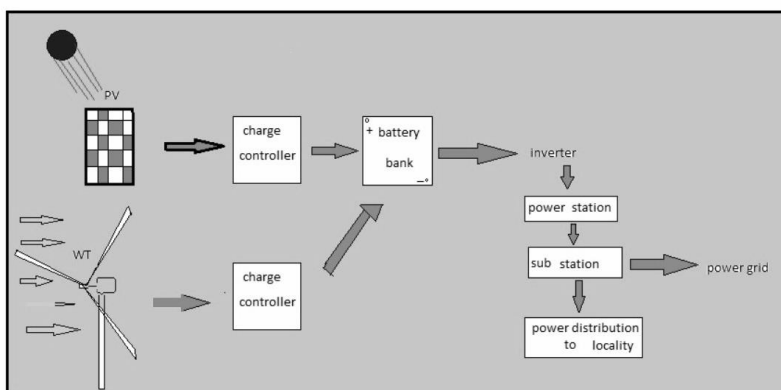


Figure 2.1. Diagram of a Hybrid Wind and Solar Energy System. Ayirewura Vitus Tibiru, “The potential of hybrid solar-wind electricity generation in Ghana,” (diagram), doctoral dissertation, (University of Ghana, 2013), 10, [http://ugspace.ug.edu.gh/bitstream/handle/123456789/5206/Ayirewura%20Vitus%20Tibiru\\_Potential%20of%20Hybrid%20Solar-Wind%20Electricity%20Generation%20in%20Ghana\\_2013.pdf?sequence=1&isAllowed=y](http://ugspace.ug.edu.gh/bitstream/handle/123456789/5206/Ayirewura%20Vitus%20Tibiru_Potential%20of%20Hybrid%20Solar-Wind%20Electricity%20Generation%20in%20Ghana_2013.pdf?sequence=1&isAllowed=y)

The benefit to the hybrid system would be continuous, 24-hour operation, harvesting solar energy while the sun is up and later switching to wind energy when the sun sets, which makes this system *more productive and sustainable* than independent wind or photovoltaic (PV) systems. Along with this, wind and solar energy are both non-finite resources and can be consistently harvested into storage until needed.<sup>167</sup>

<sup>165</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 53.

<sup>166</sup> “Lighting-up isolated communities in Ghana with microgrids,” SNV Netherlands Development Organization, (2018). <https://snv.org/update/lighting-isolated-communities-ghana-microgrids>.

<sup>167</sup> Ayirewura Vitus Tibiru, “The potential of hybrid solar-wind electricity generation in Ghana,” doctoral dissertation, (University of Ghana, 2013), 10, [http://ugspace.ug.edu.gh/bitstream/handle/123456789/5206/Ayirewura%20Vitus%20Tibiru\\_Potential%20of%20Hybrid%20Solar-Wind%20Electricity%20Generation%20in%20Ghana\\_2013.pdf?sequence=1&isAllowed=y](http://ugspace.ug.edu.gh/bitstream/handle/123456789/5206/Ayirewura%20Vitus%20Tibiru_Potential%20of%20Hybrid%20Solar-Wind%20Electricity%20Generation%20in%20Ghana_2013.pdf?sequence=1&isAllowed=y)

The REMP also states a goal of increasing the amount of Standalone Wind Systems, or small-scale wind systems meant to power individual households or businesses, to 0.09 MegaWatt peak (MWp) by 2020, which would be \$630,000 USD according to the REMP.<sup>168</sup> However, the only current small-scale wind generation seems to come from the Wind/Solar PV hybrid model. Thus, to further invest money into new small-scale projects without first understanding and observing the effectiveness of this project does not seem economical nor effective. The Ghanaian government and energy stakeholders should widely disseminate pilot projects with multi-year studies determining their effectiveness and ability to further efficiently implement projects across Ghana.

However, in questioning true effectiveness, Gabra, Miles, and Scott compare economic viability through a cost analysis of levelized cost of energy of wind, diesel, and PV standalone systems throughout SSA and conclude that wind energy is not the most profitable for Ghana on a smaller scale, in comparison to PV and diesel, nor for any surrounding West African countries (Figure 2.2). A region would need high speeds of greater than 6 m/s to compete with the costs of small-scale diesel and PV energy sources. The only regions on the continent whose costs for wind compete with PV and diesel costs are in the horn of Africa near “Somalia, Western Sahara, Chad, and South Africa.”<sup>169</sup> The table below shows that the smaller the wind system, the more costly it becomes, due to higher maintenance costs, capital costs, and battery costs at around €10,207 EUR versus €7,672 EUR for a larger capacity wind system (Table 2.1). Standalone wind systems may not be the most economical at this time for Ghana; large-scale developments seem to be more beneficial in the country’s context.

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<sup>168</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 53.

<sup>169</sup> Samuel Gabra et al., “Techno-economic analysis of stand-alone wind micro-grids, compared with PV and diesel in Africa,” *Renewable Energy* 143, (2019), 1936. Accessed February 15, 2020. <https://doi.org/10.1016/j.renene.2019.05.119>.

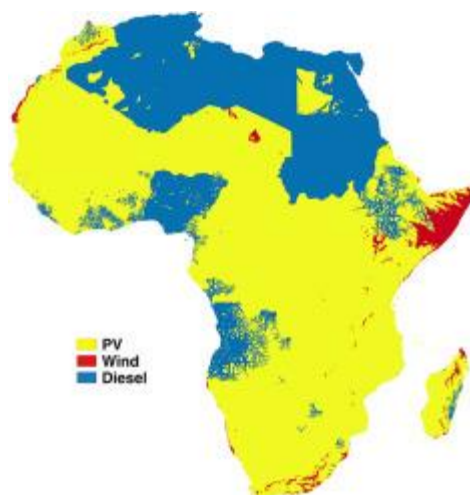


Figure 2.2. Comparisons of levelized cost of energy: wind versus PV and diesel. Samuel Gabra et al., “Techno-economic analysis of stand-alone wind micro-grids, compared with PV and diesel in Africa,” (map), *Renewable Energy* 143, (2019), 1936. <https://doi.org/10.1016/j.renene.2019.05.119>.

Table 2.1. Overall costs for wind systems, classified by mean wind speeds ( $\text{ms}^{-1}$ )

	Category I ( $2-4 \text{ ms}^{-1}$ )	Category II ( $4-6 \text{ ms}^{-1}$ )	Category III ( $6-8 \text{ ms}^{-1}$ )
Turbine cost (€)	53,025	53,025	53,025
Battery capacity (kWh)	60	25	13
Individual battery cost (€)	7590	3121	1568
Total battery cost	30,360	12,485	6270
Civil work & installation costs (€)	3200	3200	3200
Inverter cost (€)	2400	2400	2400
Miscellaneous components cost	8000	8000	8000
Total capital cost (€)	96,985	79,110	72,895
Annualised capital cost (€)	7782	6348	5849
Annual operation and maintenance costs (€)	2425	1978	1822
Total annual cost (€)	10207	8326	7672

Source: Table from Gabra et al. “Techno-economic analysis,” (2019), 1934.

### Existing Utility-scale Wind Projects

The Ayitepa Wind Farm project was fully funded in 2017 with plans to enter phase testing and initial power generation in 2020. The Ayitepa Wind Farm developed by NEK Umwelttechnik AG: Swiss Engineering Co., Atlantic Group (Atlantic International Holding Co.), and Upwind International AG (a Swiss Holding Company).<sup>170</sup> Lekela Power, a Dutch renewable energy private business, is the main investor for this project. The wind farm will be located in Southern Ghana in the Greater Accra region about 60 km east of the capital. With an estimated cost of \$525 million USD, the project will install 75 turbines covering 10,000 acres in two waves, the first of 150 MW

<sup>170</sup>“Lekela\_ayitepa\_wind\_farm\_ghana\_factsheet\_update\_dec\_2018\_v1.Pdf.” Accessed February 28, 2020. [https://lekela.com/wp-content/uploads/2019/03/lekela\\_ayitepa\\_wind\\_farm\\_ghana\\_factsheet\\_update\\_dec\\_2018\\_v1.pdf](https://lekela.com/wp-content/uploads/2019/03/lekela_ayitepa_wind_farm_ghana_factsheet_update_dec_2018_v1.pdf).

and the second of 75 MW for a final installed generation capacity of 225 MW.<sup>171</sup> A new transmission substation created near an existing 330kV power line of the West African Power Pool (WAPP) will then transfer the energy to Ghana's National Interconnected Transmission Grid (NITS). Wind turbines will produce around 400 gigawatt hours (GWh) of energy annually for on-grid use through a signed grid connection agreement with the Ghana Grid Company.<sup>172</sup> In 2017 Upwind Ayitepa signed a 25-year Power Purchase Agreement with the Electricity Company of Ghana to supply 225 MW of energy.

Developed by ENGIE, a global energy company, and eleQtra Limited, but sponsored by the Electricity Company of Ghana, Energy Commission, and Ministry of Power the Ada Wind Power Project will comprise of 16-25 utility scale wind turbines with an expected budget of \$130 million USD.<sup>173</sup> "The Project is being developed as a privately owned independent power producer [(IPP)] under a Build Own Operate structure."<sup>174</sup> It has a 20-year Power Purchasing Agreement (PPA) that entails the sale of energy to the Electricity Company of Ghana. With 50 MW of installed generation capacity, the project will be able to annually produce 150 GWh, which is enough to power 130,000 Ghanaian households or 2% of the population.<sup>175</sup>

Private interest exists in Ghana for further investment in potential new wind projects, and stakeholders are continuing research and assessments into ideal locations for such projects. In June of 2017, the 48 MW Winneba Wind Project gained a portion of funding from Access Power, a renewable energy developer and operator, to begin development, but no further information about its progress is available online.<sup>176</sup> In 2019 the Volta River Authority (VRA) announced its plans to collaborate with two wind developers, Vestas Mediterranean and Elsewedy, to develop 150MW of wind power at four identified sites in the southern part of the country based on wind resource

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<sup>171</sup> "Ayitepa Wind Farm." Power Technology | Energy News and Market Analysis. Accessed February 18, 2020. <https://www.power-technology.com/projects/ayitepa-wind-farm/>.

<sup>172</sup> "Ghana, Ayitepa – Lekela Power." Accessed February 28, 2020. <https://lekela.com/projects/egypt-gulf-of-suez/>.

<sup>173</sup> Babalwa Bungane. "Ghana: Ada Wind Power Project to Inject 50MW by 2019." ESI-Africa.com, June 14, 2017. <https://www.esi-africa.com/industry-sectors/renewable-energy/ghana-ada-wind-power-project-inject-50mw/>.

<sup>174</sup> "Ghana Wind." eleQtra. Accessed February 26, 2020. <https://eleqtra.com/projects/ghana-wind/>.

<sup>175</sup> "Ghana Wind." n.d.

<sup>176</sup> Babalwa Bungane, "Ghana: Ada Wind Power Project to Inject 50MW by 2019." ESI-Africa.com, June 14, 2017. <https://www.esi-africa.com/industry-sectors/renewable-energy/ghana-ada-wind-power-project-inject-50mw/>.

potential<sup>177</sup>; namely, Anloga, Anyanui, Lekpogunu and Akplabanya.<sup>178</sup> Ultimately, wind power in Ghana on all scales is still in its nascent stages, but it garners growing interest as the country looks to diversify its energy mix.

However, because of its high start-up costs on both utility and micro-grid level, wind project funding almost entirely comes from private and foreign entities. Private funding means that private interests are at stake which helps ensure the sustainability of a project, but it also means that along the lifetime of the project, private interests are continually primarily being served. PPAs guarantee a reliable and consistent source of electricity and maintain diplomatic relations between foreign and private companies of Ghana. While this structure ensures a consistent economic and legal relationship between the private electricity company and the government, ensuring a consistent electricity supply, it does not allow the country or its people to harvest the full revenue of its resources. A share of revenue from energy-rich resources is paid out to the country, but the vast majority of it goes to the private company using the land. Because of private and foreign investment, Ghana lacks autonomy in its electricity industry, creating larger political problems embedded in privatization. Ghana must balance the high investment required for wind projects with the funding required to fill that without becoming beholden to the interests of invested stakeholders.

The data analysis used by the Energy Commission in the 2019 REMP through research by the National Renewable Energy Laboratory, shows that some regions possess wind resources in Ghana that are classified as Class 4-5, or good-to-excellent (Figure 2.3), based on wind power density found at 50 meters high (measured in  $W/m^2$ ) as well as wind speed (measured in m/s), and were found to be marginally substantial for further wind farm development.<sup>179</sup>

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<sup>177</sup> “WPP1 Draft ESIA Report Volume 1.Pdf.” Accessed February 28, 2020.

<https://www.vra.com/media/2018/april/WPP1%20Draft%20ESIA%20Report%20Volume%201.pdf>.

<sup>178</sup> Michael Creg Afful, “Ghana: VRA To Develop First Wind Power Project | Energy News Africa.” Accessed February 17, 2020. <https://energynewsafrika.com/index.php/2019/10/15/ghana-vra-to-develop-first-wind-power-project/>.

<sup>179</sup> *Ghana - High Resolution Wind Resource / Data Catalog*, National Renewable Energy Laboratory & Negawatt Challenge, (map), (2004).

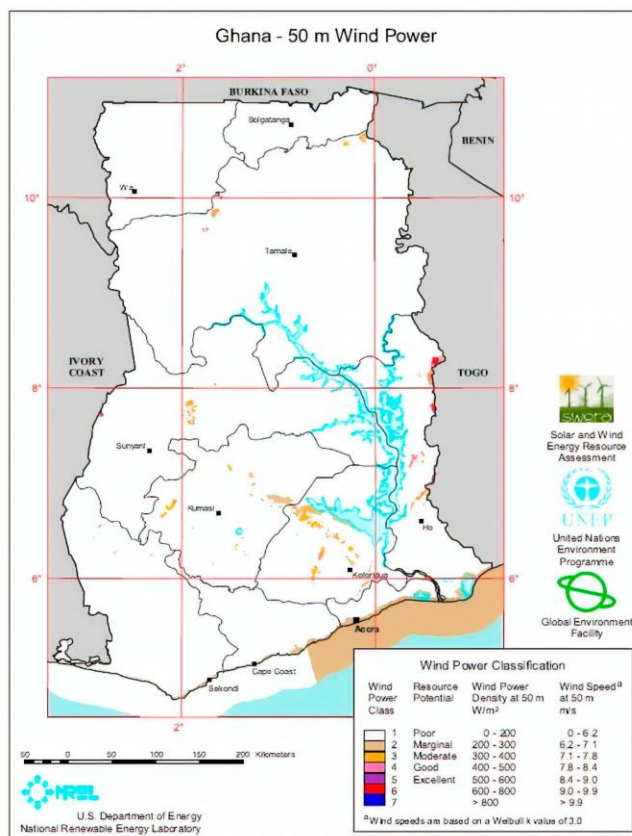


Figure 2.3. Wind resource assessment conducted by the US National Renewable Energy Laboratory and referred to in the 2019 REMP. *Ghana - High Resolution Wind Resource / Data Catalog*, National Renewable Energy Laboratory & Negawatt Challenge, (map), (2004).

Average wind speeds are 6.4-7.5 m/s, corresponding to wind class categories 2 (6.2-7.1 m/s) and 3 (7.1-7.8 m/s) (Figure 2.3). Overall, the most promising areas for deployment of wind power projects are along the mountains in the south-eastern areas and eastern coastal areas of Ghana and in high energy density locations on the eastern border with Togo. Here, resource potential was calculated at 600-800 W/m<sup>2</sup> at 50 m with wind speeds of 9.0-9.9 m/s.<sup>180</sup> However, these results produced by the Energy Commission of Ghana conflict with recent data and analyses which more favorably support wind as a widely viable energy resource.

<sup>180</sup> *Ghana - High Resolution Wind Resource / Data Catalog*, National Renewable Energy Laboratory & Negawatt Challenge, (2004).

In contrast to the government's figures, contemporary wind resource analysis by Samuel Asumadu-Sarkodie & Phebe Asantewaa Owusu found that around 5,000-6,000 MWh could be produced in potential wind farms locations like Adrafoah, Cape coast, Mankoadze, Takoradi, and Warebeba.<sup>181</sup> Using the commercial wind turbine model VESTAS V90-2.0 MW in their research, 4,000-5,000 MWh of that energy is expo to the national grid. This would add 10 MW of energy capacity to the national energy mix.<sup>182</sup> They concluded that the benefits of developing large-scale wind projects in these areas outweigh their costs, resulting in a beneficial payback for the region (Figure 2.4).<sup>183</sup> This model would cost as low as \$81.3 USD/MWh, compared to the energy production cost of SSA as a whole, which is \$115 USD/MWh before losses.<sup>184</sup> These findings present a benefit in developing *some* wind projects in these specified areas to diversify Ghana's energy mix, but only upon further feasibility research should this occur. Wind projects should be of lower priority than other renewables, due to high start-up costs and unpredictable efficiencies.

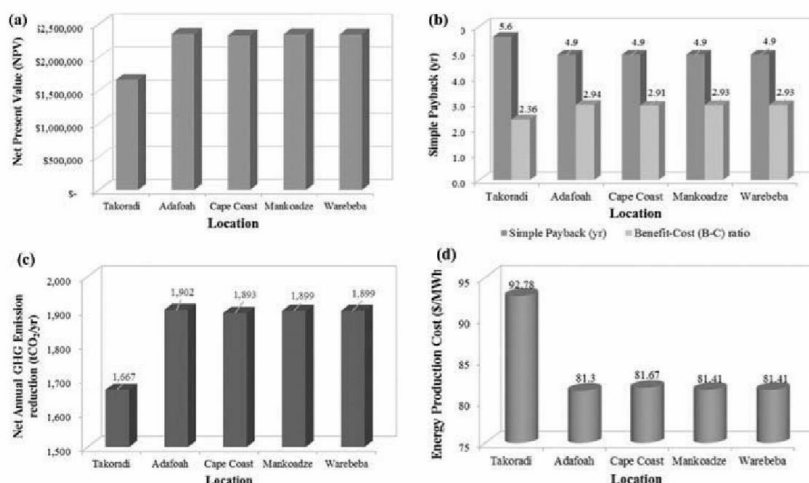


Figure 2.4 Comparing (a) net present values, (b) simple paybacks, (c) net annual GHG emission reductions, and (d) energy production costs, among the five areas in Ghana. Samuel Asumadu-Sarkodie and Phebe Asantewaa Owusu, "The potential and economic viability of wind farms in Ghana," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 38, no. 5, (2016): 700, DOI: 10.1080/15567036.2015.1122680.

<sup>181</sup> Emmanuel Osei, and Eric Essandoh. "RET Screen Assessment of Utility Scale Wind Power Generation Based on Historical Wind Speed Data-the Case of Mankoadze in the Central Region of Ghana." *Research Journal of Applied Sciences, Engineering and Technology* 7, no. 21 (2014): 4593-4600.

<sup>182</sup> Samuel Asumadu-Sarkodie and Phebe Asantewaa Owusu, "The potential and economic viability of wind farms in Ghana," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 38, no. 5, (2016): 700, DOI: 10.1080/15567036.2015.1122680.

<sup>183</sup> Ibid et al, 699.

<sup>184</sup> Ibid et al, 700.

## *Challenges and Barriers to Successful Hydropower and Wind Electrification*

### *Hydropower*

Ghana has invested hundreds of millions of dollars in hydropower electrification projects since the 1960's, and continues to heavily invest in the sector despite problems of inconsistent rainfall, dilapidated infrastructure, and a history of leaving negative social and environmental consequences in areas affected by dam creation. Of course, Ghana is not alone in the region for funding these projects. SSA as a region relies on 70% of electricity generated by hydropower in 2008, and 32% of SSA's electricity generation capacity coming from hydropower in 2016.<sup>185</sup> This begs the question of why these projects continue to be funded as they become less efficient and increasingly dependent on a water powered resource that is not always reliable due to erratic rainfall and climate change. Nevertheless, Ghana has already invested tremendously in hydropower projects, and with their continued commitment in funding expansion of the industry as laid out in their 2019 REMP, the country will continue to depend heavily on hydropower in the future. Furthermore, with numerous potential options for new hydropower project locations along with different hydropower technologies that serve other purposes such as irrigation, the country of Ghana will have to make decisions on *how* to most effectively invest in the industry, as well.<sup>186</sup>

Throughout Ghana's history, hydropower has been controversial in creating economic and social issues in the country despite its renewable status and important role in forming much of the country's power supply. From the already immense physical capital investments that Ghana has made in hydropower projects, and as the country prepares to confront increasing energy demands with more hydropower projects as laid out in their Renewable Energy Master Plan, this section will discuss an extensive list of challenges that will continue to be present in the hydropower sector.

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<sup>185</sup>Chiyembekezo S. Kaunda, Cuthbert Z. Kimambo, and Torbjorn K. Nielsen, "Hydropower in the Context of Sustainable Energy Supply: A Review of Technologies and Challenges." Review Article. ISRN Renewable Energy, (2012) 10.

<sup>186</sup> African Energy. "Ghana's Energy Sector Infrastructure." Cross Border Information, (2019).

### *Climate leading to unreliable rainfall and drought*

Perhaps the most pressing unavoidable issue is the influence that climate has on the efficiency and ability of dams to produce electricity. In part, this stems from observations that show “that there has been a clear rainfall declining trend since the 1970s in both the forest and savannah zones of West Africa.”<sup>187</sup> In fact, from 1950 until 2000, “Mean annual rainfall totals have diminished from 1,400 mm to 1,200 mm in the south and from 700 mm to 600 mm in the north.”<sup>188</sup> While seemingly small, this downward trend in precipitation, when put in combination with variable weather patterns such as droughts and increasing temperatures, has especially dramatic consequences on the viability of Ghana’s dams.<sup>189</sup>

Extreme weather years with extended droughts and decreasing rainfall will continue to be problematic for Ghana’s dam infrastructure. El Niño and La Niña weather patterns cause shifts in currents and wind patterns that bring unusual precipitation patterns among other weather changes. These changes can cause extended droughts or floods.<sup>190</sup> For example in Kenya, during the El Niño flooding event from 1997-1998, and the La Niña drought from 1998-2000, “the drought event led to a 41% decline in hydropower production and high costs to industrial production and agricultural losses.”<sup>191</sup> This decline in hydropower production can be seen very clearly in the figure below that, in addition to showing the decline in energy production in 1998 due to drought, also shows the fluctuations of production throughout the years (Figure 2.5).

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<sup>187</sup> Gyau-Boakye, “Environmental Impacts of the Akosombo Dam and Effects of Climate Change on the Lake Levels.” 26.

<sup>188</sup> Owusu, Waylen, and Y. Qiu, “Changing Rainfall Inputs in the Volta Basin.” 205.

<sup>189</sup> Gyau-Boakye, “Environmental Impacts of the Akosombo Dam and Effects of Climate Change on the Lake Levels.” 28

<sup>190</sup> “ENSO and Drought Forecasting” *National Drought Mitigation Center*. N/A  
<https://drought.unl.edu/Education/DroughtIn-depth/ENSO.aspx>.

<sup>191</sup> Olivia Serdeczny, Sophie Adams, Florent Baarsch, Dim Coumou, Alexander Robinson, William Hare, Michiel Schaeffer, Mahé Perrette, and Julia Reinhardt. “Climate Change Impacts in Sub-Saharan Africa: From Physical Changes to Their Social Repercussions.” *Regional Environmental Change* 17, no. 6 (2017) 4.

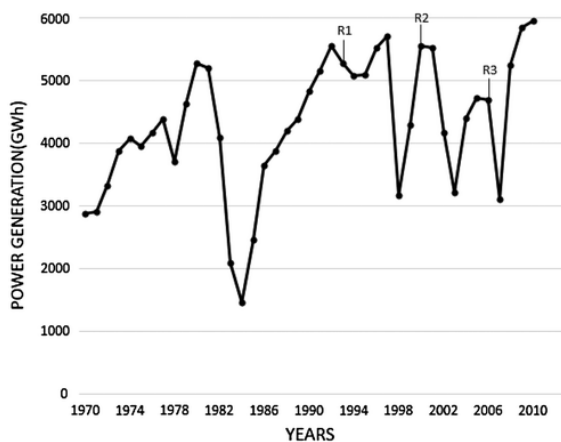


Figure 2.5. Power generated by Akosombo dam through the years 1970-2010. Drought seasons correlate with fluctuations in generation. Sylvester Afram Boadi and Kwadwo Owusu, "Impact of climate change and variability on hydropower in Ghana," (graph), *African Geographical Review*, (2017), 8, <https://doi.org/10.1080/19376812.2017.1284598>.

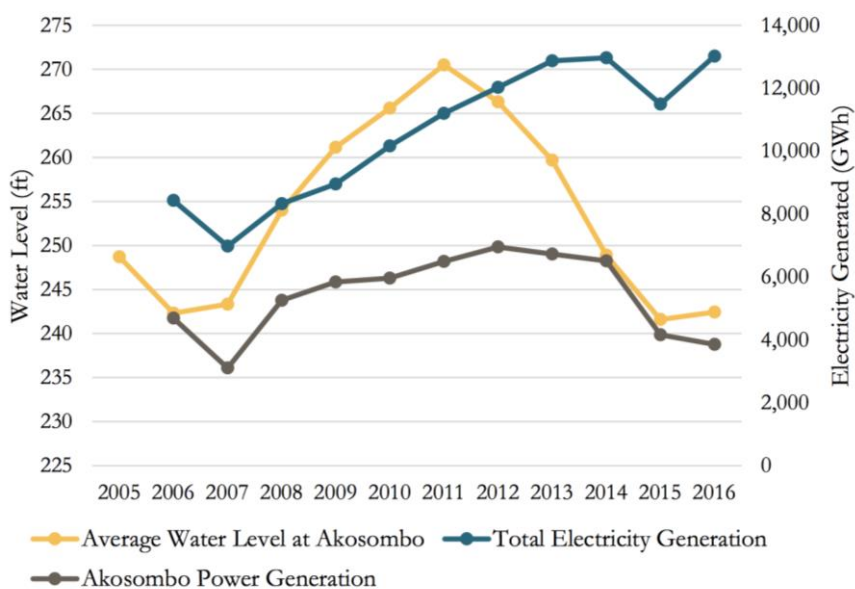


Figure 2.6. Water levels versus true generation at Akosombo dam. Ebenezer Nyarko Kumi, "The Electricity Situation in Ghana: Challenges and Opportunities," (graph), CGD Policy Paper. Washington, DC: Center for Global Development, 10, <https://www.cgdev.org/publication/electricity-situation-ghana-challenges-and-opportunities>

Furthermore, this correlation between water level, water precipitation, and energy production can be seen in the graph above, where the brown line represents energy production and falls with lowering water tables (Figure 2.6). As one study illustrated the correlation between rainfall and power generation, stating, "for every 1 mm increase in rainfall there is a 2.964 GWh increase in

power generation implies that if rainfall reduces, power output will also reduce.”<sup>192</sup> Of course, while Ghana has witnessed a gradual downward trend, another study shows that, “on a global level... global hydropower generation potential is predicted to increase, but very little (less than 1%...)”<sup>193</sup> Though views on the plausibility of predicting the rate of depleting water tables vary, it is certain that droughts and changing weather patterns will directly affect the ability of Ghana to depend on hydropower in the future.

### ***Social problems: Sinohydro and Bui Power Authority***

Since the Ghanaian independence, dams have promised industrialization, job production, national electrification, and better quality of life. These promises have not always been realized, sometimes with devastating consequences. Initially, the resettlement of the 80,000 people displaced by the Akosombo Dam in the 1960's was a socio political disaster.<sup>194</sup> Approximately 60% of the resettled community population migrated away after the first few years due to poor living conditions and half built amenities in the houses where they were relocated.<sup>195</sup> Moving forward 50 years, however, Ghana placed nearly all decisions regarding relocation, employment, management, planning, and communication with foreign partners during the construction of the Bui dam in 2008 in the hands of the Bui Power Authority (BPA).<sup>196</sup> Under the BPA, resettlement of communities displaced by the Bui Dam were far more secure as the process included relatively open communication, monetary compensation, two acres per family for farming, a community center, a nursery school, and overall very modern and well-built infrastructure for the new communities.<sup>197</sup> Nevertheless, core social and efficiency problems persisted: “Power generation runs at about a quarter of its nameplate capacity” and “1,216 people have been resettled which is 40% the original estimate.”<sup>198</sup> Other issues ensued following the influx of 1,836 construction

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<sup>192</sup> Sylvester Afram Boadi, and Kwadwo Owusu. “Impact of Climate Change and Variability on Hydropower in Ghana.” *African Geographical Review* 38, no. 1 (2019) 27.

<sup>193</sup> Kaunda, Kimambo, and Nielsen, “Hydropower in the Context of Sustainable Energy Supply.” 12.

<sup>194</sup> Hilton, “Akosombo Dam and the Volta River Project,” 253.

<sup>195</sup> Miescher and Tsikata, “Hydro-Power and the Promise,” 23.

<sup>196</sup> Paul W. K. Yankson, , Alex B. Asiedu, Kwadwo Owusu, Frauke Urban, and Giuseppina Siciliano. “The Livelihood Challenges of Resettled Communities of the Bui Dam Project in Ghana and the Role of Chinese Dam-Builders.” *Development Policy Review* 36 (2018) 15.

<sup>197</sup> Miescher and Tsikata, “Hydro-Power and the Promise,” 42.

<sup>198</sup> Yankson et al., “The Livelihood Challenges of Resettled Communities of the Bui Dam Project in Ghana and the Role of Chinese Dam-Builders,” 8.

workers from outside the area, causing inflated prices, increased competition, and depletion of local resources.

While the Bui dam was managed and executed almost solely by Ghana's state-owned BPA, the Chinese state-owned construction corporation, Sinohydro, provided "a wealth of expertise and engineering capabilities to the Ghanaian hydropower sector," yet avoided all environmental and social externalities caused by the operations.<sup>199</sup> Complaints were made of the seemingly unchecked relationship that the BPA had to the project, where, "Ghanaian workers have complained of poor salaries, cramped quarters, as well as health and security concerns."<sup>200</sup> Furthermore, "unlike their Chinese counterparts, they [Ghanaian workers] enjoyed no resting days, no annual leave."<sup>201</sup>

While the quality of the relocation facilities and compensation improved compared to the 1960's Akosombo dam project, social assessment did not guarantee the long-term well-being of displaced people, despite official discourses of improving lives through relocation.<sup>202</sup> Although encouraged to "seize opportunities afforded by the dam,"<sup>203</sup> without access to technical job training or even basic education, "...very few locals were going to be employed in skilled jobs as they were mostly illiterate."<sup>204</sup> The core problems of lacking employment and electrification along with inequality in who reaps the benefits of electricity from these dams continue to be unresolved. This cycle of poverty and low positive impact to Ghanaian people is a recurring theme especially with regard to hydropower projects. These larger global influences will be discussed in a later section.

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<sup>199</sup> Yankson et al., "The Livelihood Challenges of Resettled Communities of the Bui Dam Project in Ghana and the Role of Chinese Dam-Builders." "The Livelihood Challenges," 18

<sup>200</sup> Miescher and Tsikata, "Hydropower and the Promise," 46.

<sup>201</sup> Ibid..

<sup>202</sup> Heidi Hausermann, "Ghana Must Progress, but We Are Really Suffering: Bui Dam, Antipolitics Development, and the Livelihood Implications for Rural People", *Society & Natural Resources* 31, no. 6 (2018): 643.

<sup>203</sup> Hausermann, "Ghana Must Progress, but We Are Really Suffering." 636.

<sup>204</sup> Miescher and Tsikata, "Hydropower and the Promise," 42.

### *Dam preferences and infrastructural inefficiencies*

Dams vary in design and capacity, each configuration with its own set of positive and negative qualities regarding their economic and electrical efficiencies, environmental and social impacts. In general, there are three main types of dams: run-of-river, reservoir (storage), and pump storage.<sup>205</sup> All three of these main types consist of using the downward pressure from either gravity (the drop in altitude of a river for example) or mass (the weight of the water of a lake), to force water through a tunnel in order to spin a turbine.<sup>206</sup>

The run-of-river hydro scheme is completely dependent on the water flow from the stream or river and does not store water. While this scheme does not physically change the landscape (less social and ecological burden) and is less expensive, its downfall is that it cannot store water to help in times of drought or for irrigation purposes.<sup>207</sup> Additionally, depending on the location of the project, if there is too much water flow, the run-of-river system may need to ‘spill’ water which is essentially wasted energy that could have been utilized to its full potential by a dam system.<sup>208</sup>

The reservoir (storage) and pump storage are similar to each other in that they are not dependent on a constant flow of water, but rather store up water reserves to be released to the river below. The shortcomings of the reservoir scheme consist of it being more expensive due to more required labor and materials to build the dam, and it also creates larger social and ecological consequences due to its creation of a reservoir and impediment of the rivers below it. Positively, the reservoir system is more economically and electrically efficient than the run-of-river scheme due to its ability to build up reserves and release water as needed. Next, the pump storage scheme is similar to the reservoir scheme in theory, yet relies on a system using two reservoirs to pump water up to the higher elevation reservoir when energy/water resources are plentiful and then relying on gravity to release that water to create energy when energy demand is high.

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<sup>205</sup> “Renewable Energy Technologies: Cost Analysis Series.” *IRENA 1: Power Sector*, no. 3/5 (June 2012). [https://www.irena.org/documentdownloads/publications/re\\_technologies\\_cost\\_analysis-hydropower.pdf](https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-hydropower.pdf). 8.

<sup>206</sup> IRENA, “Renewable Energy Technologies: Cost Analysis Series.” 8.

<sup>207</sup> *Ibid.*

<sup>208</sup> *Ibid.*

In addition to the type of dam or hydropower project, the size is equally as important; size will determine the energy production capacity, the reserve time of a dam during drought periods, cost, and other variables. While larger hydropower projects are located near the centralized power grid to ensure there is enough demand during peak output times, small hydro projects are commonly off grid and used for more local use.<sup>209</sup> Large hydropower projects, while more economically efficient, also have larger social and ecological implications than smaller projects. Generally, in West Africa these mini hydropower dams, commonly known as Small Hydro Projects (SHP's), are defined as having a generation capacity of under 10 MW.<sup>210</sup> While SHP's can have a water storage component, they are also frequently constructed as 'run-of-river' plants.<sup>211</sup> Additionally, the One Village, One Dam initiative, serves to provide many small hydropower dams throughout Ghana. These dams focus predominantly on irrigation and for the most part have been implemented unsuccessfully.

Similar to any investment in physical capital, dams will become dilapidated over time. Well built, small dams can produce up to 50 years until they require "major new investments on parts."<sup>212</sup> In general, hydropower plants have long lifetimes, lasting from about 30 to 80 years with "regular upgrading of electrical and mechanical systems but no major upgrades of the most expensive civil structure."<sup>213</sup> In 2006, a retrofit project was completed where the Akosombo dam replaced its turbines, increasing the electricity output from 912 MW to 1020 MW.<sup>214</sup> Additionally, on top of the dilapidating infrastructure, these dams could benefit greatly from improved technical adaptation measures to mitigate challenges from drought and flood years.<sup>215</sup> Some methods include the "use of several small-scale generating units instead of one large-scale generating unit," installing new turbine technologies that are better equipped for 'a variable flow environment,' and

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<sup>209</sup> IRENA, "Renewable Energy Technologies: Cost Analysis Series" 11.

<sup>210</sup> IRENA "Renewable Energy Technologies: Cost Analysis Series", 38.

<sup>211</sup> Jean Marie Takoueu, "GHANA: BPA Commissions a Mini Hydroelectric Power Plant in Hohoe." *Afrik 21*, November 19, 2019. <https://www.afrik21.africa/en/ghana-bpa-commissions-a-mini-hydroelectric-power-plant-in-hohoe/>.

<sup>212</sup> Chiyembekezo S. Kaunda, Cuthbert Z. Kimambo, and Torbjorn K. Nielsen, "Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa." *Review Article. ISRN Renewable Energy*, (2012) 5.

<sup>213</sup> IRENA, "Renewable Energy Technologies: Cost Analysis Series", 7.

<sup>214</sup> Deborah Darko, Michael Kpessa-Whyte, Emmanuel Obuobie, Pius Siakwah, Obodai Torto, and Dzodzi Tsikata. "The Context and Politics of Decision Making on Large Dams in Ghana: An Overview." *Future DAMS*, (2019) 7.

<sup>215</sup> Darko et al. "The Context and Politics of Decision Making on Large Dams in Ghana" 30.

by installing “flood attenuation [designs]... like dams, barrages, weirs, settling basins, and channels.”<sup>216</sup> However, as discussed, the most suitable way to mitigate the effect of droughts on hydropower production may be to build types and sizes of dams that are most efficient in dealing with the predicted increase of extreme weather.

### *Wind*

Although planned and in progress wind projects exist in Ghana, they still lack meaningful and reliable wind power generation, with no existing utility scale wind power and 0.01 MWp of standalone wind power. The only actual wind power generation is going towards irrigation and groundwater pumps, rather than electricity.<sup>217</sup> Because of its recent introduction into Ghana’s energy mix and the high cost to wider scale implementation, wind power currently only exists in Ghana through prototype and pilot projects.<sup>218</sup>

There are several theories as to why there is a lack of prioritization on wind energy in Ghana. Numerous infrastructural, social, cultural, and economic barriers exist that prevent these few pilot projects from being fully implemented and systemized. In the context of renewable energies as a whole, the shortcomings stem from a lack of advanced technology, expertise, local participation, investment, and research development, not to mention the wavering infrastructure. These barriers make the result of even the most advanced wind farms futile in the grander scheme. Not only does Ghana lack a strong history of successful wind projects to bolster confidence for the investment of more in the future, but supportive infrastructure for the projects, like transmission lines and substations, are insufficient. Even with the most advanced wind turbines that minimize generation losses, the existing infrastructure of the national power grid results in distribution and transport losses that severely limit the consumable electricity supply. Inadequate grid infrastructure further inhibits renewable energy from developing effectively.

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<sup>216</sup> Kaunda, Kimambo, and Nielsen, “Hydropower in the Context of Sustainable Energy Supply.” 12.

<sup>217</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 46.

<sup>218</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 30.

### ***Finance, Trade and Regional economic relationships for wind***

Financial barriers are one of the most pressing issues to wind power development. High start-up costs to build new wind infrastructure in land surveys, wind turbines, grid connection, and batteries all require a high initial investment which require immense social support, openly dedicated political leaders, and private investment to take on such an endeavor. Funding for the Lake Turkana Wind Power Project in Kenya was sourced solely from private funding and secured through a PPA backed by the Kenyan government <sup>219</sup>. Relying on private funding requires the Government of Ghana to make its markets attractive to investors through tariffs, investment schemes, and guarantees of high payoffs for their investments. However, this position leaves Ghana vulnerable to unfair or unequal agreements that disproportionately benefit the foreign and/or private investor over the needs of the country. Because of a less consistent and proven history of successful wind power in Ghana, the country is less competitive in the international energy market. More promising and rivaling opportunities elsewhere in Africa stimulate investment in those countries, so Ghana lacks significant leverage in bargaining agreements.

Another funding option would be reallocating resources or revenue from one area of the energy sector to another. However, in the petroleum sector, one of Ghana's most revenue-generating resources in its energy mix, foreign oil companies come into Ghana and rent out the oil reserves. While Ghana receives a small cut of the revenue from that reserve, it is a fraction of the amount that the petroleum company makes selling it to other countries. This lack of ownership over resources stems from financial limitations but is actualized through a lack of machinery and mining infrastructure. Thus, Ghana loses autonomy not only over its geological resources but also over their resulting revenue that can be used to fund renewable technologies and increase infrastructure that will provide electricity access for all Ghanaians.

According to local opinion, Ghanaians seem to be hopeful for a future with reliable electricity in the wake of hydropower but are unaware of the potentials of other renewable energies such as wind. Hydropower is talked about more “positively” and widely, whereas wind is rarely discussed,

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<sup>219</sup> Chirambo Dumisani, “Addressing the Renewable Energy Financing Gap in Africa to Promote Universal Energy Access: Integrated Renewable Energy Financing in Malawi.” *Renewable and Sustainable Energy Reviews* 62 (September 1, 2016): 793–803. <https://doi.org/10.1016/j.rser.2016.05.046>.

due to its novelty and inapplicability around the whole country. Especially in regards to the One Village, One Dam initiative, “people think of it positively, but they want to see it before they believe.”<sup>220</sup> With respect to wind projects, on the contrary, they “haven’t heard anything of the sort.”<sup>221</sup> For solar power, it is easy to see in any region in Ghana why solar is a promising energy resource for the whole country as the sun is prevalent all day and year round. However, the small number of people living in areas ideal for wind power (locations with low population density) fuels the public belief that wind resources in Ghana are minimal. While irrigation and water pumps are an important aspect of the capacity wind can contribute to the national energy mix, it currently only has agricultural use, which similarly shields it from the popular eye. This lack of local awareness of renewable energies could also translate to a lack of interest and local participation.

Larger market barriers have also limited the development of the wind market in Ghana. There is an ‘over-contracting’ in new plants, something that seems to have a bad connotation within a system that already wants to decrease the creation of new pilot projects. This inclination is evident in their prohibition on new licenses for solar PV standalone projects. Due to the already lacking investment market, lack of creditworthiness in the eyes of financial stakeholders, and high generation costs, Ghana must allocate their funds with caution.<sup>222</sup> Therefore, Ghana is prioritizing its finances towards technologies that have historically proven to work, such as thermal and hydropower as opposed to a relatively nascent technology like wind.

In addition, Ghana’s position as a primary exporting economy also poses a barrier to national electrification efforts. Ghana exports much of its total energy production, which decreases the potential energy benefit the region could receive for itself. While not specifically renewable energy, the European Union imports from western African states represent “4.2% for oil, 3.6% for natural gas, and 12.7% for uranium.”<sup>223</sup> In particular, Nigerian oil contributes to core European oil companies like Shell, Total, and Eni. Thus, western African states play a large role in the economy of EU states in the health of private oil companies, the creation of domestic jobs, and the payment

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<sup>220</sup> Apam, Personal Interview, 2020.

<sup>221</sup> Baffour-Ata, Personal Interview, 2020.

<sup>222</sup> “Ghana Energy Situation.” Energypedia. Accessed February 3, 2020. [https://energypedia.info/wiki/Ghana\\_Energy\\_Situation](https://energypedia.info/wiki/Ghana_Energy_Situation).

<sup>223</sup> Karim Karaki. “Understanding ECOWAS Energy Policy: From National Interests to Regional Markets and Wider Energy Access?” European Centre for Development Policy Management, March 2017. 10.

of taxes. The benefits of this export/import scheme “reduce incentives for ECOWAS Member States to invest in regional energy trade and infrastructure.”<sup>224</sup> Because western African countries play a significant role in the EU’s energy mix, the countries have the ability to hold collective bargaining power around their resources. Western African countries need to leverage this bargaining power in order to assert their power in agreements with foreign investors.

As a larger regional entity, ECOWAS has the potential to help countries like Ghana use this regional leverage to navigate and escape economic dynamics of dependency. Originally established by the 1975 Treaty of Lagos and intentionally evolved since, ECOWAS now serves as a political and economic organization that aims to uphold peace in the region, promote regionalism, and to “foster the ideal of collective self-sufficiency.”<sup>225</sup> A regional entity like ECOWAS is crucial to dismantling an extensive history of export oriented dependency enforced on many African nations by their former colonizers. During the post-independence era, many African nations followed their colonizers in a modernization model based heavily on industrializing.

Colonial metropolises also failed to set up any import-substitution industries prior to independence, making most African nations dependent on their economic relationships with their previous colonizers in the 1960s and 1970s. Virtually all trade, both imports and exports, was “still directed toward the former colonizers.”<sup>226</sup> During independence negotiations, economic dependency was often hidden in independence criteria, often giving preferential trade agreements and developing bilateral aid relationships solely with colonizer countries.<sup>227</sup> The majority of economies were predominantly monocrop exporting economies, and industrialized countries in Europe and North America encouraged African nations to continue producing commodities they held comparative advantage in. This was and remains to be a cyclical process that proves harmful for African nations— if they produce comparative advantage commodities like food products, they will never develop industry and infrastructure to develop comparative advantage in other manufactured

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<sup>224</sup> Karaki, “Understanding ECOWAS Energy Policy,” 10.

<sup>225</sup> “Basic Information | Economic Community of West African States(ECOWAS).” Accessed February 14, 2020. <https://www.ecowas.int/about-ecowas/basic-information/>.

<sup>226</sup> April Gordon, and Donald Gordon. *Understanding Contemporary Africa*. 4th ed. Boulder, Colorado: Lynne Rienner Publishers, 2013, 112.

<sup>227</sup> Gordon and Gordon, *Understanding Contemporary Africa*, 113.

goods, and will always continue to export goods that leave them at the hands of their colonizers or other wealthier foreign actors and unprotected from international market shifts.

Today, Ghana's economy and development still are very much dependent on foreign actors and funding. Structural adjustment programs in the 1980s and 1990s allowed for predatory lending practices by many international banks. Aid and development project implementation was withheld or threatened to be withheld unless African nations could comply with policies put forth by the banks or unless development projects matched the values of international financial institutions like the International Monetary Fund or World Bank. In the last twenty years, these unfair demands, conditionalities and constraints made by international donors have been critiqued by most African nations. Many countries are trying to combat predatory practices through initiatives like the New Partnership for Africa's Development (NEPAD).<sup>228</sup> However, many of the loans put forth by new Chinese initiatives in Africa are cycling back to the older story of structural adjustment and threaten to place nations into debt traps. Chinese banks like the Export-Import Bank of China, as well as Chinese corporations like Sinohydro Corporation, a state run entity and the "world's largest hydropower construction company" that funded Bui dam, have provided Ghana with billions and billions of funds in aid, loan, and construction for infrastructure projects.<sup>229</sup> Many of the countries affected by China's Belt and Road Initiative have worried about debt traps forming in the future, and Ghana should feel much the same.<sup>230</sup> Though Chinese money can fund projects that drive growth, the potential for a Chinese debt (and thus political and economic influence) trap, is incredibly risky. ECOWAS has the potential to combat this dynamic and provide western African nations the leverage they need to lead their own development while receiving outside funding.

### ***The Chinese Strategy in SSA: Case study on Ghanaian Hydropower***

Foreign investment and influence also works its way into energy policy, which is covered up by a lack of transparency and funding. The REMP "forms part of a broader set of initiatives" promoted by the Danish government called China-Ghana South-South Cooperation Renewable Energy

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<sup>228</sup> Gordon and Gordon. *Understanding Contemporary*, 115.

<sup>229</sup> "Sinohydro Corporation." International Rivers. Accessed February 11, 2020. <https://www.internationalrivers.org/campaigns/sinohydro-corporation>.

<sup>230</sup> French, *China's Second Continent: How a Million Migrants Are Building a New Empire in Africa*, 189.

Technology Transfer.<sup>231</sup> Thus, the REMP is not only a document made as a political move to promise electricity to voters, but it was also an agreement made in conjunction with international interests.

China has permeated the Ghanaian energy sector so heavily that Chinese funding even backs Ghana's 2019 REMP. The REMP suggests that China's internal development strategy is an unqualified success and promotes the emulation of Chinese action on many fronts. In the Acknowledgement section of the document, it states that "funding for the development of the plan was made available by the 'China-Ghana South-South Cooperation on Renewable Energy Technology Transfer' project, which is a collaboration between the Energy Commission in Ghana, the Ministry of Science, and Technology in China together with the [United Nations Development Programme] UNDP Country Offices in Accra and Beijing," and that it encourages "exchange of expertise and technology between China and Ghana, building on China's unique development experience."<sup>232</sup>

In Ghana today, the Chinese government continues to fund a variety of development initiatives. According to the Ghana Investment Promotion Centre (GIPC), in June of 2017, China pledged to provide \$15 billion USD for a Ghanaian economic transformation plan, the details of which have not been fully elaborated on. At the same time, the GIPC claimed that there was potential for \$4 billion USD more worth of funding if discussions and negotiations in the following months continued to go well. Some of this funding will go towards needs in "water, energy, railways, sanitation, road etc." that Vice President Mahamudu Bawumia, the head of government delegation to China, claimed are so "massive that we needed a sort of Marshal plan to be able to lay the foundation for the strategy of agricultural transformation as well as industrialisation."<sup>233</sup> In these negotiations, the GoG presented economic development projects like the "One District, One Factory" project and the "One Village, One Dam" project. The Chinese agreed to fund these projects, as well as others across various sectors. This same GIPC Press release claimed, very

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<sup>231</sup> "Ghana's Renewable Energy Master Plan Out-Doored." Accessed February 28, 2020.

<http://energycom.gov.gh/rett/news-and-events/93-ghana-s-renewable-energy-master-plan-out-doored>.

<sup>232</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 2019.

<sup>233</sup> "Ghana Secures \$15 Billion Chinese Funding For Transformation Agenda - Ghana Investment Promotion Centre (GIPC)." Accessed February 4, 2020. <https://www.gipcghana.com/press-and-media/538-ghana-secures-15-billion-chinese-funding-for-transformation-agenda.html>.

broadly, that the Chinese ExIm bank had also made a commitment of \$1 billion to “support Ghana’s infrastructure.”

The largest hydropower project the Chinese have funded and constructed was Ghana’s Bui Dam in 2005. The dam is Ghana’s second largest behind Akosombo.<sup>234</sup> Bui was originally planned to be built at the same time as Akosombo, however the initial plan was compromised by a relationship with the World Bank that did not allow the government to finance “an additional major power project.”<sup>235</sup> Additionally, the economy of Ghana was in disarray in the 1960s, and during and after the construction of Akosombo, there were not sufficient resources nor necessity for immediate construction of the Bui dam. The VRA itself claimed that the Akosombo dam would be sufficient for supplying Ghana’s electricity until 1975 or 1976, so, construction of Bui was repeatedly delayed. During the energy crisis of the early 1980s, the government began to be accused of neglecting Bui as a source of power that could have helped Ghana during the energy shortage.<sup>236</sup> Finally, in 1998, the “new VRA chief executive, G. O. Doky, announced plans for preparatory studies for the final designs and development of Bui.”<sup>237</sup>

Bui dam was both financed and constructed indirectly by the Chinese, and its presence is emblematic of the larger Chinese development strategy in SSA. Despite its similar role in modernization and nationalization discourse to the Akosombo dam, Bui is financed differently. Akosombo was financed through a combination of Ghanaian government funds and loans from Development Banks and Western companies and governments, whereas in the construction of Bui, the Ghanaian government is only responsible for about 10% of the total cost.<sup>238</sup> Financing of Bui comes predominantly through two loans from China- one concessionary loan of \$263.5 million from the Chinese government, and a buyer’s credit facility of \$298.5 million from ExIm China.<sup>239</sup> Buyers credit loans are another short term loan often proposed by exporters or foreign lenders (in this case, China) to importers (Ghana). The terms of credit are negotiated between the lender and

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<sup>234</sup> Miescher and Tsikata, “Hydro-Power and the Promise,” 26.

<sup>235</sup> Ibid, 28.

<sup>236</sup> Ibid, 30.

<sup>237</sup> Ibid, 34.

<sup>238</sup> Ibid,” 45.

<sup>239</sup> Ibid.

buyer, and with buyers' credit, it is easier for sellers to "pursue and execute large export orders."<sup>240</sup> This loan structure appears to be especially conducive for the financing of Bui dam because of the necessity of many exports from China through the Sinohydro Corporation. Bui's financing structure demonstrates the lack of ownership across the hydropower sector, and the credit terms in Chinese funding are intentionally lenient, allowing China to act with more authority on projects in Ghana.

Through their support of "One Village, One Dam," (1V-1D) the Chinese promote a policy initiative that some do not think plausible or see as a waste of resources. "One Village, One Dam" is a rural development policy that aims to alleviate poverty by creating small reservoir dams that will support dry season farming in rural areas.<sup>241</sup> It is one of the government's "flagship policies" that was put forth by the current National Patriotic Party (NPP) under President Akufo-Addo, that vowed to build a small, rainwater supplied dam in each district of the country.<sup>242</sup> 1V- 1D is no longer supported by some Ghanaians, as they do not think the project will be feasible or effective, or that it will not be carried out as the government promises. Amos Apam, a representative serving the District Assembly from Kpantari and head teacher at a school near the district capital, claimed that people in his village "believe it [1V-1D] will help stop rural urban migration and generate economic activities for them," but that, overall, "people are skeptical until they see."<sup>243</sup> According to Apam, the government has just recently (early January 2020) begun to survey more villages for the potential of this project, when funding has been secured for a number of years.<sup>244</sup> Mark Akologo Asigini, a mathematics teacher at a vocational school employed through the Department of Community Development, also is skeptical of the policy. "The problem is that it is the dry season and all the dams are dried up, so the goal of the policy has not been achieved," he said.<sup>245</sup> Asigini's point describes data on overall decreases in water table levels and dam impoundment in Ghana that were poorly constructed in general. As China continues to fund

<sup>240</sup> Will Kenton, "How Buyer's Credit Works." Investopedia. Accessed February 12, 2020.

<https://www.investopedia.com/terms/b/buyers-credit.asp>.

<sup>241</sup> Abugbilla, Personal Interview. 2020.

<sup>242</sup> "1V-1D One of the Biggest Deceptions Served to Ghanaians – Sammy Gyamfi." Accessed February 12, 2020.<https://www.ghanaweb.com/GhanaHomePage/NewsArchive/1V-1D-one-of-the-biggest-deceptions-served-to-Ghanaians-Sammy-Gyamfi-864364>.

<sup>243</sup> Apam, Personal Interview. 2020.

<sup>244</sup> Ibid.

<sup>245</sup> Mark Akologo Asigini, Personal Interview. 2020.

hydropower projects, they are funding projects that, as the climate changes, are becoming less reliable and less helpful to everyday Ghanaians.

Asigini's and Apam's skepticism is echoed by officials higher in the government in the National Democratic Congress (NDC) minority party. Sammy Gyamfi, a communications officer for the NDC, called the policy "one of the biggest deceptions ever to be perpetrated on the people of this country," and that the minimal amount allocated for dam construction- 250,000 Ghanaian cedis (about \$45,500 USD), was only sufficient to construct "shoddy" dams. Though the minority party may be opposed to projects that the Chinese government supports, feelings towards a heavy Chinese presence in the country are indeed mixed. Kofi Bentil, a co-founder of Ghanaian think tank IMANI, said, "If you look at the elite, they think that China is the key to the future— a country that will provide lots of money without asking a lot of questions."<sup>246</sup> Edward Brown, the Senior Director of Research and Policy Engagements at the Africa Centre for Economic Transformation (ACET), claimed in an interview with journalist Howard French that there is little true partnership between the Chinese and local African authorities. "On the African side there is no meaningful input. The Chinese decide what they want... Yes, they consult with the African countries a bit, but in a way it is only to tell them what [they— the Chinese] have already decided to do.... They will take whatever they can get from you, and if you are not prepared for it, it's too bad for you."<sup>247</sup>

China has played a role in financing and constructing hydropower projects since the Bui Dam. Pwalugu Dam is a proposed mid-size, "multipurpose" dam aimed towards providing irrigation and energy supply. The Pwalugu Dam is set to be the largest infrastructure project in the northern part of Ghana since independence, and plans to provide electricity and irrigation to villages that remain disconnected to the national grid.<sup>248</sup> The project, which is estimated to cost \$366 million USD, is approved and administered by the VRA, but is financed and constructed by the Chinese Sinohydro Corporation, giving Sinohydro enormous agency in the project.<sup>249</sup> Construction on the dam began

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<sup>246</sup> French, *China's Second Continent*, " 206.

<sup>247</sup> French, *China's Second Continent*, " 189.

<sup>248</sup> "Ghana to Commence Construction of Pwalugu Multipurpose Dam." Accessed February 12, 2020.

<http://www.chinagoabroad.com/en/articlet/ghana-to-commence-construction-of-pwalugu-multipurpose-dam>.

<sup>249</sup> "Ghana: Sinohydro Builds Pwalugu Dam | African Energy." Accessed February 5, 2020. <https://www.africa-energy.com/article/ghana-sinohydro-builds-pwalugu-dam>.

November 29, 2019 and is set to take three and a half years.<sup>250</sup> Even within the government today, there is much debate about the value and transparency of Chinese funding and their role in creating the Pwalugu Dam. On February 5, 2020 minority members of parliament called for the halt of the Pwalugu deal and construction, calling it too expensive and lacking transparency. Minority Leader Haruna Iddrisu claimed that, in the financing of Pwalugu, “It is obvious that President Akufo-Addo is attempting to saddle the state with huge debts that have the dangerous potential of crippling this nation.” “How come local companies are not involved in a giant project such as this...?,” he later asked.<sup>251</sup> Originally from Kpantarigo in the Upper East Region where Pwalugu is being built, Francis Abugbilla, a PhD Candidate in International Studies at the University of Washington, is also skeptical as to whether or not the government will follow through on promises made regarding the dam. He believes that if “what is on paper and what will actually be on the ground” align, the dam will be a “major contribution in terms of development to the north.” However, he recognizes the criticisms of cost inflation, saying that “sometimes governments use these projects as a way of getting money.”<sup>252</sup> The Pwalugu dam project is a timely example of the economic relationship between China and Ghana in the hydropower sector.

### *Conclusion*

The current energy culture of Ghana supports hydropower over all other renewable energies, but growing research shows the potential of other sources to supplement hydropower’s generation inadequacies. Though hydropower is the most prominent green energy technology in Ghana, providing up to 43.2% of Ghana’s total energy capacity, its importance can at times be overstated, overshadowing the potential of other renewable energy technologies. “Dams symbolized the modern state’s techno-economic strength...” thus requiring an acknowledgement of their historic presence in future energy policies.<sup>253</sup> However, dams are also “necessary for powering Ghana’s shift from a ‘traditional’ to ‘modern,’ nation”, signaling hydropower’s critical place in enabling the funding, infrastructure, and future place of renewables in Ghana’s energy mix.<sup>254</sup> This provides

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<sup>250</sup> “Ghana: Sinohydro Builds Pwalugu Dam | African Energy.”

<sup>251</sup> “Drop Highly Inflated \$366m Pwalugu Dam Project – NDC MPs to Akufo-Addo.” Accessed February 7, 2020. <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Drop-highly-inflated-366m-Pwalugu-dam-project-NDC-MPs-to-Akufo-Addo-857698>.

<sup>252</sup> Abugbilla, Personal Interview, 2020.

<sup>253</sup> Hausermann, “‘Ghana Must Progress, but We Are Really Suffering’” 635.

<sup>254</sup> Hausermann, “‘Ghana Must Progress, but We Are Really Suffering’”, 635.

a large goal on the part of Ghana's leaders to change the narrative on renewable energies and shift it towards a positive experience for consumers, one which is not just dependent on one resource, rather, many at once.

In comparing research that the Energy Commission of Ghana uses versus that of contemporary studies on renewable sources in Ghana, we have found a considerable amount of discrepancies, leading to policies lacking adequate justification. The REMP refers to outdated wind research from 2004 done by the US National Renewable Energy Laboratory<sup>255</sup> and wind measurements from the Energy Commission from the years 1999, 2006, 2011, and 2012<sup>256</sup> to justify feasibility for further utility wind system development on the coast. This data is highly outdated and inconsistent amongst published research, therefore lacking credibility in justifications for contemporary energy planning. In regards to hydropower, for the purposes of this report, we used the REMP's claim that 43.2% of its installed energy mix is from hydropower.<sup>257</sup> The World Bank, however, claims that 50.86% of Ghana's total electricity came from hydroelectric sources in 2015.<sup>258</sup> Despite the claim of 43.2% of the total energy mix, a significant portion of the electricity generated from hydropower is exported or traded. The primary energy supply is defined as "energy production plus energy imports, minus energy exports, then plus or minus stock exchanges," and hydroelectricity only accounts for 5.27% of this.<sup>259</sup> These values are from 2015, at the earliest. These varying numbers come from different and outside parties, including foreign and private companies, preventing the Government of Ghana from appropriately planning and implementing policy in the energy sector. We call to the attention of the Energy Commission of Ghana the need to consolidate and centralize these studies. This could also be a beneficial step to ease research costs for prospective investors and also provide uniform data for investors. If Ghana were to declare plans in energy development, it must have a credible resource analysis to follow through with its conclusions.

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<sup>255</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 74.

<sup>256</sup> *Ibid*, 73.

<sup>257</sup> *Ibid*, 32.

<sup>258</sup> "Electricity Production from Hydroelectric Sources (% of Total) - Ghana | Data." (2020)

<sup>259</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 3.

Today, climate change and decreasing rainfall affects the efficiency of Ghana's dams. This is based on the data shown by the climate section of this paper. Despite climate effects, Ghana should not completely halt continued investment in hydropower projects. There is still huge potential for electricity production from dams. In fact, while Africa has 12% of the global hydropower potential (the unused energy production potential from hydro sources) it only uses 3 percent of it.<sup>260</sup> Specifically in Ghana, as of 2010 there were 21 mini-hydropower sites "identified and assessed in the country with potential electricity output ranging from 4 kW to 325 kW."<sup>261</sup> There is clearly room for increased use of the hydropower potential in the country, yet it must take into account potential climate, social, and environmental consequences.

Aid and investment relationships must also be collaborative and allow both parties the opportunity to reach compromised solutions. Ghana, and SSA in general, must build an economic base that promotes future growth and opportunity, working on developing infrastructure, technical skills, and entrepreneurship that can eventually propel the country forward without significant or lenient foreign aid. In turn, China must allow it to do so— not by halting aid and loans all together, but by developing partnerships rather than beneficiary systems, by establishing collaborative relationships and respecting and adhering to the power and desire of local people.

In order to prevent future consequences to Ghana from extreme weather events, it is crucial that Ghana diversifies its energy mix to include higher dependability from sources other than hydropower, whether it be through solar, wind, or renewable biomass sources. Based off of the aforementioned wind data, micro-grid wind power is not sufficient on its own, due to lack of wind resources in Ghana, higher upstart costs, and lack of legislative support; it could only ever be supplementary to a hybrid system, which, could be an option for a more efficient way to electrify rural areas, upon further feasibility studies focused on hybrid systems. However, utility scale wind power does prove to be plausible in some coastal areas in Ghana, and could produce a significant amount of energy, which could be added to the national grid. Nonetheless, it could be best to allocate efforts and funds towards more promising hydropower and solar technologies until further

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<sup>260</sup> Appleyard, "Africa's Hydropower Future." (2014)

<sup>261</sup> Kaunda, Kimambo, and Nielsen, "Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa." 8.

and more accurate feasibility studies are done, as well as infrastructure allows for optimal payoffs and increased interest in investment.

Furthermore, as a preemptive solution to future droughts, Ghana should make future hydropower projects pump storage dams or reservoirs to best adapt to future weather patterns. This is because pump storage and reservoir dams are multipurpose dams, which means they are both able to convert water into energy, and also use their water storage for irrigation purposes in times of drought. Of course, while these dams are more economically costly, and have a more detrimental impact on the environment and therefore social systems on waterways, the flexibility of water storage dams will be crucial as Ghana further invests in the industry. Due to this flexibility of holding water reserves over long periods of time (determined by the size of the dam), hydropower is often seen as, “an ideal complement to variable renewables as, when the sun shines or the wind blows, reservoir levels can be allowed to increase for a time when there is no wind or sunshine.”<sup>262</sup>

Hydropower projects have historically been integral to Ghana’s energy production and agricultural needs and will continue to play this essential role in the future, but as it time goes, hydropower simply is not enough on its own to satisfy the energy demand. The national energy mix could benefit from diversification and investment towards energies such as solar, wind, and renewable biomass in the future. As Ghana continues to invest in hydropower technology, it is crucial that they keep in mind the likelihood of increases in extreme weather events as droughts and inconsistent rainfall have led to blackouts and economic and social inefficiencies due to the overdependence on hydropower electricity production in the past. In addition, as the industry expands, it is recommended that returns from these projects have real benefits for Ghana’s citizens by reinvesting in education so that Ghanaians can have a real chance to begin to be a larger part of employment in the sector.

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<sup>262</sup> “Hydropower,” IRENA, 4.

### III. SOLAR

Ghana has the potential to become a model for sub-Saharan electrification by embracing and promoting the use of solar energy in its non-electrified and low-electrified communities. Solar power can become a reliable source of energy for Ghana as non-renewable sources pose threats to the health and environment of the country and the limitations of hydropower increase. Although most countries utilize solar energy in limited quantities, the climate of Ghana makes solar energy an ideal form of energy production. As a general theme, solar energy is looked upon to increase the ability of the energy sector in its contribution to the energy load throughout the year and the provision of energy to the most undeveloped communities through smaller solar products such as solar lanterns and Solar Home Systems (SHS), and medium-scale solar microgrids.

Ghana currently stands in a moment in history in which it has the potential to surpass industrialized countries by embracing and expanding the use of solar technology. However, the path towards greater integration of solar energy into Ghana's energy landscape is not a simple one. This chapter will detail the critical economic factors that need to be considered for small scale solar, micro-grid distribution, and global solar supply chain considerations. It will also explore the reality that solar energy cannot be implemented successfully in Ghana unless politics at all levels are considered; including the roles of trade unions, local electoral politics, and international politics.

#### *Solar Overview*

##### *Limits of Non-Solar Sources:*

The 2019 Renewable Energy Master Plan (REMP) by the Ghanaian Ministry of Energy acknowledges that the use of fossil fuels can negatively impact the health of Ghana's citizens. It claims that "pollution [that is] emitted by fossil-fuel powered plants is linked to breathing problems, neurological damage, heart attacks, and cancer."<sup>263</sup> Reducing the use of fossil fuels can have significant benefits including "reduc[ing] premature mortality and lost workdays, and it reduces overall healthcare costs."<sup>264</sup> Currently, a significant portion of electricity is generated using fossil fuels. Thermal energy makes up approximately 67% of energy generation in Ghana

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<sup>263</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 1.

<sup>264</sup> *Ibid.*

and most thermal energy plants are partially reliant on light crude oil or heavy fuel oil,<sup>265</sup> in addition to natural gas.<sup>266</sup> Even though natural gas produces a lower amount of carbon dioxide than other sources, all of these sources are fossil fuels that contribute to pollution, and thereby to climate change. Additionally, a steady supply of natural gas is not guaranteed, as Nigeria (which supplies Ghana with a significant portion of its natural gas) prioritizes meeting its own gas demand first, and only then exports excess supply to countries like Ghana.<sup>267</sup> This creates an added vulnerability in electricity generation, as it prevents Ghana from being able to reliably produce energy.

Although hydro energy made up approximately 32% of the installed grid electricity generation capacity by the end of 2018,<sup>268</sup> it has proven to be unreliable as a source of energy. For example, increased rainfall variability and meteorological drought contributed to placing the water levels,<sup>269</sup> in both 2015 and 2016, below the minimum water levels in the Akosombo Dam.<sup>270</sup> This pattern of increased drought is likely to continue with the ongoing climate change. Additionally, most large-scale hydro dams have already been built, leaving only small and medium scale projects that would cap at about 800 MW.<sup>271</sup> While this is not a small number, it is a limitation of hydropower, meaning that once all possible dams are built, future growth in this area cannot be expected. Between the years 2000 and 2018, the population in Ghana grew from approximately 19 million to approximately 29 million and will continue to grow.<sup>272</sup> As such, supplements to thermal and hydro energy must be considered in order to provide sustainable energy to the increasing population in the long run.

Currently, many Ghanaians depend on generators as backup sources to the national grid and on wood fuel for cooking. According to the REMP, “in the year 2013, firewood was the main source

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<sup>265</sup> International Energy Agency, “Africa Energy Outlook 2019,” (2019), 23.

<sup>266</sup> Energy Commission of Ghana, National Energy Statistics 2009 - 2018, Energy Commission of Ghana, 2019. 7. (Accessed March 2, 2020). [http://www.energycom.gov.gh/files/ENERGY\\_STATISTICS\\_2019\\_Updated.pdf](http://www.energycom.gov.gh/files/ENERGY_STATISTICS_2019_Updated.pdf)

<sup>267</sup> Ibid, 68.

<sup>268</sup> National Energy Statistics 2009 - 2018, Energy Commission of Ghana, 7.

<sup>269</sup> Owusu, Waylen, and Qiu, “Changing Rainfall Inputs in the Volta Basin,” 202.

<sup>270</sup> International Energy Agency, “Africa Energy Outlook 2019,” (2019) 19.

<sup>271</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 32.

<sup>272</sup> International Energy Agency, “Africa Energy Outlook 2019,” (2019), 228.

of cooking fuel for more than 40% of households in Ghana, followed by charcoal and gas.”<sup>273</sup> In 2018, only about 25% of people had access to clean cooking, even though Ghana’s reported data states that 84% of people have access to electricity.<sup>274</sup> All of these sources (generators, wood and fossil fuels) have negative health impacts because of their release of carbon dioxide. Additionally, since women are typically the responsible for cooking in traditional Ghanaian households, they are placed at a higher exposure to this pollution, alongside their children. Given the limitations and dangers that these forms of energy carry, solar energy presents a viable alternative in both the short and long-term.

### *Benefits of Solar Energy*

Ghana aims to expand its economy throughout the “One District, One Factory Initiative”, which is a massive industrialisation campaign across the country.<sup>275</sup> This initiative seeks to expand the following sectors of the economy by establishing a factory in every district: input/raw material producer groups, agro processing and business, textiles and clothing, ICT, pharmaceutical and cosmetics, waste management, distribution and trading, tourism, arts and crafts.<sup>276</sup> While this policy may have been made for personal political interests, it can be used as a general guideline of a manner through which Ghana might strengthen its economy. Local manufacturing of solar panels and solar products can help create jobs, which would help advance the goal of this initiative. In the REMP, the GoG identified a large opportunity to assemble and manufacture solar products within Ghana to serve the local market and the ECOWAS trade bloc.<sup>277</sup> Ghana has the potential to play a large role in the global solar supply chain beyond assembly and manufacturing. Endowed with large silica deposits and a light manufacturing sector, Ghana, in coordination with other African countries can build an end-to-end solar supply chain. This endeavor will give job opportunities to unskilled, and skilled labor alike. As it applies to the domestic Ghana market, stand-alone systems from small solar lighting appliances to solar home systems (SHS) including 250W and 400W panels present a valuable economic development opportunity. Not only this, but increased access to electricity can allow for increases in small businesses and tourism. Of equal

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<sup>273</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 6.

<sup>274</sup> International Energy Agency, “Africa Energy Outlook 2019,” (2019), 228.

<sup>275</sup> <http://1d1f.gov.gh/>

<sup>276</sup> Ibid.

<sup>277</sup> Energy Commission of Ghana, “REMP,” 24.

importance is the fact that access to electricity could allow for increased time spent on education and internet connectivity in schools.

Electrification can also be highly beneficial to social structures. Ghana has a large young population and providing commodities for entertainment in their own communities can help reduce mass migration to cities. One example of the result of such mass migration is the rise in kayayei workers.<sup>278</sup> These are typically young women who carry loads in city markets. This type of marginalization of young women can be reduced through increased access to education, entertainment and employment within these young people's own communities, which can be supported through electrification. Additionally, having access to reliable electricity can help reduce the negative health impact of carbon emitting fuels. In this sense, while Ghanaian society in general can greatly benefit from increased electrification, rural communities and rural women in particular would benefit greatly.

### ***Ghana's Existing Solar Landscape:***

Data regarding access to electricity in Ghanaian villages is not extensive or easily accessible. One possible explanation for this can be found in looking at how "access" to electricity is defined and recorded. According to USAID, in the National Electrification Scheme adopted in 1989, 'access' is defined as the ability to connect to the grid and is applied only to- communities greater than 500 households in size, accessible by road, and situated within 20 kilometers of existing distribution lines. Villages that do not meet these criteria are not considered in the access rate calculations."<sup>279</sup> In addition, USAID states that "data regarding the size of Ghana's off-grid population can be difficult to obtain and at times contradictory."<sup>280</sup> Even with sources such as the Ghana Statistical Service (GSS), the data that is provided is often not extensive, or up to date. Accessing all rural isolated villages in order to gather data can be very challenging, due to poor infrastructure and marginalization of these communities in Ghanaian society. However, these communities would receive the benefits experienced by their urban counterparts if they are taken into account when

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<sup>278</sup> James Opare, "Kayayei: The Women Head Porters of Southern Ghana." *Journal of Social Development in Africa* 18, no. 2 (2003): 33-48.

<sup>279</sup> Power Africa Off-grid Project, "Off-Grid Solar Market Assessment Ghana," (U.S. Agency for International Development, October 2019), 2.

<sup>280</sup> *Ibid*, 2.

determining electricity accessibility. According to the World Bank Collection of Development Indicators, it is necessary that the government, private sector, and NGOs look closely at the three districts (Upper West, Upper East and Northern Ghana).<sup>281</sup> By doing so, addressing the issue of accessibility due to the lack of main roads and identifying feasible projects that could be implemented in each district will be possible.

Access to the use of individual solar panels as well as production of solar panels is rather limited in Ghana. From our interviews, it was clear that solar panels were seen as a potential solution to small scale electrification but also poses some barriers. Amos, from northern Ghana, shared that solar panels had the potential of allowing a family to “use televisions and lights,” and hoped that solar panels might allow for the use of fridges.<sup>282</sup> However, Gloria, a sociologist from Kumasi, argued that “solar panels are reliable but very expensive to buy.”<sup>283</sup> All of the individuals that we interviewed had a positive and hopeful view for solar panels, but even Kumasi city residents admitted that solar panels were only available to the “very rich.”<sup>284</sup> Of all the renewable technologies, we were given the impression that people had the most hope in solar PV technologies. This may be because our interviewees had previous exposure to this technology from NGO donations or because this technology fits well and seems logical due to Ghana’s geographical climate.

### ***The Implementation of Microgrids***

In the REMP, the GoG outlined a strategy and implementation plan for the distribution of microgrids for the years 2020-2030. In this plan, the REMP emphasizes the deployment of microgrids in and around the Volta River, which is consistent with previous microgrid deployment up until this point.<sup>285</sup> According to this plan, 300 new microgrids would serve communities with a population above 500 that cannot be connected to the national grid for economic reasons by 2030. Microgrids will be electrified using generation sources solar, wind, biofuels, hydroelectric, and diesel.<sup>286</sup> The REMP recognizes that challenges to this deployment include local technical

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<sup>281</sup> World Bank, 2000; Lorenzo, 2000; BMZ, 2001.

<sup>282</sup> Apam, phone interview, January 24th 2020.

<sup>283</sup> Gloria Adu Ofori, video call interview, January 29th 2020.

<sup>284</sup> Ibid.

<sup>285</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017), 21

<sup>286</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 38.

expertise in remote communities, a lack of transportation infrastructure, and a high operational cost of mini grids.<sup>287</sup> To address some of these challenges, funding pools established through Multilateral Development Bank (MDB) partnerships such as the World Bank's Ghana Development and Access Project (GEDAP), and foreign government aid have played a role deploying over a hundred microgrids in the past decade.<sup>288</sup> The GoG has also promoted energy efficiency through demand-side management, supported the integration of currently deployed stand-alone systems with the mini grids, and provided water transportation infrastructure to build mini grids in the Volta River.<sup>289</sup> The Government of Ghana has pursued a state-owned enterprise (SOE) microgrid operational model in which officials from utility companies manage microgrids.<sup>290</sup> With the GoG's government-driven microgrid strategy in mind, we will detail the history and current state of the mechanisms that make microgrid deployment possible in Ghana, and explore the drivers of their success and failure. Through our analysis we find while microgrids can be profitable as a business unit if managed correctly, primary challenges to its success are electricity misuse due to a low levels of electricity education, and project unviability after the donor organization leaves caused by a lack of sustained funding and expertise.

Under the REMP, publicly owned electricity distribution companies, including the VRA and Power Distribution Services (PDS), have been instructed to lead nationwide microgrid implementation. On the other hand, private participation under current law is limited to procurement and installation of microgrids, leaving the operations to utility companies. Despite this, one private microgrid operator, Black-Star Energy, a Ghanaian limited corporation, has operated at the tolerance of the government, owning and operating 17 microgrids throughout Ghana. As the law stands, microgrid operators must maintain three licenses to operate: a power generator, power distributor, and power retailer license, as a normal utility would.<sup>291</sup>

There are a variety of market-based factors that make the long-term sustainability of microgrids challenging. Donor organizations have been known to focus on the period of the project, not

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<sup>287</sup> Ibid, 39.

<sup>288</sup> USAID, "Off Grid Solar Market Assessment Ghana" *Power Off Grid Project* (October 2017), 21

<sup>289</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 38-39.

<sup>290</sup> USAID, "Off Grid Solar Market Assessment Ghana" *Power Off Grid Project* (October 2017), 21

<sup>291</sup> USAID, "Off Grid Solar Market Assessment Ghana" *Power Off Grid Project* (October 2017):23

factoring in long-term sustainability. After their withdrawal, the project is not left as a functioning business and often fails soon after.<sup>292</sup> Foreign donor intervention is usually highly subsidized, so when operations are taken over the cost of energy increases substantially due to the lack of cheap-domestically produced components. Entrepreneurs are unable to collect tariffs from the community, who are unwilling to pay higher electricity prices.<sup>293</sup> While panels have a relatively long product lifetime, inverters and small wires required to get photovoltaic (PV) energy to devices and appliances can be frequently misused and break from electricity overload.<sup>294</sup> Mechanisms for replacing inverters and wiring are needed to maintain microgrid systems. Another factor that limits the sustainability of microgrids is the donation of materials from foreign countries. Solar panels and other PV components can be donated by developed countries as a means to dispose of surplus domestic supply and support employment in their own countries during economic downturn. These donations can be used as tax write-offs for donor organizations.<sup>295</sup> All of these market-based factors contribute to the business model failure and reduce the viability of microgrids as a long-term solution to rural electrification.

Education on the topic of electricity and maintenance of electrical equipment in rural communities can be improved upon. A study conducted by the Ministry of Power on the long term performance of small-scale microgrids in rural Ghana found that communities frequently overload the capacity of electricity systems.<sup>296</sup> In this study, fourteen rural communities received small scale solar PV systems for the purpose of charging phones and lanterns. The study found that inverters were frequently misused as community members plugged in high-voltage appliances such as ironing machines and heating devices that exceeded inverter capacity.<sup>297</sup> In the future, this might be avoided with better education towards understanding the limits and mechanics of electricity systems. Education in those areas might allow for a greater life-span of solar PV systems and hence longer access to electricity.

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<sup>292</sup> Divine Atsu, Emmanuel Okoh Agyemang, and Stephen A.K. Tsike, “Solar Electricity Development and Policy Support in Ghana.” *Renewable and Sustainable Energy Reviews* 53 (January 2016): 796

<sup>293</sup> Atsu, Okoh Agyemang, and Tsike. “Solar Electricity Development and Policy Support in Ghana.” 798

<sup>294</sup> Michael Acquah, “Ghana, Rural Electrification, Solar PV Systems, Sustainable Development.” *Energy and Power*, 2017, 19

<sup>295</sup> Atsu, Okoh Agyemang, Tsike, “Solar Electricity Development and Policy Support in Ghana.” 796.

<sup>296</sup> Acquah, “Ghana, Rural Electrification, Solar PV Systems, Sustainable Development.” *Energy and Power*, 14.

<sup>297</sup> *Ibid*, 19

In this same study, the financial performance of the microgrid was measured, and proved the business model is viable given good management. Five communities out of fourteen achieved positive net income with an average payback period of 2.3 years. One of the largest impediments to steady financial performance is poor management.<sup>298</sup> One of the primary drivers of project failure is the lack of fee collection causing maintenance to be unfunded.<sup>299</sup> Timely reporting of revenues, expenses and meter monitoring allows tariff collection to take place. Thus, a critical element of success in microgrid projects is the skill and attentiveness of system operators.

### *Suppliers*

While the Government of Ghana (GoG) embraces solar microgrids as a viable, short-term solution to electrification, Ghana currently lacks a strong private legal framework for microgrid regulation, thus decreasing the viability of microgrids as a reliable solution. According to USAID's Off-Grid Solar Market Assessment for 2019, "the GoG views microgrid development as top-down and government-driven."<sup>300</sup> In fact, there is currently no official licensing framework for private microgrids.<sup>301</sup> This has resulted in only a few private sector microgrids being developed. Instead, the bulk of the microgrids have been donated by international aid organizations.<sup>302</sup> Major microgrid donations that are now government operated include donations from the African Development Bank's Rural Enterprises Programme (AfDB-REP), which donated 55 microgrids, and the U.S. Trade Development Agency (USTDA), which donated 50 microgrids.<sup>303</sup> These microgrids are able to serve a couple thousand customers. According to USAID, "the country's only private operator of multiple microgrids is Black Star Energy, which operates 17 microgrids that serve approximately 6,000 customers in the Ashanti and Brong-Ahafo Regions."<sup>304</sup> In this sense, while use of microgrids is expanding, this is only happening in a limited capacity with control remaining in the hands of the central government.

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<sup>298</sup> Ibid.

<sup>299</sup> Atsu, Okoh Agyemang, and Tsike, "Solar Electricity Development and Policy Support in Ghana." 797

<sup>300</sup> Power Africa Off-grid Project, "Off-Grid Solar Market Assessment Ghana," (U.S. Agency for International Development, October 2019), 21.

<sup>301</sup> Ibid, 22.

<sup>302</sup> Ibid, 21.

<sup>303</sup> Ibid, 21.

<sup>304</sup> Ibid, 22.

Utility scale solar farms are currently sparsely spread throughout the country. In March 2019, a total of 130 Provisional Wholesale Electricity Supply Licenses had been issued to potential Independent Power Producers (IPPs).<sup>305</sup> However, of these, only 63.8% were issued for solar photovoltaic generation.<sup>306</sup> Furthermore, while about 30 IPPs had obtained Siting Permits, only 4 companies had been granted Operational Wholesale Electricity Supply Licenses.<sup>307</sup> The largest of these companies included BXC (Ghana) Company Limited, which built a 20MW solar PV plant, and Meinerger Technology Company Limited, which also built a 20MW solar PV plant. While only 4 utility scale solar farms are currently allowed to operate, more are in the process of obtaining required licensing for future operation.

However, the Energy Commission also states that “in view of the excess grid generation capacity, [and] the over-subscription of Power Purchase Agreements (PPAs) for solar and wind projects, the Energy Commission has placed a temporary suspension of the issuance of Provisional Licenses for utility-scale solar PV and wind energy projects”.<sup>308</sup> Since there is enough grid generation through current projects, there is less incentive to keep working toward increasing the number of solar PV utility scale farms. Similar to the limitations placed on microgrids, such a suspension will limit private generation of solar power and place more control in the hands of the central government. Additionally, claiming that there is “excess grid generation capacity” demonstrates a compliance with depending heavily on thermal and hydro energy: the issue prioritized is not shifting to renewable energy, but rather simply having enough energy generation.

In terms of government owned utility-scale PV plants in Ghana, the first was the Navrongo solar farm. This farm has about 2.5 MWp in generation capacity. It was financed, developed, and owned by Volta River Authority (VRA). It was quickly developed and built with the help of foreign engineers and companies and was able to begin commercial operation in 2013. The Bui Power Authority has also begun an initial 50MW Solar Project which commenced in April 2019 is expected to be operational in 2020.

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<sup>305</sup> Energy Commission of Ghana, “2019 Energy (Supply and Demand) Outlook for Ghana,” (2019), 62.

<sup>306</sup> Ibid..

<sup>307</sup> Ibid.

<sup>308</sup> Ibid, 63.

Small and businesses supply stand-alone solar systems from 10W-5kW, imported from outside Ghana. The primary product in this industry segment is the Solar Home System (SHS), along with Solar Lanterns, and Solar Pumps. SHS companies operate differently depending on the company. However, popular methods of financing are cash and carry (upfront payment) and the pay-as-you-go model. Such companies include Azuri technologies, Wilkins Engineering Ltd., PEG Ghana, Burro Brands, Zola and others. Some of these companies are foreign owned. Zola, for example, is a Silicon Valley based company, with investors and advisory partners including Tesla, General Electric, USAID, Power Africa, International Finance Corporation and more. Other companies such as Azuri technologies are Chinese owned companies. Similar to solar panels, a large portion of solar products are being purchased from foreign companies.

### ***The Market for Solar Home Systems and Methods for Financing Them***

In the REMP, Ghana set targets to electrify 1000 communities to get the country closer to 100% electrification by 2030.<sup>309</sup> To fill the energy gap, the Solar Home System market has grown substantially in grid-connected areas as a back-up source of energy.<sup>310</sup> In rural Ghana, SHS systems were installed for basic lighting of common spaces, irrigation, cooking, and charging stations.<sup>311</sup> However, in recent years, improvements in transmission and distribution infrastructure throughout the national grid have reduced the rate of outages and this has caused a reduced need for SHS systems to be purchased as back-up electricity sources.<sup>312</sup> Its success in rural Ghana depends on overcoming financial restraints, rural employment issues in areas with low infrastructure and education levels, and unclear tariffs. Solar Home Systems (SHS) are an independent panel and battery unit with a maximum capacity of 5kW, comprising a majority of the global stand-alone market in Ghana alongside solar lanterns. The primary function of these products is to increase the energy security of on-grid customers by offering alternative sources of energy while outages occur. In 2017, solar home system unit sales reached its peak at 65,000 units

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<sup>309</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 3.

<sup>310</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017): ES-3

<sup>311</sup> Atsu, Okoh Agyemang, and Tsike, “Solar Electricity Development and Policy Support in Ghana.” 795.

<sup>312</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017): ES-4

sold, however in 2018 only 40,000 units were sold.<sup>313</sup> This trend may continue with the deployments of microgrids. One of the challenges outlined in the REMP is that increased deployment of microgrids will reduce non-grid connected communities' reliance on the SHS market.<sup>314</sup> Thus, it is critical to understand how the SHS companies can be grown to serve markets that will remain non-grid and non-microgrid connected.

NGOs, commercial lending, crowdfunding, venture capital, and consumer financing all play a role in the SHS market in Ghana. There are different revenue models used for SHS companies contingent on their partnerships and customer demographics. One of these models is the cash and carry model, where a good is exchanged for money in a one-time purchase. Pay-as-you-go revenue models act as a leasing or mortgaging system for SHS, this has become increasingly popular as it allows low-income customers access to the technology without paying a high upfront cost.<sup>315</sup> The weakness of the pay-as-you-go model is that it relies on rural banks or mobile banking to collect payments. Communities without banks or mobile coverage are not able to receive this service. Finally, partner organizations can act as distributors by buying the SHS to re-sell and can facilitate the transaction through extending financing arrangements to consumers.

### *Operational Challenges*

Historically, SHS companies have experienced challenges reaching rural communities. Low telecommunications coverage hinder the ability to leverage the pay-as-you-go revenue model because the systems rely on mobile banking. Thus, telecommunications coverage is closely tied to the success of stand-alone energy system deployment. However, this problem is receding, as Ghana is the fastest growing mobile market in Africa.<sup>316</sup> Logistics costs are another barrier to reaching communities. Poor roads and no reception can make the journey out to rural markets challenging for salesmen, with high transportation costs and no guarantee of sales. USAID estimates that 80% of the off grid market is currently unserved due to poor mobile coverage and poor transportation.<sup>317</sup>

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<sup>313</sup> USAID, "Off Grid Solar Market Assessment Ghana" *Power Off Grid Project* (October 2017):14

<sup>314</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 38.

<sup>315</sup> USAID, "Off Grid Solar Market Assessment Ghana" 12

<sup>316</sup> *Ibid*,17

<sup>317</sup> *Ibid*, 15

Training and retaining rural personnel to act as salesmen and technicians for SHS poses another challenge. There is a low supply of skilled technicians who can install and maintain SHS technology.<sup>318</sup> Rural employees require more training to gain technical skills, and can lose contact with the company if their village has no cellular reception. Finally, the low purchasing power of customers limits the products that businesses can directly sell. The market in rural communities are primarily NGO buyers, who require budgetary approval for larger purchases that can take up to six months to attain. If the NGO does not have a mandate that is closely tied to electrification, purchases may never occur.

To support SHS businesses, avenues for customers to obtain credit from local markets can help increase purchases. PV systems have a high up-front cost and low maintenance costs. Buying a 1.2 kW system is close to \$1000 USD. The availability of debt instruments to spread out this cost over time is critical to ensuring market growth. This has been done through partnerships with microfinance institutions (MFI), rural banks, and Village Savings and Loan Associations (VSLA), who are able to extend credit to those who are interested in purchasing a SHS.<sup>319</sup> However many Ghanaians cannot access credit. In 2017, approximately 7 million people in Ghana did not have a formal bank account or mobile wallet, particularly women.<sup>320</sup> Credit risk is a serious concern of both SHS company investors and dealers, so the PAYGO model has experienced pushback.<sup>321</sup> In this area, there is still more work to be done to create the financial markets necessary to fund SHS purchases.

The tariff structure of solar lanterns, SHS, and pico-solar imports has made imports of small-scale solar systems costly. While ECOWAS has a 5% duty on “solar generators”, the Ghana Revenue Authority (GRA) categorizes these products as “solar home theaters,” which are subject to a 15% duty and 20% value-added tax. Additionally, the GRA categorizes solar lanterns as a “battery powered torch” subjecting it to even higher tariffs.<sup>322</sup> Harmony in terms of tariffs under ECOWAS

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<sup>318</sup> Atsu, Okoh Agyemang, Tsike. “Solar Electricity Development and Policy Support in Ghana.” 798

<sup>319</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017):15

<sup>320</sup> Ibid, 20

<sup>321</sup> Atsu, Divine, Emmanuel Okoh Agyemang, and Stephen A.K. Tsike. “Solar Electricity Development and Policy Support in Ghana.” 798

<sup>322</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017):16

and the GRA would decrease uncertainty and help business operations for international and regional SHS businesses. This is especially important to note because most firms are internationally owned. For example, Zola is a Silicon Valley based company, with investors and advisory partners including Tesla, General Electric, USAID, Power Africa, International Finance Corporation and more.<sup>323</sup> Other companies such as Azuri Technologies are Chinese owned companies. Thus, import tariffs are critical considerations for their SHS companies.

### ***Meeting Ghana's Rural Energy Needs Using Solar Technology***

To better tackle the energy needs of rural Ghana, it is crucial to understand the needs of each region, district, and village. A majority of the information that was found is based on estimates from Ghana Statistical Service (GSS).<sup>324</sup> It displays that rural communities are not only facing a lack of energy access but also lack of information in terms of their specific needs due to their rural status. The following tables provide an estimate of the districts and populations in the rural sectors of Northern, Upper East, and Upper West Ghana (Table 3.1). It is important to consider that GSS is only providing a general budget to electrify each town in these districts using solar energy.

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<sup>323</sup> "About Us." ZOLA Electric, n.d. <https://zolaelectric.com/about-us/>.

<sup>324</sup> "Ghana 2003 Demographic and Health Survey." Ghana Statistical Service (GSS). Fact Sheet, 2003.

Table 3.1. Estimated costs of planned projects to provide electricity to rural communities in the regions of (a) Northern, (b) Upper East, and (c) Upper West of Ghana.

Region / District	No of Towns	Estimated Pop.2010	Estimated Pop.2020	Cost Estimate (US\$)
<b>Northern</b>				
Bunkrugu Yunyoo	49	40,421	51,718	4,923,080
East Mamprusi	41	38,767	49,606	6,832,638
Tolon kumbungu	68	50,836	65,044	6,494,470
Tamale	23	15,893	20,334	2,843,848
Bole	12	4,624	5,913	5,476,797
Savelugu	29	10,406	13,305	4,878,133
Central Gonja	19	10,730	13,726	8,662,721
Sawla Tuna Kalba	24	10,207	13,053	6,533,923
West Mamprusi	53	60,122	76,933	9,534,804
Gonja West	45	23,564	30,142	9,822,364
Kpandai	33	14,605	18,677	7,218,123
Gonja East	40	18,091	23,142	9,563,780
Karaga	21	7,095	9,073	7,130,862
Gushiegu	39	14,194	18,150	7,762,024
Nanumba South	13	4,280	5,474	3,674,414
Saboba	19	6,037	7,718	4,511,376
Nanumba North	25	7,973	10,196	4,084,621
Chereponi	30	9,555	12,215	4,691,347
Yendi	38	13,605	17,400	7,319,184
Zabzugu	34	13,374	17,099	7,473,648
<b>Sub-Total for North</b>	<b>655</b>	<b>374,379</b>	<b>478,918</b>	<b>129,432,158</b>

(a)

Region / District	No of Towns	Estimated Pop.2010	Estimated Pop.2020	Cost Estimate (US\$)
<b>Upper East</b>				
Bawku Municipal	0	0	0	0
Bawku West	41	26,303	33,327	7,220,029
Bolgatanga Municipality	23	18,417	23,333	3,245,444
Bongo	31	38,452	48,726	7,121,169
Builsa	42	28,711	36,373	8,166,369
Garu-Tempane	64	56,127	71,116	11,226,810
Kassena Nankana East	12	9,987	12,652	1,911,478
Kassena Nankana West	37	31,004	39,286	6,358,305
Talensi-Nabdam	51	46,690	59,160	9,515,761
<b>Sub-Total for Upper East</b>	<b>301</b>	<b>257,716</b>	<b>329,756</b>	<b>54,765,364</b>

(b)

Region / District	No of Towns	Estimated Pop.2010	Estimated Pop.2020	Cost Estimate (US\$)
<b>Upper West</b>				
Jirapa	30	22,399	28,657	3,598,970
Nadowli	44	45,660	58,427	6,156,203
Wa East	43	41,700	53,360	7,776,516
Sissala East	15	18,385	23,527	9,511,319
Wa Municipal	9	8,888	11,374	2,470,136
Sissala West	21	16,393	20,974	5,535,763
Wa West	62	44,793	57,306	6,373,578
Lawra	45	28,868	36,932	3,525,986
Lambussie-Karni	29	19,221	24,590	3,359,230
<b>Sub-Total for Upper West</b>	<b>298</b>	<b>246,307</b>	<b>315,147</b>	<b>48,307,701</b>

(c)

Source: "National Electrification Scheme (NES)," (tables), Draft Report for Master Plan Review 2011-2020, (July 2010), 44-45.<sup>325</sup>

### Investing in Solar Energy

Ghana's south western region is likely to receive grid extension, while the REMP indicates that the Lake Volta region is most likely to receive microgrids.<sup>326</sup> This indicates that under the current plan much of rural Ghana will not get the opportunity to be electrified under government utility programs. With this access gap in mind, we seek to prioritize and prescribe solar solutions for rural communities unlikely to receive grid-extension or microgrids. To gain an accurate picture of geographies that are unlikely to become grid-connected in the next decade, we have pulled from previous literature that stipulates grid expansion priority will be given based on a cost-economic development basis. That is, meeting the highest electricity demand while minimizing inter-settlement dispersion that is more conducive to distributed energy resources (DER), and

<sup>325</sup> "National Electrification Scheme (NES)," (tables), Draft Report for Master Plan Review 2011-2020, (July 2010), 44-45.

<sup>326</sup> Abdul-Salam Yakubu, and Euan Phimister. "The Politico-Economics of Electricity Planning in Developing Countries: A Case Study of Ghana." *Energy Policy* 88 (January 2016): 300

minimizing the connective distance from the grid. With these assumptions in mind, researchers in the United Kingdom conducted a spatial analysis of Ghana, and found that future grid connection will most likely be concentrated in the South West region of Ghana.<sup>327</sup> While the REMP highlights the government’s national objective to electrify the Lake Volta Region with microgrids, other communities have not received the same attention.<sup>328</sup> In the past, multiple-donor projects through the Ghana Energy Development and Access Project (GEDAP), and other foreign government or international institutions have focused on Lake Volta Region.<sup>329</sup> However, for many other communities not located in this area, there are few official means for achieving electrification, often leaving these communities to rely on NGOs for their energy needs. For rural regions that are not likely to receive microgrids soon, we have identified that medical facilities should be a priority in SHS deployment for lighting purposes, solar lanterns are critical towards realizing the benefits of residential rural electrification, and solar pumps will greatly benefit the rural agrarian economy.

### *Medical facilities*

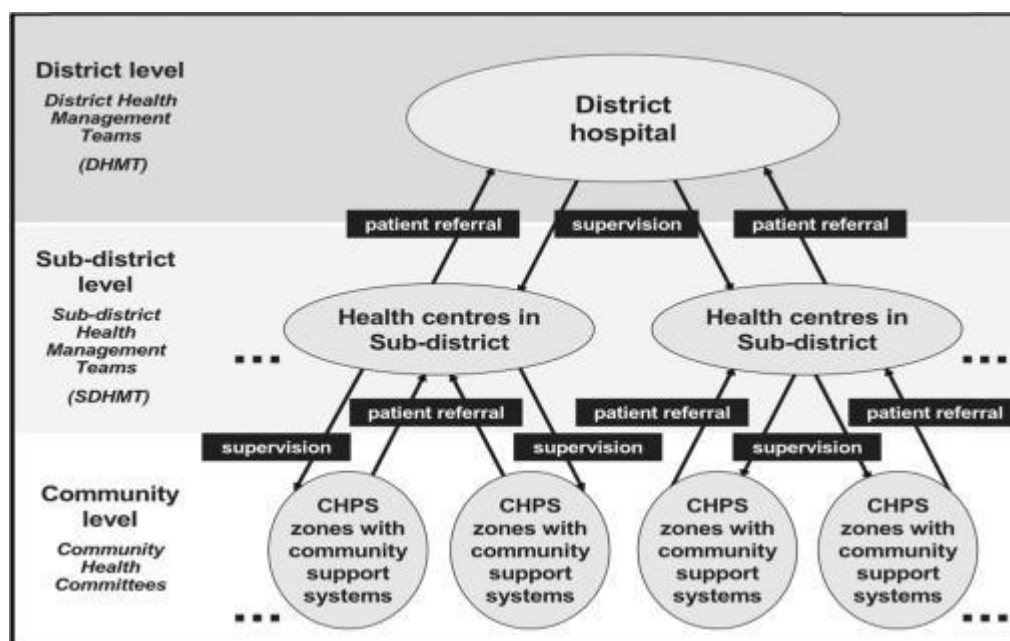


Figure 3.1. Operational chart of health facilities in rural Ghana divided into three levels: (a) district level, (b) sub-district level, and (c), community level. Agbenyo, Fauster, Abraham Marshall Nunbogu, and Alfred Dongzagla. “Accessibility Mapping of Health Facilities in Rural Ghana,” (chart), *Journal of Transport & Health* 6 (September 2017), 10.

<sup>327</sup> Ibid.

<sup>328</sup> Energy Commission of Ghana, “Renewable Energy Master Plan”, (2019):38.

<sup>329</sup> USAID, “Off Grid Solar Market Assessment Ghana” *Power Off Grid Project* (October 2017):22

Rural health service is an important national and international priority for Ghana, so its electrification should be prioritized as well. The availability of electricity to support proper rural health services is less than adequate in the northern regions. A number of international, national, and local institutions, NGOs, and private companies have been deploying renewable energy systems to rural communities in the developing world where health care in rural areas is a national priority.<sup>330</sup> Since the health clinic may be the only electrified building in a given village, providing light for that facility could improve the social life of a community through activities like night education classes. In a personal interview with Francis Abugbilla, a PhD candidate at the University of Washington, he expressed that in his previous experience, having even one public space in a rural community with electricity could be very helpful. This was because this space could then be used to hold public meetings, an essential aspect of community organization. In this manner, even minimal electrification of community spaces such as clinics can have significant impacts.

### *Residential*

In residential households, solar lantern lighting is a critical factor for improving health. In Ghana statistics have shown that approximately 75% of the rural population use kerosene lamps for lighting in 2012.<sup>331</sup> Lighting is most prominently provided through kerosene lamps or disposable battery powered LED lights. Kerosene is filled with soot and emissions which have been known to cause illnesses such as tuberculosis and increase the likelihood of asthma and cancer.<sup>332</sup> Disposable batteries can also compromise health if not disposed of properly. Rural communities often do not have the necessary infrastructure to avoid the health impacts of improper disposal. In a comparative study between the cost effectiveness of solar lanterns, kerosene lanterns, and disposable battery powered lanterns conducted at Kwame Nkrumah University of Science and

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<sup>330</sup> Ken Olson, and Antonio Jimenez. "Renewable Energy for Rural Health Clinics." U.S. Dept. of energy: *National Renewable Energy Laboratory*, 1998: 1-10

<sup>331</sup> C.K.K Sekyere, F.K. Forson, and F.O. Akuffo, "Technical and Economic Studies on Lighting Systems: A Case for LED Lanterns and CFLs in Rural Ghana." *Renewable Energy* 46 (October 2012): 282

<sup>332</sup> Bensch, Gunther, Jörg Peters, and Maximiliane Sievert. "The Lighting Transition in Rural Africa — From Kerosene to Battery-Powered LED and the Emerging Disposal Problem." *Energy for Sustainable Development* 39 (August 2017): 13

Technology (KNUST), solar lanterns had the lowest total cost over a two year period.<sup>333</sup> Thus, the health, education, and cost effectiveness of solar lanterns indicates that they should be a top priority for rural lighting.

### *Agriculture*

The impact of the lack of electricity in the lives of agricultural workers has had detrimental effects on their social well-being. Along with that, besides the harsh living conditions, this population often times faces a sense of social exclusion, which can happen when people or areas suffer from unemployment, poor skills, low incomes, and unfair discrimination.<sup>334</sup> Given this context, it is crucial to ‘tie together’ territorially disjointed, centralized, or isolated rural areas; by understanding which technology best suits the rural communities and providing physical infrastructure, the government will be able to increase social inclusion.

The current lack of energy access in rural Ghana affects agricultural livelihoods and productivity growth.<sup>335</sup> However, there are technologies that could be implemented to support the rural workforce. Solar-powered irrigation, for example, is a type of project supported by the Energy Commission of Ghana and UNDP, in the northern region. Launched in October 2014, this program has installed a solar-powered irrigation pump in four communities of northern Ghana: Tamalgu, Nakpanduri, Datoyili and Fooshegu. As a result of this specific type of solar technology, farmers can now irrigate their farm fields regularly.<sup>336</sup> Altogether, it is estimated that the pumps are capable of watering up to 15 hectares of land, while the solar panels have a total capacity of 22.5 kilowatts and are capable of delivering up to 1 million litres of water each day.<sup>337</sup> The previous example helped to identify that it is more feasible to provide off-grid solar technologies such as irrigation systems.

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<sup>333</sup> Sekyere, and Forson, and. Akuffo, “Technical and Economic Studies on Lighting Systems: A Case for LED Lanterns and CFLs in Rural Ghana.” 287

<sup>334</sup> World Bank, 2000; Lorenzo, 2000; BMZ, 2001.

<sup>335</sup> Replication-Receiver. “Solar-Powered Irrigation: A Boost for Farming Productivity: UNDP in Ghana.” UNDP. UNDP, May 21, 2019.

[https://www.gh.undp.org/content/ghana/en/home/presscenter/articles/2018/solar\\_power\\_irrigation.html](https://www.gh.undp.org/content/ghana/en/home/presscenter/articles/2018/solar_power_irrigation.html).

<sup>336</sup> Ibid.

<sup>337</sup> Ibid.

The impact of projects that support solar energy in the agricultural sector could alleviate the problem of migration to cities due to lack of job opportunities, especially north-south migration. A series of interviews with individuals from the Upper East Region of Ghana reported some of the limitations that exist in terms of information sharing in regards to solar energy.<sup>338</sup> A common issue that arose during the course of our interviews was a lack of information concerning rural populations and their access to electricity.<sup>339</sup> In addition, there were disproportionately fewer investment projects in the northern regions of Ghana in the past decade, leading to increased inequality among the north-south divide, resulting in increased poverty rates.<sup>340</sup>

### *The Role of Decentralization in Understanding Community Needs*

One of the ways in which solar energy could be best approached in rural Ghana is through the decentralization of energy institutions. Centralized formal institutions may lead to inappropriate rural electrification solutions that are not adapted to the users' needs.<sup>341</sup> For example, in Ghana, despite the demand for household lighting, solar street lights are being installed, which does not align with the priorities of the rural communities.<sup>342</sup> Decentralization is meant to facilitate participative decision-making and community engagement, thus enhancing the chances of a technology to meet the needs of the population. Decentralized institutions may be preferred for rural electrification since local users know best what they need and who they can trust. Indeed, issues for off-grid systems related to decentralization often arose as qualified specialists with the required (cultural and technical) expert know-how are not available in remote areas.<sup>343</sup>

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<sup>338</sup> Apam. Personal Interview, January 29th, 2020.

<sup>339</sup> Abugbilla,. Personal Interview. January, 29th, 2020

<sup>340</sup> Emmanuel Amankwah, "Solar Energy: A Potential Source of Energy for Agricultural and Rural Development in Ghana." *Journal of Agriculture and Ecology Research International* 3, no. 4 (October 2015): 131–40.

<sup>341</sup> Sara Feron, "Sustainability of Off-Grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review." *MDPI: Sustainability*, December 2016: 6-10. [www.mdpi.com/journal/sustainability](http://www.mdpi.com/journal/sustainability).

<sup>342</sup> Ibid: 12

<sup>343</sup> Ibid: 17

## *The Political Landscape of Solar Energy*

### *Privatization*

Privatization of state-owned enterprises is often seen as the solution to economic inefficiencies by leaders in Washington DC; in fact, the practice of advocating for privatization has become so widespread that it was included in what John Williamson famously labeled as the “Washington Consensus”.<sup>344</sup> However, privatization of energy in Ghana has historically faced obstacles. In the past, utility workers have been vocal about changes in the utility sector and about privatization of the ECG. For example, the Secretary General of the Trade Union Congress (TUC), Dr. Kofi Asamoah, has argued that “the solution to the utility problems in the country does not reside in privatization of ECG. This, he claimed, will be a landmark privatization whose consequences can be catastrophic”.<sup>345</sup> He strongly questioned the effectiveness of privatization, saying that the

*“Government should come out and tell us where the concessions have worked, otherwise, our checks on the African continent and a few external countries outside the African countries have shown that the concession or the concessionaire or whatever they call it has not worked as it's being propagated”.*<sup>346</sup>

In a 2017 press conference, the Public Utility Workers Union (PUWU) of the TUC, expressed their desire for the government to consider them and their positions as stakeholders before moving towards privatization of the ECG.<sup>347</sup> The PUWU made it clear that they were against the privatization of the ECG, as they feared the adverse effects on rural electrification as well as increased electricity tariffs that privatization might bring about.<sup>348</sup> Privatization did increase tariff

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<sup>344</sup> “The Strange /History of the Washington Consensus” Journal of Post Keynesian Economics 2004, Taylor and Francis. Ltd. (Accessed March 3, 2020).

[https://www.jstor.org/stable/4538920?seq=2#metadata\\_info\\_tab\\_contents](https://www.jstor.org/stable/4538920?seq=2#metadata_info_tab_contents)

<sup>345</sup> “Public Utility Workers Union in Ghana Applauds the Support of PSI.” PSI, July 20, 2016. <https://www.world-psi.org/en/public-utility-workers-union-ghana-applauds-support-psi>.

<sup>346</sup> Ibid.

<sup>347</sup> “Public Utility Workers Union Cautions Government on the Privatization of ECG.” GhanaWeb.com, April 7, 2017. <https://www.ghanaweb.com/GhanaHomePage/business/Public-Utility-Workers-Union-cautions-government-on-the-privatization-of-ECG-526692>

<sup>348</sup> Ibid.

prices, however the increase in prices placed new threats to the ECG instead of simply helping to pay for costs of operation as predicted by the Millennium Challenge Corporation (MCC). According to the Energy Commission, in 2018 purchases of generators rose as some consumers (non-residential and industrial consumers) viewed generators as being more cost-competitive to the grid because of their high consumption needs.<sup>349</sup> This trend was a concern to the Energy Commission as it could reduce the income and profit of the existing electricity utility companies.<sup>350</sup> In this manner, increased tariffs had unintended negative economic effects on the company.

This fear of increased electricity prices is not totally unfounded as in the past, other commodities such as water have also faced these price increases. For example, in May 2001 water fees in Ghana increased by 95% as a result of International Monetary Fund and World Bank policies that attempted to place water prices at the market rate.<sup>351</sup> In this case, price increases disproportionately negatively affected the poor, becoming what Patrick Apoya, representative of the Community Pact for Health and Development, called “a deadly poison and a prescription for death for the poor.”<sup>352</sup> When discussing electrification of rural areas, both access and price must be considered. When interviewing Gloria, a sociologist from Kumasi, she revealed to us that while visiting a village, she was surprised to find out that some people had never paid an electricity bill, as they claimed they had never received a bill. While this may be true, it is also possible that these bills were never paid because of financial constraints. Possible negative effects of privatization such as these must be acknowledged when considering widespread privatization of the electricity sector. The extent to which citizens would oppose privatization of the microgrid market remains unknown, as the government has limited private participation in this area.

### *Electrification as a Political Tool*

During an interview with a PhD student named Frank Baffour-Ata, he expressed concern about the role of politicians in energy expansion, asserting that the government “looks at how electrification benefits the citizens, but it also looks at how it will benefit they themselves as

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<sup>349</sup> Energy Commission of Ghana, “2019 Energy (Supply and Demand) Outlook for Ghana,” (2019), 3.

<sup>350</sup> Ibid, 3.

<sup>351</sup> “Privatization of Ghana's Water.” Michigan Citizen (Highland Park, Mich.), 2002.

<sup>352</sup> Ibid.

politicians.”<sup>353</sup> While this claim may not be true for all electrification cases, political interests are still a significant factor in the expansion of electrification. In his article, Ryan C. Briggs found that foreign aid can be used to help incumbent politicians stay in office.<sup>354</sup> He argues that the aid given to Ghana has been allocated in the past in such a manner that would help incumbents do better in elections. For example, incumbents from the National Democratic Congress (NDC) party gave the most aid for electrification to areas that had given them the most votes in 1992, such as rural areas and the national periphery, especially the southern Volta Region.<sup>355</sup> In 1999, aid was reduced since donors did not fully disburse the promised funds, partly due to economic instability and the volatile nature of donations.<sup>356</sup> Briggs found that this affected the 2000 election by reducing the votes given to the NDC.<sup>357</sup> Ultimately, the NDC lost about 5 percentage points in votes, as a result to lower electrification progress than in past years.<sup>358</sup> It is clear then, that decisions on electrification are made to reward voters and can also be used to have impact on future elections. However, votes do not always determine if a community gets aid for electricity, and other factors, such as the educational status of local leaders, can impact if a politician decides to give this aid.<sup>359</sup>

According to our interview with Amos, a teacher in northern Ghana, this discrepancy likely would not occur if local committees are in charge.<sup>360</sup> Instead, he claims that this happens when politicians are working with NGOs to provide electricity to rural communities; as demonstrated by Briggs, the promise of electrification can ultimately help politicians strengthen their position with their constituencies and gain more votes in the future elections.<sup>361</sup> While the GoG claims in the REMP a desire for increased renewable energy sources and for increased rural electrification, they deny private companies from coming in to help fulfill these goals. While other factors may influence these actions, there is a possibility that such limitations are placed because local politicians want to continue to reap the benefits that come with having the power to decide which communities receive microgrids. If private companies were to provide microgrids to communities based on

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<sup>353</sup> Baffour-Ata, Personal Interview, 2020.

<sup>354</sup> Ryan C. Briggs, "Electrifying the Base? Aid and Incumbent Advantage in Ghana." 50, no. 4 (2012): 603-24.

<sup>355</sup> Ibid, 605.

<sup>356</sup> Ibid, 622.

<sup>357</sup> Ibid.

<sup>358</sup> Ibid, 617.

<sup>359</sup> Abugbilla, Personal interview, 2020

<sup>360</sup> Apam. Personal interview, January 24th 2020.

<sup>361</sup> Ibid.

demand or need, politicians would not be able to utilize microgrids as a tool for their own political gain.

Furthermore, in “Political Autonomy and Resistance in Electricity Sector Liberalization in Africa,” Brass et al. argue that civil servants have also distributed solar panels based on political motivations rather than need.<sup>362</sup> Brass et. al found that decisions made by civil servants were “shaped by the politics of place, with goods distribution guided at least partially by historic relationships between citizens, politicians, donors, and civil servants.”<sup>363</sup> Even though civil servants are not voted into their positions, they were unable to fully escape the influence of politicians.<sup>364</sup> It is important to note that Brass et al. did not find that solar panels were being distributed in order to reward loyalists, or to induce swing voters, but rather to motivate future voter turnout.<sup>365</sup> This may create difficulties in trying to predict where solar panels will be distributed, since these decisions are not based on past voter patterns and highlights the importance of access to data on communities to guide future electrification strategies. More importantly, this points to the fact that political needs and citizens’ needs do not match up perfectly, and maybe at odds, in terms of electrification.

#### *Donations for Solar Electrification*

Additionally, we must also consider the impact of international stakeholders on the solar landscape in Ghana. Challenges to Ghanaian autonomy might arise because of the prominent roles of NGOs and international aid providers. While these stakeholders are attempting to expand electrification in Ghana, issues arise as their practices limit the creation of a strong domestic market in Ghana that encompasses local manufacturers, companies and financing institutions that can contribute to expanding the supply of solar energy technologies. In the REMP, Ghana has made it clear that they support greater local participation in the renewable energy sector. In

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<sup>362</sup> Jennifer N. Brass, Justin Schon, Elizabeth Baldwin, and Lauren M Maclean. "Spatial Analysis of Bureaucrats' Attempts to Resist Political Capture in a Developing Democracy: The Distribution of Solar Panels in Ghana." *Political Geography* 76 (2020): *Political Geography*, January 2020, Vol.76

<sup>363</sup> Ibid.

<sup>364</sup> Ibid.

<sup>365</sup> Ibid.

considering how to promote the manufacturing of solar lanterns, the REMP lists the following as important steps: “Ensur[ing] compliance of local content and local participation for solar lantern procurements; Provid[ing] incentives for local assembly/manufacturing.”<sup>366</sup> In fact, pursuant to increasing domestic solar cell production and production of goods used in the electricity industry, Ghana passed the Local Content and Local Participation Regulation for solar products. The goal of this law is to achieve a minimum of fifty-one percent equity participation in wholesale supply and distribution in the electricity supply industry in Ghana and 60% local content.<sup>367</sup> It is also meant to develop capacity in the manufacturing industry for electrical cables, solar cells, conductors, accessories, and more.<sup>368</sup> However, it is difficult for these companies to compete to sell their products when NGOs are distributing free products. More importantly, since NGOs and donors are giving free solar technologies, the financial institutions that can help finance the purchase of solar technologies in the long run are less incentivized to develop.<sup>369</sup> There is a dilemma between affordability through subsidies and donations, and strengthening private markets through price liberalization.

Both vendor or supplier finance and consumer finance are essential to the creation of a strong solar market.<sup>370</sup> According to researchers from the University of Ghana, the World Bank, and ARB Apex Bank, “only rarely...has the donation approach seeded a large enough market for competition to drive prices down such that commercial sales take over on a sustainable basis.”<sup>371</sup> This article argues that solar homes systems specifically, require this financing in order to cover the high upfront costs.<sup>372</sup> However, as evidenced by the need of a pay-as-you go model, it is clear that even smaller, less costly products such as lanterns and lightbulbs may sometimes be out of economic reach for many families across Ghana, and specifically in rural areas. As such, a developed and suitable microfinancing system can have significant impacts on the expansion of solar energy by allowing more low-income households to purchase solar products.

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<sup>366</sup> Energy Commission of Ghana, *Renewable Energy Masterplan*, 26.

<sup>367</sup> Energy Commission. “Local Content and Local Participation.” Energy Commission. Ghana Publishing Company, 2017. [http://www.energycom.gov.gh/files/Local Content and Local Participation Regulations, 2017 \(L.I. 2354\).pdf](http://www.energycom.gov.gh/files/Local Content and Local Participation Regulations, 2017 (L.I. 2354).pdf).

<sup>368</sup> Ibid.

<sup>369</sup> William F Steel, Nana Akua Anyidoho, Frank Y Dadzie, and Richard H Hosier. "Developing Rural Markets for Solar Products : Lessons from Ghana." *Energy for Sustainable Development*, 2016, *Energy for Sustainable Development*, April 2016.

<sup>370</sup> Ibid, 183.

<sup>371</sup> Ibid, 179.

<sup>372</sup> Steel et al. “Developing Rural Markets for Solar Products”.

### *Financing and Future Access*

The bulk of microgrid development financing comes from official development assistance (ODA) from foreign government development agencies, NGOs, and multilateral development funds. In the absence of major changes in the way the GoG treats energy production, current trends in Ghana are likely to continue. That is, grid-scale and microgrid solar PV technology distribution will continue to be dominated by the central government in partnership with foreign governments and aid organizations, while small scale solar PV technology distribution will be implemented through NGOs and private companies.

### *Foreign Investments and Aid*

Foreign aid in the form of grants and donations will likely continue to affect the expansion of solar energy. Ghana has historically relied heavily on foreign aid for the installation of microgrids in off-grid areas, and since there is currently no licensing pathway for private producers of microgrids, there will likely continue to be dependence on donations from foreign stakeholders. Additionally, given the temporary hold on provisional licenses for solar IPPs, large scale utility farms are also to reach a cap after the current farms in planning are built.<sup>373</sup> In these areas, there are clear limits to solar energy expansion that are being set up by the GoG.

Currently, numerous countries participate in the market for solar technology, including China, India, the United States, Western Europe, and Japan. However, in recent years, China has taken the lead. According to Amankwah-Amoah, an economist at the University of Bristol, “although Germany has historically had a strong reputation in the domestic solar industry, China has recently emerged as the world’s largest solar panel maker, with exports to European, North American, and African markets.”<sup>374</sup> Solar panels have become more cost-effective as innovation and economies of scale have improved its viability. With little local Ghanaian solar panel competition, it is highly likely that low-cost Chinese panels will continue to dominate the global market.

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<sup>373</sup> Energy Commission of Ghana, “2019 Energy (Supply and Demand) Outlook for Ghana,” (2019), 63

<sup>374</sup> Joseph Amankwah-Amoah, “Solar Energy in Sub-Saharan Africa: The Challenges and Opportunities of Technological Leapfrogging,” (Thunderbird International Business Review Vol. 57, No. 1 January/February 2015), 19.

In Ghana, Chinese investors and companies have been active participants in funding and running mining operations, as well as participating in the energy sector. As previously mentioned, the Sinohydro Corporation Limited was responsible for the construction of the Bui hydropower plant and had financial support from the Exim Bank of China and the GoG. In terms of solar power, Chinese companies have also been active in SSA. For example, in 2017 the Chinese Jiangxi Corporation for International Economic & Technical Co, Ltd. began to build a 50-MW solar power project in Kenya. Additionally, as a result of huge production levels of solar panels in China as well as technological breakthroughs, there has been a 50% price decline on solar panels.<sup>375</sup> This has been beneficial to SSA, as these products are now more affordable than in the past, however further price drops are still needed in order for solar PV technologies to become widely accessible.

However, this influx of solar panels and other solar PV products creates heavy competition on domestic companies. Amankwah-Amoah succinctly describes the dilemma faced by Sub-Saharan governments by claiming that: “there is an intrinsic tension between creating conditions to attract investors on one hand and the need to create conditions that facilitate technological diffusion and foster growth in the nascent industry on the other”.<sup>376</sup> As previously stated, in Ghana, there is currently only one domestically owned solar panel company, SPS. In South Africa, there is a larger domestic solar panel production that has been present for a longer period of time, and these producers have experienced intense competition from Chinese solar PV companies<sup>377</sup>. Being aware that foreign companies can have a detrimental impact on local growth, the GoG passed the Local Content and Local Participation regulations (Electricity Supply Industry (ESI)) Regulations, 2017, (L.I. 2354), in an attempt to maintain a Ghanaian workforce in the energy sector. Africa is expected to become one of the fastest growing markets for solar PV<sup>378</sup>, and hence SSA presents an opportunity to Ghanaian solar panel producers. Local manufacturing companies can generate jobs as well as supply neighboring countries with this in-demand product. As this regulation only passed 3 years ago, it might be too soon to know its effects, however it does demonstrate Ghana’s desire for greater economic autonomy and development.

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<sup>375</sup> Amankwah-Amoah, “Solar Energy in Sub-Saharan Africa”, 16.

<sup>376</sup> Ibid, 28.

<sup>377</sup> Ibid, 23.

<sup>378</sup> Ibid, 19.

Another manner in which international actors have been active in Ghana's solar market is through aid funding. Although aid has come from donors, much of this aid often has attached conditions. For example, under the Obama administration's Power Africa initiative, in 2014 the MCC and the GoG signed the Second Compact also known as the Ghana Power Compact. This compact gave large funding amounts to Ghana to help "support the transformation of Ghana's electricity sector and stimulate private investment."<sup>379</sup> However, the compact included stipulations for reform in order to get more funding. The initial amount given was of \$308.2 million USD, and then up to \$190 million USD in funds would be made available if Ghana accomplished a set of reform targets set forth in the Compact.<sup>380</sup> In this sense, it is clear that aid was not being given unconditionally, but only within the guidelines and under conditions set by the U.S.

These conditions include raising tariffs imposed on consumers to recover the costs of operation of ECG as well as increasing private sector participation. Specifically, the MCC Compact stipulated that ECG must engage in a "long-term concession or partial privatization agreement among the Government and an Acceptable ECG power service provider (PSP) that leverages private capital to address operational and commercial competencies necessary for the specific challenges of ECG's operation."<sup>381</sup> A similar requirement was made for the Northern Electricity Distribution Company (NEDCo).<sup>382</sup> Regardless of warnings such as those made by workers and groups like the Trade Union Congress, this partial privatization of ECG and NEDCo took place, and as a result the GoG was able to receive the full \$498.2 million USD. However, in 2019 the ECG was returned into the hands of the GoG, under claims that the private management of the Power Distribution Services (PDS), a consortium based in the Philippines, had engaged in fraud.<sup>383</sup> It should be noted that the PDS was only operating the ECG for a bit longer than the 5-year requirement set forth by the compact. After this period of time, the ECG remained highly indebted to GridCo: by March

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<sup>379</sup> "Millennium Development Authority (MiDA) - Ghana Power Compact." 2014.

<sup>380</sup> "Millennium Challenge Compact Between the United States of America Acting Through The Millennium Challenge Corporation and the Republic of Ghana," 2014, Annex I-9.

<sup>381</sup> Ibid, Annex V.

<sup>382</sup> Ibid.

<sup>383</sup> "Energy Minister Cites Fraud as Reason PDS Contract Was Suspended." GhanaWeb.com, July 31, 2019. <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Energy-Minister-cites-fraud-as-reason-PDS-contract-was-suspended-768185>.

2019 approximately 607 million (about \$114 million USD) were owed.<sup>384</sup> Similarly, NEDCo also owed GRIDCo approximately 177 million cedis (about \$33 million USD).<sup>385</sup> Overall, while privatization was meant to reduce the use of “implicit subsidies,” and help make sure that costs of operation were covered, the result after the 5-year timeline points to the fact that privatization did not make inefficiencies cease. Regardless, the GoG had to remain in the agreement of partial privatization in order to have access to the promised funds. As such, these funds placed new requirements and restrictions on the GoG in how they managed their power sector.

Furthermore, it is well known that other funders, such as the World Bank, also support reform and neoliberal policies that can place countries under similar restrictions in return for aid. According to Gore et al., the World Bank has been active in promoting reforms in Ghana, Uganda, and Tanzania.<sup>386</sup> These “governments accepted reforms to acquire financial support for their electricity sectors and to signal to other donors and investors that efforts were being made to improve economic efficiency.”<sup>387</sup> While Ghana, Uganda, and Tanzania all accepted reform, Ghana and Tanzania “moved more slowly and implemented reforms less deeply, owing to their access to other financial support and domestic political conditions and resistance.”<sup>388</sup> From our previous descriptions of privatization of energy in Ghana, it is clear that overall, privatization is not highly supported and is not as efficient as funders claim, yet it is embraced in exchange for the opportunity to expand electrification.

In terms of the expansion of solar power throughout Ghana, it becomes evident that funding solar electrification initiatives may be difficult if the aid needed for this expansion comes attached with stringent requirements. Moving forward, it must be considered that programs to electrify rural communities in Ghana might require aid, and this aid has its own implications. Historical examples of foreign aid demonstrate that either privatization is heavily pushed, or free products are given,

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<sup>384</sup> “GRIDCo Staff Threaten Strike over ECG, VALCO, NEDCo Debts.” ghanaweb.com, November 22, 2019. <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/GRIDCo-staff-threaten-strike-over-ECG-VALCO-NEDCo-debts-801224>.

<sup>385</sup> Ibid.

<sup>386</sup> Christopher D Gore, Jennifer N Brass, Elizabeth Baldwin, and Lauren M Maclean. “Political Autonomy and Resistance in Electricity Sector Liberalization in Africa.” *World Development* 120 (2019): 209.

<sup>387</sup> Ibid.

<sup>388</sup> Ibid.

placing pressure on local markets. Hence, the expansion of solar energy will undeniably be impacted by the views and decisions made by foreign stakeholders. The manner in which solar energy expansion is funded and implemented should consider all stakeholders equally, not simply foreign stakeholders.

In the past thirty years, ODA financing in Ghana has been limited to microgrid pilot programs and humanitarian efforts that do not scale, are finite in project length, and become unsuccessful after the donor organizations leave. This is caused by a lack of local capability to maintain the microgrid absent external assistance. This is not to diminish the efforts of pilots, as they have been valuable case studies for the development of successful micro grids in the future.

### ***Local Government and Electrification***

The current energy access agenda of Ghana's government is still guided by the National Electrification Scheme (NES) of 1989.<sup>389</sup> Although the NES has done a good job comprising various financing mechanisms, five year electrification plans, and supplementary programs, it has also created a criteria that does not consider many rural villages such as its requirement that communities be greater than 500 households in size, are accessible by road, and situated within 20 kilometers of existing distribution lines.<sup>390</sup> However, all the villages that do not meet these criteria are not considered in the access rate calculations. Data regarding the size of Ghana's off-grid population can be difficult to obtain and at times contradictory. This criterion is problematic because it leaves the project in the villages unprotected and not adequately equipped with the comprehensive skill set and competence to allow them to succeed.

Some of the consequences of the NES criteria has been the lack of engagement of the communities. The social engagement is often limited to the acquisition of land for the project, assembling people for the often festive inaugurating or commissioning of projects.<sup>391</sup> This means that it is not common for people in rural areas to take care of project management issues or other supervisory

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<sup>389</sup> Feron , "Sustainability of Off-Grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review." 6-10.

<sup>390</sup> "Off-Grid Solar Market Assessment: Ghana." *Power Africa* , October 2019: 2.

[https://www.usaid.gov/sites/default/files/documents/1860/PAOP-Ghana-MarketAssessment-Final\\_508.pdf](https://www.usaid.gov/sites/default/files/documents/1860/PAOP-Ghana-MarketAssessment-Final_508.pdf).

<sup>391</sup> Ibid, 12

responsibilities. As a result, some communities neither assume any responsibility for the functioning of the project nor see themselves as significant players in the projects' successes or failures. The rural communities lack of communication concerning the applications and limitations of off-grid PV systems can lead to false expectations and negative perceptions, thus constraining their acceptance. That is why community engagement is crucial for the implementation of any future project in the rural areas. Decentralization in terms of community engagement will facilitate adaptability and participative decision-making, thus enhancing the chances of a technology to meet the needs of the population.

The GoG recognizes the importance of Metropolitan, Municipal, and District Assemblies (MMDAs) in the development and deployment of renewable energy technologies (RET). As a result there is an interest in empowering MMDAs to promote development. There is inadequate human and institutional capacity, limited awareness of RET options, limited financing, limited incentives for business operation in rural areas, no clear initiatives to integrate renewable energy into development plans, and inadequate small scale technology to support low levels of electrification. To address these problems, the REMP briefly touches on some solutions; incorporate RET into district development plans, identify and promote incentives that will attract RET investment, and increase human and institutional capacity at the MMDAs levels.

Ghana has an official channel that empowers communities to connect to the grid, but it is restrictive to national-grid connection and requires significant community cost-sharing, leaving the poorest communities behind. The Self-Help Electrification Program (SHEP) is a government program mandated by the Ghanaian Government in NES to empower rural communities' ability to receive electricity. Pursuant to giving communities more agency in their electrification efforts, this community driven program provides an administrative framework for district level officials to connect their communities to the national grid. This program should be considered as the biggest determinant in rural electrification in Ghana, electrifying over 1000 communities between 2009 and 2016.<sup>392</sup> In a study conducted in 2016 which surveyed the results of the SHEP, communities

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<sup>392</sup> Frank Adusah-Poku, and Kenji Takeuchi, "Determinants and Welfare Impacts of Rural Electrification in Ghana." *Energy for Sustainable Development* 52 (October 2019): 54

electrified by the program increased their average household expenditure by 10-20% towards buying appliances and other electricity powered products, indicating increased economic activity.<sup>393</sup> However, this program and its benefits are skewed towards better-off communities. To qualify, communities must be no further than 20km away from an existing medium voltage grid line, erect all necessary distribution poles, and wire one third of households.<sup>394</sup> There is no such program for communities beyond the 20km range. Furthermore with the community's responsibility to erect electricity poles and wire their own households only the wealthier communities and community members tend to receive electrification. The benefits of electrification are also less pronounced in poorer households who have difficulty affording electricity products.<sup>395</sup>

### ***Conclusion***

Impartiality on behalf of the government is essential to addressing the needs of the most marginalized members of Ghanaian society. Using electrification through solar energy, or other sources, for the purpose of gaining votes must be mitigated and brought to an end. This is necessary for small, isolated communities to get the equal treatment as larger communities (who would provide more votes). Instead of these decisions being left up to politicians, third parties should be used to avoid biased preferences. For example, instead of having politicians tell NGOs where solar panels or mini grids should be distributed, the NGOs should be given data on the current electrification situations and decide for themselves. Overall, politicians should be given less power in the decision making for solar energy expansion and there should be an emphasis on local leadership, which is vital to achieving greater electrification. Although there are people who are considered experts on electrification, local Ghanaians know their needs most thoroughly due to their lived experiences. These communities are in a unique position to support solar expansion through political engagement and their consumption choices.

International stakeholders such as NGOs, the World Bank, and other investors, need to help in the creation of a market for solar-energy, in the sense that solar-energy as a commodity will thrive.

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<sup>393</sup> Adusah-Poku, and Takeuchi, "Determinants and Welfare Impacts of Rural Electrification in Ghana."55.

<sup>394</sup> Ibid, 53.

<sup>395</sup> Ibid, 60.

Instead of forcing privatization of state-owned enterprises, the World Bank and other investors should encourage the growth of already privately-owned enterprises, such as solar panel manufacturing. Similarly, NGOs must think about the effect of their decisions in the *long run*. Overall, these stakeholders must align their decisions to fit local needs. Immediate solutions can address immediate needs; however, these will not create a system where Ghana can be self-reliant in terms of electricity. Only the most pressing issues should be addressed in this manner of single time donations, including getting clinics and hospitals fully electrified.

In recent years, Ghana's economy has been growing fairly quickly and its population has doubled within the course of a decade. Hence, Ghana has great potential for further economic growth. However, this growth is dependent on access to electricity, for powering businesses, schools, hospitals, homes, and more. While Ghana has one of the highest reported electrification rates in SSA, more work is needed for this access to be reliable, to expand to rural communities, and to become sustainable in the long term. Solar power presents a viable alternative to hydropower and thermal power. This alternative could help reduce vulnerabilities in the electricity sector by reducing reliance on imports of natural gas from neighboring countries and reducing the reliance on water levels of dams.

Achieving extensive production and consumption of solar PV technologies will not be quick or simple. Rather, considerations to the economic, social and political factors must be given. In terms of politics, all levels of organizations and power should be considered, as all have the potential to impact in which manner and to what degree solar PV technology expands; however, special focus should be given to trade unions, local electoral politics, and international politics. While most parties support the expansion of access to electricity, the manner in which they support this goal must be considered in the context of Ghana's goals for increased local participation and local economic growth. Solar energy can be used as a supplement in the short term, but it is equally important to treat solar energy as a potential replacement in the long term; therefore, plans and decisions should be made accordingly.

## CONCLUSION & RECOMMENDATIONS

Every day, thousands of communities in Ghana continue to live without electricity and those who have access to it often lose it regularly because of dumsor. It is important to note that sub-Saharan Africa as a region contributes the least to climate change, yet is impacted the most; thus, Ghana disproportionately shoulders the responsibility to solve an issue that is currently growing due to energy usage and technology in the Global North. Acknowledging this, Ghana is at a historical moment of opportunity. If Ghana continues to pursue its commitment to renewable energy development, it has the power to not only transform the international and national energy sectors, but also to reshape its economy, pioneer novel solutions to climate change, and transform the lives of its people. In practice, this will largely depend on the GoG: on their decisions regarding how they deal with national and international private companies, governments, and NGOs.

Recommendations to provide renewable energy to a community rely heavily on the terrain, socioeconomic status of the region, and the weather. All three of these differ heavily within sub-Saharan Africa; within Ghana alone, different areas of the country can maximize the utilization of different technologies. For example, Northern Ghana has a dry season and a rainy season, whereas the South has rainfall all year round. These differences strongly impact what energy mix is best suited for each region; hydro power cannot work efficiently in the North if there is a drought and reservoirs dry up. Infrastructure in each country also differs. While large cities may benefit from using one type of energy, smaller villages may not require the same amount of power, thus different types of communities may also require different energy strategies. There is no one solution for the electrification of sub-Saharan Africa because every country comes with its own set of influencing factors, whether it be the wealth of the country, cultural norms, or other. Our recommendations below are meant to offer insight into potential energy sources that can be considered when developing electrical grids in SSA and provide a framework for future research and recommendations in the region.

### ***Infrastructure***

As Ghana looks to reconfigure its energy sector, these recommendations will address the foundations of infrastructural enhancement and development. We affirm the efforts of the Government of Ghana within the past decade to increase the reach and reliability of the national grid. Within this section, we seek to promote more concrete, actionable steps to correspond with the following measures: national grid/transmission lines, reliability to address losses and blackouts from dumsor, and new research before new development. These recommendations will address the infrastructural proposals for each renewable energy sector to improve energy access and efficiency to most effectively promote economic growth, political commitment, and social development.

1. **The Energy Commission of Ghana (ECG) should implement a 5-10 year monitoring period to annually measure the efficiency of existing wind and hybrid standalone, and utility scale wind projects to determine areas for improvement before further development.** This proposal aims to stimulate investment and maximize the cost-effectiveness and social impact of existing and future wind power projects. Ghana's wind power systems are still in planning, testing, or pilot phases because the longitudinal effectiveness studies necessary to scale up these projects to a commercial level do not exist. The high startup cost of wind projects makes wind power an even riskier investment when the desirable results have not yet been measured or proven. Thus, we propose that the ECG and the Ghana Energy Access and Development Project implement a monitoring scheme in partnership with the ECOWAS Center for Renewable Energy and Energy Efficiency, a regional body with existing resources for these monitoring efforts, to annually collect data to assess the benefit and progress of these projects. These measurements should use quantitative indicators to ensure a systematic and reliable evaluative format. While taking into account local environmental and market circumstances like variable weather patterns, the most impactful measurement indicators/criteria for Ghana would be (1) annual rates of growth in energy access, production, and use; (2) achieved energy generation versus cost of energy for the consumer; (3) annual value added to the local economy in manufacturing,

employment, and educational involvement.<sup>396</sup> Previous such assessments conducted by the International Energy Agency and United Nations Environment Programme (UNEP) have found these to be the most effective measurement criteria for countries looking to develop their renewable energy sector. While this assessment is likely low cost, we propose partnering with the UNEP to source these funds. This recommendation focuses on wind-centric projects, but such assessments could be applied to other renewables if found to be effective.

2. **Within the hydropower sector, specifically, we recommend only implementing reservoir or storage pump dams, as opposed to run-of-river dam schemes.** This will maximize efficiency and power capacity, provide irrigation to nearby communities, and mitigate the effects of variable weather patterns from climate change. The value of storing water as an energy and irrigative resource will be crucial to supporting agricultural and energy needs through future drought years. As of 2016, Ghana had identified 17 possible dam construction sites. Although there are little concrete plans for each dam implementation strategy, we recommend they only be constructed if they are planned as reservoir or storage pump dams.
  
3. **We support the construction of the planned multi-purpose Pwalugu dam, but only after a thorough audits of its budget and at a non-inflated unit cost.** In Zambia, Uganda, and Ethiopia, for example, similar sized dams were constructed at a unit cost of about \$1 million USD.<sup>397</sup> Before re-starting construction on Pwalugu, we support a public and transparent budget audit of the financing and finance structure of Pwalugu. If comparable in cost to the hydropower projects mentioned above, Pwalugu dam would provide crucial energy and agricultural infrastructure to the north of Ghana.

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<sup>396</sup> “Assessing\_the\_effectiveness.Pdf.” 16. Accessed March 1, 2020.  
[https://backend.orbit.dtu.dk/ws/files/69996503/Assessing\\_the\\_effectiveness.pdf](https://backend.orbit.dtu.dk/ws/files/69996503/Assessing_the_effectiveness.pdf).

<sup>397</sup> “Drop Highly Inflated \$366m Pwalugu Dam Project – NDC MPs to Akufo-Addo.” Accessed February 7, 2020.  
<https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Drop-highly-inflated-366m-Pwalugu-dam-project-NDC-MPs-to-Akufo-Addo-857698>.

4. **To prepare for the future of the growing biomass energy sector we recommend that the Ministry of Energy of Ghana establish a task force aimed at researching potential localities well-suited for the requirements and offerings of biomass technologies.** The Research, Statistics and Information Management Directorate and Renewable and Alternative Energy Directorate should collaborate to create this task force. Because it is imperative that biomass gasification experts and national energy and agriculture officials take part in the research process, we suggest at least one representative from each of these stakeholders be part of the task force. An expert on the technology from D.E.S.I. Power or Husk Power Systems, the two most prominent gasifier manufacturers in the region, an official from NEDCo and an official from the Policy, Planning, Monitoring and Evaluation Directorate of the Ministry of Food & Agriculture should make up the research team. The Ministry of Energy should commit to public delivering the results of this research no later than 2025 to ensure biomass is a part of Ghana's energy future.

***Social engagement:***

Community-based development is vital to the sustainability of broader policy implementation. Policy solutions are more effective and durable when community needs serve as the starting point for future interventions. Individuals must be empowered through education, community organizing, and technical training in order to promote community-driven solutions and equitable partnerships between communities and stakeholders. The following recommendations are intended to provide a framework for social engagement that ensures that community needs are considered in the implementation of government, NGO, and private-sector interventions.

1. **We recommend all foreign investment firms within the energy sector be required to partner with and fund a grant program through the Ghana Ministry of Education for higher education and research in applicable technical fields.** The Ghana Investment Promotion Centre should demand a grant or grant-like program be part of all new investment contracts and make project approval contingent on the existence of such programs. These grants will have preferential consideration for students from villages and

townships affected by energy infrastructure construction (for example, students whose families were displaced by the construction of Bui dam) to receive an applicable degree at Kwame Nkrumah University of Science and Technology or another accredited university with credibility in the applied sciences. This could also be expanded to support research in other areas of the energy sector such as, developing biomass technologies and to spurring the development of biogas. The funding levels for these grant programs should be established through a cooperation between the Ghanaian Ministry of Education, the GIPC, and the Ministry of Energy. These grant programs will bolster the skilled Ghanaian workforce, allow for future domestic ownership of energy infrastructure projects, and eventually reduce the need for foreign skilled workers in the energy infrastructure economy, all while serving as a form of corporate community engagement for the investors themselves.

2. **Support for community groups and local NGOs-- such as the Centre for Energy, Environment, and Sustainable Development (CEESD) and KITE-- with interest in biogas technology and implementation is essential to ensuring the dissemination and sustainability of the technology.** Following the model that has been used in Ghana for public health-related campaigns, the Ghanaian government--specifically the Environmental Protection Agency (EPA), as an offshoot of its training school-- should collaborate with NGOs in providing educational and technical workshops on biogas to communities in order to increase knowledge of the technology and to ensure proper implementation and maintenance of digesters. Due to the public health benefits related to biogas as a form of waste management, such campaigns would relate closely to existing public health initiatives. Induction of more local NGOs as members of the Biogas Association of Ghana (BAG) may help facilitate such partnership between state and non-state actors. This intervention is closely related to our recommendation for the introduction of a regulatory system for biogas in Ghana, as workshops and education materials should reflect the forthcoming national standards.

### ***Investment: Local and Foreign***

The following recommendations will consist of how to improve investment dynamics and relationships within the energy sector in Ghana. Reshaping certain elements of energy investment will lead not only to improved energy access and efficiency, but economic development and further emergence of Ghana both as a force in global markets and a leader in sub-Saharan electrification. This section includes recommendations that fall broadly under the following categories: diversifying the energy investment portfolio, moving towards local representation and in foreign funded projects and initiatives, and specific investment opportunities and strategies within various renewable energy technologies.

1. **The Ghanaian government should improve local sovereignty and leadership in foreign investment relationships by establishing and enforcing uniform, centrally regulated and administered conditions that require foreign investors to collaborate with and include leadership from Ghanaian ministries and employees in the development of new energy infrastructure projects.** This is especially applicable to the role of the Chinese government in the hydropower sector. Today, Ghana has a very liberal policy towards foreign ownership. Currently, all foreign investment projects must register with the Ghana Investment Promotion Centre (GIPC). For companies that have 10% or more Ghanaian ownership, the minimum capital requirement is \$200,000 USD. This raises to \$500,000 USD if there is no domestic ownership and to \$1 million USD for trading companies with no domestic ownership, and trading companies (“firms that buy or sell imported goods or services”) must also employ 20 Ghanaian employees.<sup>398</sup> For example, South Africa is a leader in domestic ownership. There is even a push in certain industries for a 30% ownership requirement of black South Africans in all foreign ownership.<sup>399</sup> The GIPC should dramatically increase its domestic ownership requirements at all capital investment levels. We propose domestic ownership requirements of 20% at all capital investment levels, and all foreign companies over 50 employees should have at least 25% Ghanaian employees, 50% of which should be positions above entry level or labor-oriented

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<sup>398</sup> U.S. Department of State. “2019 Investment Climate Statements: Ghana.” U.S. Department of State Investment Climate, 2019. [https://www.state.gov/reports/2019-investment-climate-statements/ghana\\_\\_trashed/](https://www.state.gov/reports/2019-investment-climate-statements/ghana__trashed/).

<sup>399</sup> U.S. Department of State. “2019 Investment Climate Statements: South Africa.” U.S. Department of State Investment Climate, 2019. <https://www.state.gov/reports/2019-investment-climate-statements/south-africa/>.

positions. Eventually, this policy aims to decrease reliance on foreign skills and investment, as well as promote more collaborative aid and investment dynamics that allow Ghanaian people, public entities, and companies to have control in the future of energy infrastructure development in their country.

### ***Government and Policy Change***

The recommendations within this category will focus on the specific role of the central government and local governance structures regarding policy creation, amendment, and implementation by various actors. At the central level, this includes foreign policy in relation to other nation-states and international agreements. This report recognizes that although Ghana has created and implemented past policies and legislation that have been beneficial in the advancement of energy generation and electrification in Ghana, changes and additions to policy can further enhance Ghana's ability to reach its goals outlined in the 2019 Renewable Energy Master Plan.

1. **The central Government of Ghana should expand the Self-Help Electrification Program (SHEP), which is part of the National Electrification Scheme (NES), to give communities the official mechanism to request microgrids if grid extension is not feasible.** Currently, there is no policy mechanism for rural communities to ask the Government of Ghana for a microgrid. While the REMP highlights the government's national objective to electrify the Lake Volta Region with microgrids, other communities have not received the same level of access.<sup>400</sup> We propose SHEP become a primary component of Ghana's microgrid deployment strategy, funded through the Ghana Energy Development and Access Project (GEDAP) and respective AfDB and World Bank programs which currently finances microgrid deployment in the Lake Volta region. To be eligible for a microgrid, communities should demonstrate they have at least 2 community members skilled in electricity to conduct contract-based maintenance services on the microgrid, wire 1/3 of households, and be at least 20km away from a current medium voltage grid line. The biggest benefit of the SHEP microgrid deployment model is it empowers communities and decentralizes the responsibility of electrification towards the local level.

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<sup>400</sup> Energy Commission of Ghana, "Renewable Energy Master Plan", (2019):38.

**2. The Ghanaian government should collaborate with other biogas stakeholders to establish regulations on biogas installation and maintenance.** The Biogas Association of Ghana (BAG) serves as an existing coalition of private and public stakeholders, including the Energy Commission and the Environmental Protection Agency, and has the potential to serve as a starting point for conversations surrounding regulatory measures. With input from the various members of BAG, standards for biogas can be implemented across the private and public sector and monitored by BAG or one of its members, such as the Energy Commission. National regulations will ensure that biodigesters are installed and operated in a sustainable manner and will provide a framework for government/NGO-driven workshops and/or training on biogas technology.

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