Gauging Access to Electricity:

How do Multi-Tiered Frameworks Address the Shortcomings of Binary Variables When Measuring Rural Communities Access to Modern Electricity?

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Abstract:

Access to electricity can have tremendous effects on the day to day lives of the world's billions of people living in poverty. According to the International Energy Agency, approximately 1.2 billion people did not have access to electricity in 2013. Literature suggests a strong correlation exists between rural poverty and access to electricity. People in rural communities suffer regarding health, education and overall economic livelihoods often due to a lack of a safe and reliable energy source (Peter et al., 2012). Therefore, the reduction of energy poverty is closely linked to the reduction of poverty as a whole. However, there is a fundamental flaw in how academics, governments, and NGOs measure access to electricity. The majority of stakeholders use binary variables, such as percentage of a population with grid access, to gauge access to modern electricity. However, binary variables can vastly overestimate the correct level of access to electricity. In fact, if policy makers and academics were to follow the traditional measurement of electricity, India would stand at a village electrification rate of 96.7 percent and an LPG connection high enough to cover 60% of its population. This paper discusses the need to redefine how we measure access to electricity, and examines if multi-tiered frameworks are more capable at measuring the actual level of access to electricity. It calls on documentation and data from academics and policy makers, along with surveys done by the author in two regions in Tanzania.

Furthermore, this paper presents the Household Access to Electricity Framework (HAE), a novel approach to measuring a household or small businesses' access to reliable modern electricity. The HAE is inspired by other multi-tiered frameworks, such as the Global Tracking Framework (GTF) and the ACCESS framework. However, these frameworks have multiple shortcomings that the HAE address. The HAE attempts to strike a balance between the ideal metric that best captures access to electricity, and the real limitations often faced by NGOs. A series of 128 surveys and 15 interviews were carried around across two regions in Tanzania, Arusha and Shinyanga. The surveys focused on access to electricity for rural households, businesses, schools, and clinics in the area. The HAE framework is broken into five dimensions and four tiers: Capacity, Duration, Reliability, Quality, and Affordability. The data provides insight into differences between the traditional measure of access and the genuine level of access to electricity. Expanding on this suggest there is significant evidence that a simple binary system over estimates the rate of electrification in rural communities. Additionally, the high frequency of complete blackout days, low level of support from national providers, and relatively high levels of energy expenditure for grid connected locations, further distorts the actual effectiveness of rural energy policies. The data collected was then applied to the GTF to observe strengths and weaknesses between the GTF and HAE frameworks. It was discovered that the GTF remains very binary in nature. The HAE provides a relatively better measurement across a continuum of tiers and dimensions.

Developing a robust multi-dimension, multi-tiered energy access measurement will assist academics and governments in constructing effective policies. Through this measurement; data can be disaggregated and aggregated together to better facilitate planning and strategy, project design, progress monitoring, impact evaluation, and comparisons access areas and over time (GTF, 2015). Multi-tiered datasets will allow for governments and key stakeholders can clearly identify bottlenecks and target policy interventions.

Keywords: Energy Poverty, Multi-Tiered Frameworks, Rural Development, Rural Electrification

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Table of Contents

1.0 Introduction

According to the International Energy Agency (2015), approximately 1.2 billion people did not have access to electricity in 2013. Furthermore, due to population growth and under-development in energy infrastructure, particularly within rural regions, an estimated 1 billion people will still be without access to modern energy in 2030 (UNESCO, n.d.). Statistics show that 95% of those living without electricity are located in Sub-Saharan Africa and developing Asia (IEA, 2015). The majority of those affected live in rural settings, rural electrification rate in rural Sub-Saharan Africa is only 17% (IEA, 2015). While electricity may not be able to create all conditions for economic growth, it is essential for basic human needs and economic activity (IEA, 2013). In fact, a majority of literature suggest a strong correlation exists between rural poverty and access to electricity. This connection is due to electricity being a pre-requisite for productive activities (Torero, 2014). People in rural communities suffer regarding health, education and overall economic livelihoods due to a lack of a safe and reliable energy source (Peter et al., 2012). Therefore, the reduction of energy poverty is closely linked to the reduction of poverty as a whole. However, the methods used by academics, international organizations, and governments neglect to capture the complexity of energy poverty.

The traditional way of measuring rural access to electricity is through binary variables, i.e. 'Yes' or 'No', which undermines the connection between energy poverty and access to modern and reliable electricity. The use of a binary measurement or similar approaches, such as village electrification rate or LPG connections, can vastly overestimate the actual level of access to electricity (Jain, A., et al., 2015). In fact, if policy makers and academics were to follow the traditional measurement of electricity, India would stand at a village electrification rate of 96.7 percent and an LPG connection high enough to cover 60 percent of its population (Jain et al., 2015). There have been multiple attempts to transition to more complex measurements (Barnes et al., 2011; AGECC, 2010; IEA, 2015). The Multidimensional Energy Poverty Index (MEPI) and the Total Energy Access Standard are well-known examples, however, each one still fails to gauge energy access on a multi-tiered level. Therefore, it is crucial to develop a multi-dimensional, multi-tiered energy access measurement and framework that addresses gaps within current measurements. Furthermore, it is important to explore how multi-tiered frameworks can assist academics, NGOs, and governments in constructing effective policies towards addressing energy poverty.

Along with giving an analysis of current trends in measuring access to modern energy, this paper presents a novel approach to measuring access to modern and reliable electricity, the Household Access to Electricity (HAE). The aim of the HAE framework is to develop a framework for measuring access to electricity that strikes a balance between the precision needed to understand the interconnected issues that affect access to modern electricity, and the simplicity required to ensure that it can be adopted on an international scale. The framework used for the HAE is inspired by the Global Tracking Framework (GTF) which was developed by the World Bank and the Energy Sector Management Assistance Program (ESMAP) in February 2014 in response to the Sustainable Energy for All initiative (SE4All) initiative. The HAE also pulls from the ACCESS framework developed by Jain, A., et al. (2015) supported by the Council on Energy, Environment, and Water (CEEW).

However, due to data constraints, the GTF has recognized that the framework still overly relies on binary metrics for measuring energy access (IEA, 2015). Therefore, the GTF needs to be re-designed and contextualized to overcome its binary tendencies. The ACCESS framework begins to address some the shortcomings but is contextualized for rural India. The HAE overcomes these issues by employing a series of categories and metrics that can easily be collected, yet maintains the ability accurately to measure access to modern and reliable electricity. Unlike frameworks developed for the SE4All, the HAE focuses primarily on household and SME access to electricity using demand sided data collection techniques. Overall, the results are positive. Through the HAE multiple bottlenecks to access to modern electricity were identified. The HAE reviled that the 'reliability' of electricity place a significant role in household and SME decisions. Furthermore, when the HAE data is inserted into the GTF framework, the HAE does a relatively better job at gauging a household or SME's access to electricity along a continuum without overly relying on binary variables.

2.0 Literature Review

2.1 Existing Approaches to Measuring Access to Energy

Following the standard discourse of development literature, access to modern energy has significant links to reducing poverty and increasing overall socio-economic status of the world's poorest, particularly rural communities. However, measuring energy poverty and, therefore, access to modern energy has proved to be quite difficult. Two initial challenges emerge when attempting to measure access, the absence of a universal definitions of access, and the difficulty of measuring against any definition in a precise manner (ESMAP, n.d.). According to Wang et al. (2015), there are three units to measure access to modern energy, energy service availability, energy service quality, and satisfaction of energy demand for human's survival and development. Furthermore, the methods can range across four broad categories, single indicators, dashboards, composite indices, and multi-tier frameworks (Bhatia, & Angelou, 2015). Moving from binary indicators to multi-tier indices adds complexity while attempting to give a relatively more precise measurement of access.

Gathering reliable data is at the foundation of evaluating energy poverty (Wang et al., 2015). Data collection can be from the demand-side, household surveys, and interviews, or from the supply side, primarily through national utility data. The IEA uses supply side measurements, via a percentage of utility connections, which allows for larger quantities of data collection and analysis. However, public service data in developing countries is often scrutinized as unreliable, and the IEA's approach does not account for off-grid systems. The World Bank (2012) uses a demand side approach by using various household surveys. These surveys are subject to sampling errors and inconsistences, but a demand side approach provides better insight to the actually quality and quantity of access at the grassroots level. The following sections provide a brief overview of the different categories and associated measurements.

2.3.1 Single Indicators

Single indicators are the standard choice to measure access to electricity by a vast number of academics, international development agencies, and government organizations (UNDP, 2009; WEO, 2010; IEA, 2014; WHO 2016).These indicators are easy to interpret, and can be measured using existing surveys and household data. Single indicators use various minimum thresholds, such as per capita consumption or energy supply. However, these minimum thresholds, such as power consumption, are dependent on several external factors, such as household income and size, reliability, capacity, and energy efficiency, that single indicators fail to capture. Furthermore, single indicators are frequently technology specific (i.e. grid connection), and ignore off-grid systems and energy efficient appliances. Lastly, from a measuring and policy development view, single indicators are incapable of measuring improvement in access to lower tiers (Bhatia & Angelou, 2015)

Using the economic poverty line as inspiration, Barnes et al. (2011), developed a demand consumption approach called the energy poverty line. By determining the minimum level of energy consumption, below which consumption becomes insensitive to changes in household income, they were able to establish the minimum amount of energy consumption for a household, the Energy Poverty Line (Barnes et al., 2011). However, the authors did not account for cultural preferences, economic conditions, level of development, and access to coping solutions (Bhatia, M., & Angelou, N., 2015). Following the general fault of single indicators, the Energy Poverty Line failed to provide a method for contextualizing data for different regions and does not provide an approach to measure lower tier progress.

2.3.2 Dashboard of Indicators

Academics and NGOs recognized the failure of single indicators, and set out to develop a series of indicators aimed at giving a broader picture of a country or household's access to energy. A dashboard of indicators is composed of multiple single indicators designed to capture a variety of elements pertaining to access to energy. The Energy Indicators for Sustainable Develop (EISD) is a dashboard of indicators encompassing the social, economic, and environmental dimensions. It was developed by the International Atomic Energy (IAE) Agency and is divided into three dimensions, further classified into seven themes and 19 sub-themes (IAEA, 2005). The dashboard is fairly comprehensive. However, it is widely based on supply-side binary variables. Furthermore, it does not use any cause or effect to promote simplicity, thus, EISD's indicators much be carefully interpreted.

In 2009, the United Nations Development Programme (UNDP) and the World Health Organization (WHO) conducted a multiple country analysis directed at understanding energy access in developing countries. The report gathered and compiled existing country-level energy access from a supply side, and used binary indicators to relay on the information (i.e. percent of the population with a grid connection). However, dashboard indicators follow a similar fault to single indicators; they often fail to correctly measure dynamic issues associated with access and do not allow for progression among the lower tiers. In fact, the report recognizes that understanding what type of energy carriers and energy services are available, who uses them, how much they cost, and the benefits they provide to users, are factors to consider when assessing energy access (UNDP, 2009). While recognizing the complex issues surrounding access to energy, it does not lay out any frameworks to guide users to a precise form of measurement.

2.3.3 Composite Indices

Composite indices were developed to overcome the failures of indicators that use binary variables. These indices combine the simplicity of single indicators with the multi-dimensionality needed to measure access to energy accurately by aggregating a set of sub-indicators into a single metric (Bhatia, & Angelou, 2015). The indices aim to overcome shortfalls of both single indicators and dashboards by compiling several variables into a single metric that is easy to interpret. However, aggregation naturally leads to simplicity and indices may prove misleading unless correctly interpreted. To ensure that composite indices are portraying accurate data, it is important also to examine the sub-indicators.

Wang et al. (2015) attempt to construct an energy poverty comprehensive index as a basis to understand and identify energy poverty across China. Their comprehensive supply-side evaluation index was composed of 4 categories, energy service availability, energy consumption cleanliness, energy management completeness, and household energy affordability and energy efficiency. Accounting for over 20 variables across the categories the authors provide a broad view of different regional aspects of energy poverty within China. However, the authors fail to give a household perspective, and rely heavily on binary variables, thus, preventing any analysis for progression in the level of access across regions. Furthermore, their complex mathematical formula and data collection techniques inhibit the index from being carried out on an international scale.

One of the well-recognized composite indexes is the Multi-Dimensional Energy Poverty Index (MEPI). The MEPI, developed by Nussbaumen et al. (2012), is a demand-sided index that measures energy deprivation through the ownership of appliances. It is an adaption of the general Multi-Dimensional Poverty Index (MPI) and uses existing national household survey data (Jain et al., 2015). The index's goal is to measure deprivation to access to a range of modern energy services affecting individuals. It assumes that if a household owns a particular appliance than it has adequate access to the respective energy require and can use and pay for the energy services. However, this approach is flawed. It is quite common for appliances to be given as gifts, and small quantities of modern energy consumption do not constitute the household as having modern energy access (Jain et al., 2015). Furthermore, access can be disrupted by a high frequency of blackouts and power spikes. Composite indices are a welcome step forward from the traditional binary view. However, there are still significant faults that neglect fundamental aspects of energy poverty, such as aggregating results and lack of a tiered measurement.

2.3.4 Multi-Tiered Indices

More recently there has been a push by academics and international development agencies to design frameworks that capture the true complexity associated with access to electricity (Jain et al., 2015; Bhatia & Angelou, 2015; IEA, 2015). These frameworks are called Multi-tiered frameworks. Each framework and corresponding index attempts to determine intermediary stages of energy access, capturing the continuum of improvement that technologies provide (Bhatia & Angelou, 2015). Theoretically, by allowing for a range of tiers from no access to full access the multi-tiered indices can account for improvements in access to modern energy that single indicators and dashboards are unable too. Additionally, these metrics allow for a flexible definition of energy access as well as for country specific and project specific targets to be set and progress measured.

Some multi-tiered indices have been designed and carried out over the past decade. One of the first to suggest a multi-tiered approach was the UN Secretary General's Advisory Group on Energy and Climate Change (AGECC, 2010). The report's main indicator is energy usage measured in kilowatt hours (kWh) and is broken down into three levels of access. Level 1 is basic human needs and corresponds with household energy consumption between 50-100 kWh per year per person. Level 2 is defined as productive uses and is related to household energy consumption between 500-1,000 kWh per person per year. Lastly, level 3 is defined as modern society needs and is associated with modern energy services and multiple domestic appliances, 2,000+ kWh per person per year (AGECC, 2010). The report considers universal access as levels 1+2 (AGECC, 2010). However, the AGECC does not separate energy needs across various dimensions nor does it distinguish between households, economic institutions or public institutions. Second, it simplifies access to a simple indicator, kWh per person per year. By only accounting for a single indicator the report neglects to account for other external factors.

The Total Energy Access (TEA) and Energy Supply Index (ESI), developed by Practical Action Consulting (PAC), is comprised of nine parameters that define minimum standards of energy access (PAC, 2012). The TEA survey is made up of completely binary questions and does not account for various tiers of access. The TEA sets minimum standards of energy services to escape energy poverty and uses a 14 stage Yes/No questionnaire to gauge a household's access. Each household is scored on a 9-point scale and only scoring 9/9 constitutes as having total access to energy. See Appendix 'x' for the PAC survey. The scoring system is the biggest fault of the TEA framework. Despite being dimensionally extensive, the TEA's view on total access reduces their methodology to a binary framework. A household either scores a full 9/9 and has full access, or else, it is considered energy poor. The ESI is a multi-tier framework of energy access across three dimensions: household fuels, electricity, and mechanical power. Combining the ESI and the TEA it is possible to gauge access to energy, and how the supply of energy and the services it facilities are interlinked (Bhatia & Angelou, 2015). However, the TEA/ESI framework requires a significant amount of data to be collected which hinders it from being adopted on an international scale.

2.2 Moving Forward

Access to electricity is dynamic and complex. That is why it should be a priority to develop a methodology and framework that is capable of capturing the demand and supply-side deficits that can arise when gauging access to electricity. Ideally, the framework should measure to what extent energy access is a constraint to people's everyday lives, and should provide insight into how to improve access (Bhatia & Angelou, 2015; IEA, 2015; Jain et. al, 2015). Multi-tier methodologies emerge as the best approach to gauging a household, business, or public institutions access to modern energy. These frameworks allow for measuring access along a continuum and are designed to adjust to the various definitions of energy poverty. However, multi-tier frameworks require vast amounts of data and often need to be contextualized for each region. Resource constraints faced by NGOs and governments could deter the adaption of multi-tiered frameworks. Therefore, it is important to design a multi-tiered, multi-dimensional framework that strikes a balance between the cost-effectiveness and simplicity of single indicators and the accuracy and flexibility of multi-tier indices.

3.0 Methodology: Developing the Household Access to Electricity (HAE) Framework

3.1 Overview of the HEA Framework

The Household Access to Electricity (HAE) framework and the corresponding survey was developed to address the failures of current multi-tier frameworks and is intended to readdress how institutions measure access to electricity in rural communities. The survey is grounded off the multi-tier multi-dimension surveys used by the Global Tracking Framework, the World Bank, and Access to Clean Cooking Energy and Electricity (ACCESS). However, adjustments were made to address what are believed to be flaws in these frameworks, along with contextualizing the categories for rural East Africa. The framework is designed to transition from simple surveys that focus on binary measurements and outcomes to more comprehensive data collection methods while remaining cost-effective for resource-limited grass root organizations. By striking a balance between simplicity and thorough data collection, it is possible to increase the dissemination of multi-tiered frameworks, thus, overcoming a significant fault of the GTF, lack of data. The methods used in the framework encompasses the dynamics of access to electricity by using a tiered system to rank household access by using a variety of dimensions (Capacity, Duration, Reliability, Quality, Affordability). The framework scores participants across tiers ranging from 0-3, with zero being the lowest. Socio-economic and energy market sections are included to gain a better understanding of the community and potential demand for electricity.

3.2 HAE Dimensions

Each dimension examines the access of electricity from a particular viewpoint, determined by the strengths and flaws of previous multi-tiered frameworks. The framework pulls from Reddy's (2000) three types of thresholds, technological, physical, and economics. Technological thresholds include capacity and duration to determine how households are affected by the supply of electricity. Physical thresholds are composed of the reliability, and quality dimensions to examine the physical access to electricity for each household. The economic threshold gives insight into the affordability of electricity and its impact on household expenditures. There was also a section on technical skills and energy market, explores whether or not the community is in need of capacity training, and the ability and willingness to participate in a decentralized solar system program. While not directly associated with the HAE, it is important to gain an understanding of a participants' willingness to invest in off-grid systems as a proxy for a desire for electricity.

3.2.1 Capacity

A technological threshold, capacity is an indicator of the peak power drawn from the current source. Each tier corresponds to the type of appliances used if cost and reliability were not an issue. Capacity does not measure if participants own the appliance, but rather if it is possible to run them safely. The capacity tier is a divergence from the TEA's view that ownership implies capacity. The original GTF scores capacity across six tiers and three attributes, however, following the approach used in the ACCESS framework (2015), it is believed that four tiers are appropriate is gauging capacity. Tier 0 represents zero capacity to use any electrical appliance. Tier 1 captures small appliances less than 50W, such as pico-lights and phone chargers. Tier 2 corresponds with tier 1 plus basic entertainment devices, such as TVs and Laptops. Lastly, tier 3 represents the capacity to power medium to heavy load appliances, 500W and above.

3.2.2 Duration

A technological threshold, the duration is an indicator for limitations to using due to daily access. The lowest tier corresponds with less than 4 hours a day of continuous electricity, and the highest tier is 20 hours plus. Furthermore, it is important to examine the available hours of electricity/lighting during the evening. To account for nighttime access, the HAE uses zero access as tier 0. Households with 2 hours or less of electricity per night score under tier 1 and participants between 3 and five were considered tier 2. Finally, households with 6 hours or more of continuous electricity per night are given the top rank, tier 3.

3.2.3 Reliability

A physical threshold, reliability examines the frequency of full day blackouts. While periodic temporary blackouts are inconvenient, they are not counted because they are common in developing countries, particularly East Africa. Therefore, it is important to explore how unpredictable, full day blackouts may deter investment into beneficial electrical appliances. For example, if there is a high frequency of full-day blackouts, is a participant less likely invest in technology, such as Radio/TV? According to current methods, a household would is counted as having access, regardless of the frequency of blackouts. However, if the reliability of electricity has a direct effect on household decisions regarding electric power, then a household does not fully experience the perceived benefits associated with access to modern electricity (i.e. improved access to information technology). Therefore, participants were asked to estimate the number of full-day blackout per month and discuss how this may or may not have altered investment decisions. Tier 0 represents participants with an average of 5 or more random full-day blackouts a month. Tier 1 corresponds with 2-4 full day blackouts. Tier 2 experience one day a month, and tier 3 experience 0 full day blackouts per month.

3.2.4 Quality

A physical threshold, Quality uses unstable voltage deviations as a proxy for assessing the quality of electricity. The primary form of measurement is spikes or troughs in voltage. Quality is one of the most difficult aspects to measure. Due to a lack of proper voltage measuring techniques, participants were asked to estimate the number of appliances that have been damaged by surges or did not properly function due to low voltage. Similar to reliability, low quality of voltage, either through spikes or troughs, may also alter investment decisions, thus, the benefits of access. There is a difference between an appliance being damaged through a voltage spike and an appliance being unusable due to low voltage. Therefore, voltage spikes and voltage troughs were separated in the framework but follow the same ranking methodology. Tier 0 corresponds with 4 of more appliances damaged or unusable due to voltage issues. Tier 1 represents 2-3 appliances damaged or unusable due to voltage. Tier 2 correspond with one appliance, and Tier 3 households or SMEs have 0 appliances affected by voltage issues.

3.2.5 Affordability

Examining percentage of monthly income spent on electricity was the primary proxy for determining affordability. It is hard to examine the percentage at which electricity becomes unaffordable. In the United Kingdom, the affordability threshold is a monthly expenditure of 10%. However, due to energy stacking and informal markets calculating overall energy expenditure, as a percentage of income, is quite complicated in developing countries. Each household was asked to provide a monthly income and energy expenditures, both electrical and alternate energy sources, which is used to calculate the percentage of revenue spent on electricity. There is an obvious gap in the literature, and there needs to be a further exploration into energy expenditure in for rural regions in developing countries. The HAE ranks households whom percentage of income dedicated to electricity expenditure exceeding 15% as tier 0. Participants with an electricity expenditure of 10-14.9% are associated with tier 1 and is still considered unaffordable. Tier 2 corresponds with an electrical expenditure between 5 and 9.9%, and Tier 3 households or SMEs spend less than 5% of their monthly income on electricity.

Table 1 Household Access to Electricity Framework

Tier / Dimension	Tier 0	Tier 1	Tier 2	Tier 3
Capacity	No electricity	Lighting + Basic communication/entertainment (Radio/Mobile)	Lighting + AC + Entertainment/Communication (TV/Computer)	Tier 2 + Medium to Heavy loads
Duration	<4hrs	>= 4hr and <8hrs	>= 8hrs and <20hrs	20+ Hours
Night Access	No Access	Less than 2 hours	3-5 hours per night	6+ hours
Reliability	5 + days	2-4 days	1 day	0
Appliances damaged by Surges	>3	2-3	1	0
Voltage Troughs	>3	2-3	1	0
Electrical Expenditure	>15%	10-14.9%	5%-9.9%	<5%

3.3 Survey Design and Sampling Methods

A demand-side survey consisting of 27 questions was designed to mimic the various dimensions and tiers needed to determine access to modern and reliable electricity. The initial sample size consisted of 227 surveys plus 15 interviews. However, it was discovered some issues could corrupt the data. The first issue was copying of answers between participants, primarily in the Moita region. Due to communication barriers, such as illiteracy and participants whom only spoke the traditional Maasai language, there were was a need to have groups take the survey simultaneously. As a result, a couple of groups were merely copying answers from their neighbors, an example of sampling error. This sampling error reduces the number of observations from 198 to 157. Furthermore, due to cultural taboos surrounding the discussion of household finances within Maasai community, and other cultural barriers not every survey was 100% complete. While the HAE survey is intended to be completed fully, an incomplete survey still provides ample data on various subcategories. Therefore, surveys that scored on 4 or more dimensions are still included in the results. Bringing the final sample size to 128 observations, plus 15 interviews. The number of questions in the survey is considered both a strength and a limitation.

4.0 Results

4.1 Applying the HAE Framework

Examining the data provides some insight into what the energy situation looks like in the two rural areas, Moita and Bugisi. The data suggest that national grids, if available, are more likely to be located near major economic institutions, such as schools or clinics, however, participants located away from main roads and public institutions are far less likely be connected to the grid. Additionally, a participants occupation has influence on whether or not they have access to some form of electricity. Business owners are far more likely to have access to electricity than agri-pastoralist. More importantly, reliability (i.e. Number of full-day blackouts a month) was often seen as the primary issue faced by the majority of those with access to electricity. Table 4 provides the percentages for each area for the corresponding category and tier

4.2.1 Technological Thresholds

The capacity tier has 43% of households falling under tier 0, indicating zero capacity to power electrical appliances. An additional 50% fall under capacity tier 1, ability power basic electronics, less than 50W. Bugisi differs significantly from Moita in respects to tier 1, indicating that higher there are more households in Bugisi with the capacity to use basic appliances. However, Moita seems to have a significant amount of respondents with access to the third tier, 500+ watts. Tier 3 capacity is explained by the location of the shops. (i.e. close to the secondary school)

There are no significant differences between the regions in the duration category. Approximately 50% of the population has less than 4 hours of electricity a day, and the remaining 50% fairly evenly distributed across the other tiers. It appears that having the capacity to power electrical appliances does not transition over to continuous power throughout the day. One explanation could be the use of off-grid systems. Energy storage constants can inhibit households and SMEs from having continuous access. Concerning nighttime access, close to 60% of households and SMEs do not have access to electricity in the evening. Nighttime access follows a more binary distribution. Participants either have access to electricity throughout the night, 6 or more hours, or, they have zero access to electricity at night. Those with access during the daytime continue to have access at night, with only a small percentage of those with daytime access not having ample nighttime access.

Table 2 Percentage of Households and SMEs per Tier

Dimension	Tier level	Moita	Bugisi	Overall
Capacity	Tier 0	51.28%	39.29%	43.09%
	Tier 1	25.64%	50%	42.28%
	Tier 2	10.26%	9.52%	9.76%
	Tier 3	12.82	1.19%	4.88%
Duration	Tier 0	54.05%	48.57%	50.47%
	Tier 1	10.81%	5.71%	7.48%
	Tier 2	16.22%	20.00%	18.69%
	Tier 3	18.92%	25.71%	23.36%
Night-Time Lighting Access	Tier 0	60.61%	57.35%	59.42%
	Tier 1	0.00%	1.47%	1%
	Tier 2	0.00%	5.88%	3.96%
	Tier 3	39.39%	35.29%	36.63%
Reliability of Electricity	Tier 0	84.62%	77.11%	79.51%
	Tier 1	2.56%	13.25%	9.83%
	Tier 2	0.00%	1.20%	0.82%
	Tier 3	12.82%	8.43%	9.84%
Appliances Damaged by Surges	Tier 0	14.29%	6.98%	8.77%
	Tier 1	57.14%	13.95%	24.56%
	Tier 2	0.00%	16.28%	12.28%
	Tier 3	28.57%	62.79%	54.39%
Appliances unusable due to low voltage	Tier 0	0.00%	4.44%	3.39%
	Tier 1	42.86%	4.44%	13.56%
	Tier 2	0.00%	6.67%	5.08%
	Tier 3	57.14%	84.44%	77.97%
Electricity Expenditure*	Tier 0	N/A	19.35%	19.35%
	Tier 1	N/A	6.45%	6.45%
	Tier 2	N/A	16.13%	16.13%
	Tier 3	N/A	58.06%	58.06%

4.2.2 Physical Thresholds

For both regions, the quality of electricity is scored very low. The most striking outcome, although not entirely surprising, is the reliability tier. In both regions over 75% of people surveyed experience 5 or more full-day blackouts per month. Rolling blackouts are fairly common across the global south, however, interviews within the communities give in-sight into how lack of reliably access truly prohibits people from benefiting from having access to electricity. Both businesses and households mentioned that they were reluctant to invest in appliances, because the electricity is “Unpredictable”. This reinforces the notion that reliability should be taken seriously when determining access to modern energy.

A rather unexpected outcome was the voltage dimensions. Both the number of appliances damaged and/or unusable due to voltage issues was relatively higher than expected. According to the data there is a 37% chance that if you have access one or more appliances has been damaged to due voltage surges, and an 19% chance an appliance would be unusable due to low voltage. In total, 58 appliances had been damaged and 35 unusable. The potential impact of both low reliability and voltage scores is explored in the discussion section.

4.2.3 Economic Thresholds

The income category for Moita area was near impossible to gather with confidence. In the future the HAE framework needs to be re-designed for communities that are primary Subsistence agriculture/pastoralist communities. There needs to be a method to understand how much income or household wealth is spent on energy without relying directly on monetary measurements. Only six people in Moita were ranked in the Electricity Expenditure category, however, it is not enough to make any suggestions about the overall population. Analyzing the data for Bugisi indicates that those with access do not have an electrical expenditure that exceeds 15% of their income. However, this does not account for energy stacking, which when added to current electrical expenditure could push overall energy expenditure over the 15% thresholds. Additionally, over 40% of people still spend a sizeable portion of their income on electricity.

Overall, there is an interesting take-a-way from applying the data to the HAE framework. Through the weighted HAE index there are zero households or SMEs who score a perfect 3, indicating full-access to reliable modern electricity. A score that would likely be achieved by the vast majority of households in developed countries. Furthermore, the framework indicates the the Bugisi Region has statistically significant higher overall access to electricity than Moita, 1.13 versus .86.

Table 3 HAE Scores

Category	**Moita**	**Bugisi**	**Overall**	**Difference (Moita – Bugisi)**
Average Capacity Tier	0.85	0.73	.76	0.11
Average Duration Tier	1.00	1.23	1.15	-.23
Average Night Access Tier	1.18	1.19	1.18	-.01
Average Reliability Tier	0.41	0.41	0.41	0.00
Average Surge Tier	1.43	2.35	2.12	-0.92***
Average Short Tier	2.14	2.71	2.58	-0.57**
Average Expenditure Tier	N/A	1.86	1.86	N/A
Average Weighted HAE	**.86**	**1.13**	**1.05**	**-.28***

5.0 Discussion

5.1 Traditional Measurement v. HAE Framework

This paper has devoted a vast amount of effort towards developing the HAE framework and its corresponding survey and index, however, it is important to compare the HAE to other methods, particularly traditional measurements and multi-tiered frameworks, such as the Global Tracking Framework (GTF). As mentioned earlier, traditional measurements use binary variables, i.e. 'Yes' or 'No', to determine the percentage of a population with access to electricity, and multi-tired frameworks use various thresholds to determine the level of which a person has access to modern electricity.

The World Bank and SE4All use traditional methods to estimate that overall electrification rate in Tanzania is 15.3% and the African Development Bank concludes that rural electrification rate in Tanzania hovers around 11% (AFDB, 2015). Using a simple grid connection variable, the data gathered for this paper would suggest that 43.55% of households have access to electricity through the national grid, with the majority of people with a connection living close to a public institution, such as a clinic or school. Observing from a tech-neutral tech-neutral measurement, whether the household or SME has an electrical capacity above 0W, the percentage of the population with electricity increases to 58%. As off-grid systems begin to be adopted in rural communities, Tech-neutral measurements will become increasingly common for measuring technical thresholds, such as the type of connection. Current data and mapping do not account for clustering, and, forward-looking policies are placing a higher emphasis on non-grid connections (Tenenbaum et al., 2014).

Moreover, if a traditional measurement is used in determining access in Moita or Bugisi both areas would have 40% higher access levels than the national average. However, pulling from Reddy's (2000) definition of energy poverty, having minimal access does not constitute as access to modern and reliable electricity. To transition a person from energy poor to having sufficient access to modern energy, it must provide access to energy services that support economic and human livelihood development (Reddy, 2000). Observing other dimensions of energy poverty that have been argued thus far in this paper, a traditional measurement would vastly overestimate access to reliable modern energy. A relatively high number of households do have access to electricity through a simple off-grid simple or grid connection, however, as the HAE shows these connections provide low capacity levels which are vastly unreliable and relatively expensive. A dimension receives an HAE score of 3.0 only if it is comparable to the same quality of service received in developed countries. The highest HAE score is a 2.55 with the overall average at 1.05. Thus, it can be argued that a traditional measurement would have vastly overestimated the actual level of access to reliable modern electricity in both regions, and by using the HAE framework policy makers and NGOs would have a better understanding of the needs within the areas.

5.2 Global Tracking Framework v. HAE Framework

As mentioned earlier, the GTF was developed in 2013 by the IEA and World Bank as part of the SE4All initiative as an innovative framework to measure access to energy. The GTF report 2015 states that a lack of available data is the most significant obstacle to overcome, and until there is an increase in the required data, the GTF still uses binary measurements for access (IEA, 2015). While not all the data collected for the HAE can be directly applied to the GTF, it is possible to observe varying strengths and weaknesses across two frameworks.

The GTF measures access to energy through a series of five multi-tier, multi-dimensional matrices. The matrices about access to electricity are the Access to Household Electricity Supply

Matrix, the Access to Household Electricity Services Matrix, and the Electricity Consumption Matrix (IEA, 2015). The later two can hardly be considered multi-dimensional matrices as the only have 1 to 2 attributes in each. The supply matrix, shown in figure 4, is made up of 7 attributes and has five tiers. However, 4 of the dimensions are binary. Therefore, even if data were readily available for fully analyze access to modern electricity, half of the Access to Households Supply Matrix, the largest of the GTF, would be reduced to binary thresholds.

Applying the data collected to GTF allows for 7 of the 12 attributes to be analyzed from a GTF perspective. The attributes unable to be analyzed: Daily capacity (Wh per day), CR Services, Legality, Health and Safety, Annual Consumption levels (kWh per year). Attributes pertaining to direct measurement of the supply or consumption of electricity, through Wh, was not feasible due to lack of proper voltage tools. Furthermore, as mentioned early the HAE is designed to observe the electricity demand from a household perspective and less from national utility data, which is often unreliable. The Legality, and Health and Safety attributes were left out of the HAE survey. Similar to the push for tech-neutral thresholds, the HAE does not discount a household based on the legality of the connection. From an HAE perspective, a connection is a connection. However, it should be noted the HAE does not promote illegal connections, as it damages the local economy and places households in unwarranted risk. Health and Safety are important questions to ask participants, however, when designing the HAE it was determined that they do not fit into the overall objective of the HAE's view on access to modern and reliable electricity. The next sections take the data collected for the HAE and attempts to directly apply it to the GTF as presented in the 2015 report.

Figure 1 GTF Access to Electricity Supply Matrix; Source: GTF Report 2015 pg. 193

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Peak capacity	Power		Very low power, minimum 3 watts	Low power, minimum 50 watts	Medium power, minimum 200 watts	High power, minimum 800 watts	Very high power, minimum 2 kilowatts
	and Daily capacity		Minimum 12 watt-hours	Minimum 200 watt-hours	Minimum 1.0 kilowatt-hours	Minimum 3.4 kilowatt-hours	Minimum 8.2 kilowatt-hours
	or Services		Lighting of 1,000 lumen-hours per day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Minimum 4 hours	Minimum 4 hours	Minimum 8 hours	Minimum 16 hours	Minimum 23 hours
	Hours per evening		Minimum 1 hour	Minimum 2 hours	Minimum 3 hours	Minimum 4 hours	Minimum 4 hours
4. Affordability					Cost of a standard consumption package of 365 kilowatt-hours per annum is less than 5 percent of household income		
3. Reliability						Maximum 14 disruptions per week	Maximum 3 disruptions per week of total duration less than 2 hours
5. Legality						Bill is paid to the utility/prepaid card seller/authorized representative	
6. Health and safety						Absence of past accidents/ no perception of high risk in the future	
7. Quality						Voltage problems do not affect use of desired appliances	

Table 4 GTF: Capacity

Dimension	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	42.40%	0.00%	43.20%	9.60%	0.00%	4.80%
Power (By types of Appliances)	42.40%	0.00%	43.20%	9.76%	0.00%	4.88%

Table 5 HAE Framework: Capacity

Dimension	Tier 0	*Tier 1*	Tier 2	Tier 3
Capacity	43.09%	42.28%	9.76%	4.88%

Table 6 GTF: Duration

Dimension	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Hours of continuous electricity	50.47%	0.00%	7.48%	15.89%	6.54%	19.63%
Night Time Access	58.42%	0.00%	1.00%	1.00%	1.98%	37.62%

Table 7 HAE Framework: Duration

Dimension	Tier 0	Tier 1	Tier 2	Tier 3
Hours of Continuous electricity	50.47%	7.48%	18.69%	23.36%
Night Time Access	58.42%	1.00%	3.96%	36.63%

Table 8 GTF: Reliability

Dimension	Tier 0	Tier 4	Tier 5
Disruptions per week	89.34%	0.82%	9.84%

Table 9 HAE Framework: Reliability

Dimension	Tier 0	Tier 1	Tier 2	Tier 3
Full-blackouts per month	79.51%	9.84%	0.82%	9.82%

Table 10 GTF: Quality

Dimension	Tier 0	Tier 5
Appliances unusable due to voltage	27.03%	72.97%

Table 11 HAE Framework: Quality

Dimension	Tier 0	Tier 1	Tier 2	Tier 3
Appliances damaged by voltage spikes	8.77%	24.56%	12.28%	54.39%
Appliances unusable due to low voltage	3.39%	13.56%	5.08%	77.97%

Table 12 GTF: Affordability

Dimension	Tier 0	Tier 5
Affordability	51.35%	48.65%

Table 13 HAE Framework: Affordability

Dimension	Tier 0	Tier 1	Tier 2	Tier 3
Affordability	24.32%	13.51%	13.51%	48.65%

5.3 Using the HAE Framework for Access to Electricity Policies

The HAE address multiple faults associated with traditional measurements and current multi-tired measurements, such as the GTF. Furthermore, through the application of the HAE framework, it is possible to gain a clearer understanding of the various issues that prohibit access to conductive energy services. Thus, allowing for a better understanding of the number of households and SMEs without access to modern and reliable electricity, and which issues ought to be targeted by policy intervention. The duration tier, 1.16, indicates that the hours of available electricity throughout the day is relatively low. While there wasn't an in-depth exploration into how this may deter investment at the household or business level, it presents strong evidence that this aspect of access should be a priority in rural communities. It is argued that due to the revenue of off-grid system, yet, low energy storage capability could have a significant impact on electricity the duration tier. There is a strong positive correlation between having the capacity to basic electricity, night-time access, and duration. Suggesting, it is possible that when households and SMEs have access, they will continuously use electricity, and do not ration (See Table 16).

Table 14 Correlation among Electricity Supply Dimensions

Correlation	Duration Tier	Night-Time Access Tier	Capacity Tier
Duration Tier	1.00		
Night-Time Access Tier	.8887***	1.00	
Capacity Tier	.6879***	.7967***	1.00

The surge and shortage tiers are ranked among the highest in the framework. This suggests that the supply of electricity, regarding voltage peaks and troughs, is relatively stable. However, the results give a clear indication that electricity supply is one of the biggest challenges throughout the region. The reliability tier is by far the lowest tier with and an average score of .4. Unreliable access is reinforced by interviews with locals who stressed how unpredictable the blackouts could be. The reliability of electricity is primarily the responsibility of the utility company. Therefore, interventions focusing on the reliability of electricity, particularly the high frequency of full-day blackouts, will require a more top-down approach, starting with improving transmission lines and transformers.

Regarding technical thresholds, the capacity tier was ranked the second lowest tier, .77. There is clear indication that a barrier to increasing access beyond the core capacity of 50W exists. There are two possibilities for this, a lack of knowledge of the benefits of electricity or a lack of financial services available to rural communities. Data collected, along with literature on the topic, suggest that a lack of financial services is relatively more prohibitive to gaining access than a lack of knowledge (Greenmax, 2010). The correlation between the capacity tier and income, .17, gives an indication that there could be a link. During interviews with local business owners, there was a strong emphasis on the types of appliances owners would invest in if they had full access to electricity, such as light bulbs to stay open later or an electric trimmer for their barber shop. Revealing that people have an understanding of the benefits associated with access; however, there are still low rates of adoption for off-grid systems. A recent report sponsored by the Power Africa Initiative uncovered that a lack of financial services was the primary reason for slow dissemination rates of off-grid systems within rural communities (Greenmax, 2010). Therefore, governments and key stakeholders should adopt policies that promote the growth of financial services for off-grid systems and electrical appliance, whether for pico-lighting or full solar household systems. Providing rural communities with financial vehicles to invest in access to modern electricity could prove to be a faster and more cost-effective rate than expanding national grids (Tenenbaum et al., 2014). Furthermore, increases in the adoption of off-grid technology by rural communities could slow the rate of urbanization, allowing governments to develop more sustainable cities.

6.0 Conclusion

The growing emphasis on the providing the 1.2 billion people without electricity means that there needs to be a better method for measuring access. The socio-economic benefits associated with increased access to energy are interconnected and complex. Therefore, no longer can international development agencies and governments use traditional methods. Energy poverty is complicated and involves multiple factors, and, thus, a framework needs to be developed to address the multidimensional issues of access to modern energy. The HAE framework is a novel attempt at developing a multi-tiered, multi-dimensional framework that strikes a balance between the complexity needed for precisely measuring access to reliable modern electricity while ensuring that it addresses the key issues and is simple enough to be carried out on an international scale by multiple agencies.

The HAE proved that tradition measurements, percent of people with access a national grid, can vastly overestimate a household's true level of access. Furthermore, one of the most prominent multi-tiered frameworks, GTF, fails to move past binary variables. One-third of the attributes relies on a single minimum threshold, and some other attributes are designed with the majority of households falling into 1 of 2 tiers, thus, indirectly binary thresholds. The GTF needs to improve on its ability to measure across a fluid continuum. The HAE overcomes the GTFs binary faults and proves that it can capture households access to modern and reliable energy across each of its tiers and dimensions. The HAE demonstrated the importance of reliability of electricity. Full-day blackouts that are both frequent and unpredictable deter households to investing in electrical appliances that are typically closely associated with the perceived benefits of electricity, such as fridges and TVs. By disaggregating a variety of dimensions related to access to electricity, the HAE framework can provide useful insight for policy makers.

Moving forward, the framework needs to work on adjusting its view on minimum income thresholds and account for traditional rural livelihoods, such as agri-pastoralism. Additionally, there needs to be a further exploration of other aspects of access that may not be accounted for within the HAE framework, such as payment methods. Furthermore, access to modern and reliable electricity is just one aspect of access to modern energy. Unlike the GTF and ACCESS framework, the HAE does not focus on access to clean cooking fuel. Both access to electricity and clean cooking fuel are vital to pulling people out of energy poverty.

Works Cited

International Energy Agency (IEA) and the World Bank. 2015. “Sustainable Energy for All 2015—Progress Toward Sustainable Energy” (June), World Bank, Washington, DC. Doi: 10.1596/978-1-4648-0690-2 License: Creative Commons Attribution CC BY 3.0 IGO

Tanzania | Economic Indicators. (n.d.). Retrieved December 11, 2015, from http://www.tradingeconomics.com/tanzania/indicators

Bernardos, Ana; Gaston, Martin; Fernandez-Peruchena, Carlos; Ramirez, Lourdes; Vindel, Jose Maria; Pasturino Amarillo, Luis Martin; Bermejo, Diego; Liria, Juan. 2015. Solar resource mapping in Tanzania: solar modeling report. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/2015/06/24576961/solar-resource-mapping-tanzania-solar-modelling-report

Tenenbaum, Bernard; Greacen, Chris; Siyambalapitiya, Tilak; Knuckles, James. 2014. From the Bottom Up : How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/16571 License: CC BY 3.0 IGO.

Torero, M. (2014). The Impact of Rural Electrification: Challenges and Ways Forward.

Renewables. (n.d.). Retrieved December 9, 2015, from http://www.iea.org/topics/renewables/

Peter Alstone; Dimitry Gershenson; NickTurman-Bryant; Daniel M. Kammen; Arne Jacobson. 2015 Off-Grid Power and Connectivity: Pay-As-You-Go Financing and Digital Supply Chains for Pico-Solar. Berkley, California: Lighting Global .https://www.lightingglobal.org/wpcontent/uploads/2015/05/Off_Grid_Power_and_Connectivity_PAYG_May_2015.pdf

Wang, K., Wang, Y., Li, K., & Wei, Y. (2015). Energy poverty in China: An index based comprehensive evaluation. *Renewable And Sustainable Energy Reviews*, *47*308-323. doi:10.1016/j.rser.2015.03.041

Nussbaumer, P., Bazilian, M., & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. *Renewable And Sustainable Energy Reviews*, *16*231-243. doi:10.1016/j.rser.2011.07.150

Pachauri, S., & Spreng, D. (2011). Measuring and monitoring energy poverty. *Energy Policy*, *39*(Clean Cooking Fuels and Technologies in Developing Economies), 7497-7504. doi:10.1016/j.enpol.2011.07.008

Ramde, E. W., Nussbaumer, P., & Bazilian, M. (2015). Measuring and reporting on energy poverty: insights from West African countries. *African Journal Of Science, Technology, Innovation & Development*, *7*(6), 509. doi:10.1080/20421338.2015.1094238

González-Eguino, M. (2015). Energy poverty: An overview. *Renewable And Sustainable Energy Reviews*, *47*377-385. doi:10.1016/j.rser.2015.03.013

Groh, S., Pachauri, S., & Narasimha, R. (2016). What are we measuring? An empirical analysis of household electricity access metrics in rural Bangladesh. *Energy For Sustainable Development*, *30*21-31. doi:10.1016/j.esd.2015.10.007

Pfaff, J. C. (2016). Energy poverty. *Salem Press Encyclopedia*

Auerbach, M. P. (2015). Poverty Line. *Research Starters: Sociology (Online Edition)*

Barnes, D. F., Khandker, S. R., & Samad, H. A. (2011). Energy poverty in rural Bangladesh. *Energy Policy*, *39*(Special Section on Offshore wind power planning, economics and environment), 894-904. doi:10.1016/j.enpol.2010.11.014

AGECC (The UN Secretary-General's Advisory Group on Energy and Climate Change). Energy for a sustainable future. New York: AGECC; 2010.

Pachauri S, Spreng D. Energy use and energy access in relation to poverty. Econ Polit Wkly 2004;39(3):17–23.

Costantini V, Monni S. Environment, human development and economic growth. Ecol Econ 2008;64(4):867–80.

Reddy, A. Energy and social issues. In: World Energy Council and UNEP, editors. Energy and the challenge of sustainability. New York, NY; 2000.

Sachs, Jeffrey, 2005. The End of Poverty: Economic Possibilities for Our Times. Penguin Press, New York.

The World Bank, World Development Indicators (2012). Access to electricity (% of population) Data file]. Retrieved from http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2012&locations=TZ&start=2012&view=bar&year=2012

African Development Bank Group. (2015). *Renewable Energy in Africa: Tanzania Country Profile*. In F. Richard, G. Gualberti, U. Goswami, A. Cabraal, A. Wubeshet-Zegeye, M. Nkando, & . (Eds.). Abidjan, Côte D'Ivoire: Author. Retrieved from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf

Bhatia, M., & Angelou, N. (2015, July). *Beyond connections: Energy access redefined* (Rep. No. 008/15). Retrieved April, 2016, from Energy Sector Management Assistance Program website: https://openknowledge.worldbank.org/bitstream/handle/10986/24368/Beyond0connect0d000technical0report.pdf?sequence=1&isAllowed=y

International Energy Agency (IEA) and the World Bank. 2015. "Sustainable Energy for All 2015—Progress Toward Sustainable Energy" (June), World Bank, Washington, DC. Doi: 10.1596/978-1-4648 -0690-2 License: Creative Commons Attribution CC BY 3.0 IGO

IEA. *Energy Poverty: How to make modern energy access universal* (Rep.). (2010, September). Retrieved https://www.iea.org/publications/freepublications/publication/weo-2010---special-report---how-to-make-modern-energy-access-universal.html

IEA. Renewables. (n.d.). Retrieved December 9, 2015, from http://www.iea.org/topics/renewables/

IEA. (2014). *Africa energy outlook* (Rep.). Retrieved https://www.iea.org/publications/freepublications/publication/WEO2014_AfricaEnergyOutlook.pdf

Greenmax Capital Advisors. (2013, December). *Tanzania market intelligence*(Rep.). Retrieved https://www.lightingafrica.org/wp-content/uploads/2013/12/TMI_May_Final_Approved.pdf

WHO (World Health Organization). Household air pollution. Retrieved February, 2016, from http://www.who.int/indoorair/en/

WHO. (2016). *Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children* (Publication). Retrieved http://www.who.int/indoorair/publications/burning-opportunities/en/

Banerjee, A. V., & Duflo, E. (2011). *Poor economics: A radical rethinking of the way to fight global poverty*. New York: PublicAffairs.

UN (United Nations). (2015, September). Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/?menu=1300

Practical Action. (2012). Poor People's Energy Outlook - 2012. Warwickshire: Practical Action

Jain, A., Ray, S., Ganesan, K., Cheng, C., & Urpelainen, J. (2015, September).*Access to Clean Cooking Energy and Electricity* (Rep.). Retrieved http://ceew.in/pdf/CEEW-ACCESS-Report-29Sep15.pdf

ESMAP (Energy Sector Management Assistance Program). (n.d.). Retrieved April 21, 2016, from http://www.esmap.org/

IAEA (International Atomic Energy Agency). (2005). *Energy indicators for sustainable development : Guidelines and methodologies* (Publication No. 05–00389). Vienna. doi:92–0–116204–9

Salmon, C., & Tanguy, J. (2016). Rural Electrification and Household Labor Supply: Evidence from Nigeria. *World Development*,*82*48-68. doi:10.1016/j.worlddev.2016.01.016

Legros, G., Havet, I., Bruce, N., & Bonjour, S. (2009, November). *The energy access situation in developing countries* (Rep.). Retrieved http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/energy-access-situation-in-developing-countries.pdf

Boardman B. Liberalization and fuel poverty. UK: Oxford University Press; 2010.

Renewable Energy Training Program | ESMAP. (n.d.). Retireved from https://www,esmap.org/node/1354