A Planning Paradigm for Electrification in Sub-Saharan Africa: A Case Study of Tanzania

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ABSTRACT |

In Sub-Saharan Africa, a lack of clean electricity generation sources, poor electricity access and low levels of electricity consumption are profoundly stifling sustainable development. This thesis presents a specialized investigation, in context of Tanzania, of the primary paradigmatic approaches to electrification – centralized, large-scale grid systems conceived through least-cost-planning; and decentralized, small-scale off-grid systems administered through entrepreneurial pilots.

My thesis offers a new paradigm, a *mid-scale opportunistic and pluralistic planning paradigm,* to address the dynamic economic, social, environmental and political issues that have constrained the efficacy of the extant approaches to electrification. The paradigm draws upon my investigative understanding of the critical *theoretical* threads that inform the complex fabric of electricity sector development – energy economics, social science, conceptualized and technical planning, and climate change theories. Additionally, the mid-scale opportunistic and pluralistic planning paradigm weaves in my *practical* understanding of the various resources that are currently available and can be leveraged to advance electrification, particularly for communities within isolated rural regions. Using Tanzania as a case study, the paradigm proposes a new way to think about and actualize a sustainable development path towards electrification in Sub-Saharan African countries that are experiencing rapid changes in macro and micro-economies, population demography and migration, and signs of climate change.

Thesis Supervisor: Dr. Gabriella Carolini
Title: Assistant Professor

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Finally, I am blessed to have tremendous support from my family. I am particularly grateful to my parents, whose love, laughter and wisdom are grounding forces in my life.

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ACROYNMS

bcf	billion cubic feet
CO2	Carbon Dioxide
DSM	Demand-side Management
EDI	Energy Development Index
EWURA	Energy and Water Utilities Regulatory Authority
FDI	Foreign Direct Investment
FIT	Feed-in-tariff
GDP	Gross Domestic Product
GHGs	Green-house Gases
GOT	Government of the United Republic of Tanzania
GWh	Gigawatt-hours = 1,000,000,000 watt-hours
HDI	Human Development Index
IEA	International Energy Agency
IFI	International Financing Institution
IPD	Initiative for Policy Dialogue, Columbia University
IPP	Independent Power Producer
km	Kilometers
kWh	Kilowatt-hours = 1,000 watt-hours
LCP	Least Cost Planning
MEM	Ministry of Energy and Minerals
MGDs	Millennium Development Goals
MW	Megawatt = 1000,000 watts
MWh	Megawatt-hours = 1,000,000 watt-hours
MWp	Mega-watt peak
NGO	Non-Governmental Organization
NSGRP	National Strategy for Growth and Reduction of Poverty
OECD	The Organization for Economic Co-operation and Development
PSMP-13	Power System Master Plan (2013)
R&D	Research and Development
RE	Renewable Energy
REA	Rural Energy Agency

REF	Renewable Energy Fund
Rio+20	United Nations Conference on Sustainable Development (2012)
SDGs	Sustainable Development Goals
SOE	State Owned Enterprise
SPP	Small Power Producer
SPPA	Standardized Power Purchase Agreement
SSA	Sub-Saharan Africa
SSPJ	Small Power Project
TANESCO	Tanzania Electric Supply Company Limited
tcf	trillion cubic feet
TEDAP	Tanzania Energy Development and Access Project
TZ	United Republic of Tanzania
UK	United Kingdom
UN	United Nations
US	United States of America
USD	United States Dollar

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INTRODUCTION

Globally, the state of electricity access in developing countries is astonishing as billions of people, mainly in Sub-Saharan Africa, live without reliable, high quality and clean sources of electricity (see Figure 1, population without electricity by region). Through an investigation of extant approaches to electrification in low-income Sub-Saharan African countries, specifically centralized large-scale, big investment practices based on least-cost-planning and conversely decentralized small-scale off-grid ad-hoc approaches[1], my findings, based on history, empirical and anecdotal evidence, are that there are critical systemic shortcomings to both paradigms, particularly with respect to catalyzing generation, access and consumption in low-income communities within isolated rural regions.[2]

Furthermore, in context of Tanzania's need for power in isolated rural regions in the short-term (2013-2017) my findings include the following: (i) there is a need for a localized public-private entity that works with power producers to streamline processes, provide access to various types of financing, and engender local ownership in power projects; (ii) until institutional capacity constraints within the government are resolved the best opportunity to sustainably increase generation and access is through renewable energy small power producers; (iii) policy makers can help increase the sustainability of small power producers by creating parallel policies and programs that decrease connection fees, increase consumption and allow small power producers to increase generation capacity beyond the 10MW limit and remain eligible to receive financial and regulatory benefits; and (iv) the scalability of renewable energy small power projects is fortified by demand-side management programs and renewable energy vocational training programs for local community members. Ultimately, my thesis contends that to address the present-day shortage of electricity supply and lack of electricity access in low-income Sub-Saharan

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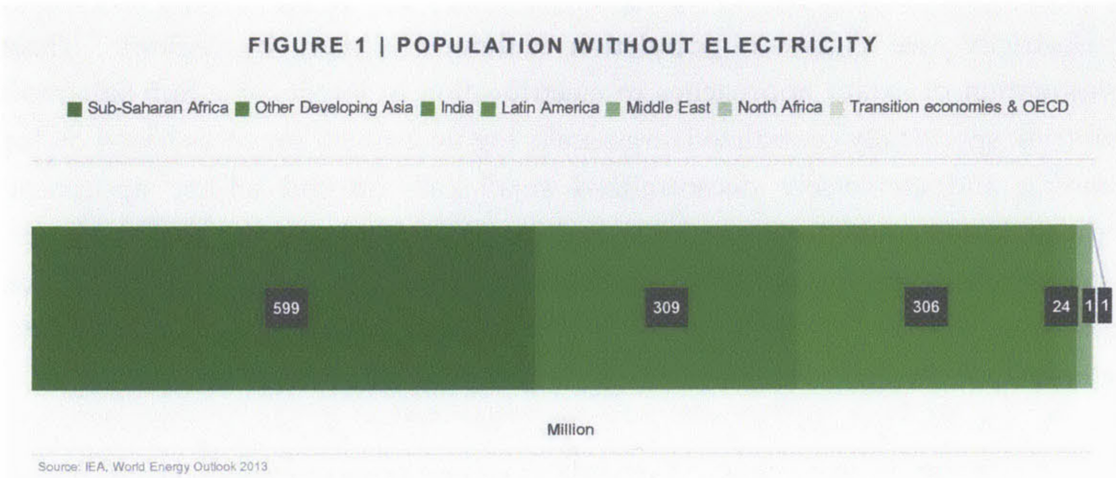
[1] Definitions: (i) centralized large-scale practices: utility-scale power projects overseen by state-owned enterprises. For reference, in Tanzania centralized large-scale power projects have capacities greater than 10MW. (ii) decentralized small-scale off-grid solutions (in this thesis "small-scale off-grid" and "small-scale" are used interchangeably): lanterns/lights, cell phone chargers, and micro-grid systems. These power solutions consist of a few hundred watts to kilowatts and serve a household or a few hundred households. For reference, such solutions align with the World Bank's Access to Electricity Supply Tiers 1, 2 and 3 – with a peak available capacity of 500 watts (IEA, World Bank Group, 2014).

[2] Definition: "isolated rural regions" is a term used by the Government of Tanzania to refer to official administrative areas within the country that do not have access to the main (or national) grid system. There are 25 official urban and rural regions in Tanzania. In this thesis, I suggest the development of mid-scale power systems for communities *within* isolated rural regions.

African countries that are experiencing rapid socio-economic changes, such as Tanzania, a new planning and development approach is requisite.

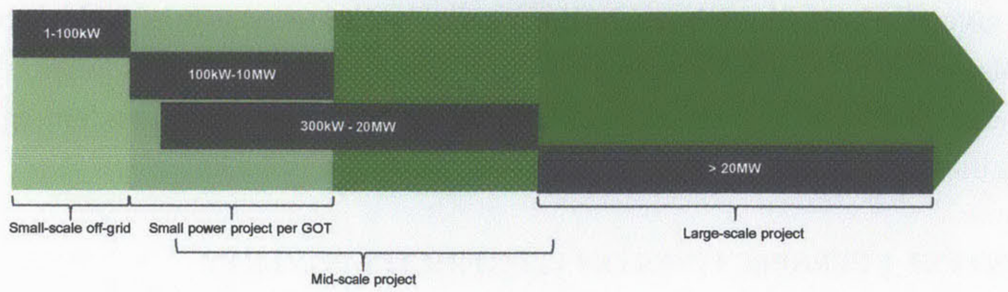


The thesis proposes a *mid-scale opportunistic and pluralistic planning* paradigm, which draws upon my investigative understanding of the critical *theoretical* threads that inform the complex fabric of electricity sector development – energy economics, social science, conceptualized and technical planning, and climate change theories – and my *practical* understanding of resources available for power producers operating in communities within isolated rural regions.[3] The mid-scale opportunistic and pluralistic planning paradigm is a novel concept that blends appropriate elements from economic development theories, least-cost-planning and entrepreneurial improvisations. Mid-scale opportunistic and pluralistic planning provides a holistic perspective for normative decision-making and development processes for policy makers and electricity project developers (see Figure 2, stylized example of the power scales as defined in thesis).

[3] A mid-scale power system is between approximately 300kW to 20MW.

FIGURE 2 | POWER PROJECT SCALES DEFINED

Power ranges are not to scale



Source: EWURA, 2014. Author: Sarah Dimson

The aim of the paradigm is to shift attention and resources towards the development of holistic policies and plans that lead to two outcomes: (i) an increase of mid-scale renewable energy power projects in the short-term; and (ii) a codified electrification process that catalyzes sustainable development[4] whereby the real effects on the economy, environment and livelihoods are measured in real time[5] in order to provide valuable feedback for any necessary adjustments to public and private sector electrification initiatives.

The thesis' focus is on scale, the use of clean power, and emphasizes the need for an original, systematic and dynamic process to advance electrification in isolated rural regions. The thesis' perspective with respect to clean power is that electricity poverty alleviation and climate change mitigation, by way of renewable energy technologies, is not a policy trade-off, it is an imperative, human-centered, pre-requisite condition for sustainable development. Further, in consideration of the thesis' focus, the thesis does not include a detailed discussion about technical specifications for upstream, manufacturing, or downstream deployment activities for renewable energy technologies.[6] However, Chapter 3 includes a discussion about renewable power technology financing in the context of the case study of Tanzania. In addition, with respect to process, electricity regulation

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[4] Sustainable development: a three pronged approach to development that considers economic, environmental and social issues in order to understand problems, from a social science perspective, and make normative policy decisions. Specific to the thesis' case study of Tanzania the environmental dimension focuses on mitigating CO_2 emissions.

[5] Real-time refers to instantaneous and short-term flows of data and information amongst key stakeholders (e.g. renewable energy financing and policies that come on-line and can be leveraged for mid-scale power projects, consumer consumption patterns, consumer purchase patterns related to power appliances, etc.).

[6] Renewable energy technologies may be sources from natural replenished resources (e.g. sun and wind). The emphasis is on renewables that are not fuel-dependent (i.e. hybrid generators such as solar paired with fossil fuels).

undoubtedly plays an important role in the viability and implementation of mid-scale renewable energy projects (Eberhard & Kapika, 2013; Tenenbaum, Greacen, & Siyambalapitiya, 2014). As a result, regulation is discussed in specific relation to Tanzania; yet, given the breadth of the topic, the regulation discussion is brief and limited to feed-in-tariffs, opportunities for engagement and apt future policy considerations. Similarly, through this investigation, tangential policy and process questions emerge, which are identified in Chapter 3.

CONTEXT | PERSPECTIVES ON ELECTRICITY POVERTY

International Energy Agencies, International Financing Institutions & Aid Agencies

In 2002, the International Energy Agency (IEA) released a seminal report that detailed the world's electricity poverty and promulgated that 1.6 billion people live without electricity (IEA, 2002). In the absence of aggressive policies and investment of financial, technological and human capital, by 2010 the number of people living without access to electricity dropped only slightly to 1.4 billion (OECD/IEA, 2010). In 2010 IEA released another energy poverty report in partnership with the United Nations Development Program and the United Nations Industrial Development Organization (hereinafter the "IEA-UN Energy Poverty Report"). The IEA-UN Energy Poverty Report advances the strong correlation between electricity and poverty as well as highlights electricity poverty across global regions. For example, the IEA-UN Energy Poverty Report underscores that in Sub-Saharan Africa approximately 600 million people are living without access to modern electricity (OECD/IEA, 2010).[7] Moreover, annual per capita electricity consumption levels in Sub-Saharan Africa are low at 535 kWh (World Bank, 2014).[8]

Low levels of access and consumption received heightened attention with the release of the IEA-UN Energy Poverty Report, which acted as a foundation for the United Nations' (UN) 2011 Sustainable Energy For All global initiative[9]. Sustainable Energy For All's objectives include the intent to provide universal access to modern energy and double the

[7] The IEA-UN Energy Poverty Report evaluates an electrification policy base case and simulates a future scenario, with corresponding investment requirements, towards increased access by 2015 and universal access by 2030. The base case is the "New Policy Scenario," which includes policies during the 2010-2015 period. The future case is the "Universal Modern Energy Access Case," which estimates urban and rural targets based on known forthcoming policies.

[8] Latin America and Caribbean (developing only) electric power consumption per capita is 1,985 kWh (2011). Per capita consumption in the US is 13,246 kWh (2011). Source: World Bank Data, 2014.

[9] Correlation between access and consumption is low (IEA, World Bank Group, 2014).

share of renewable energy in the global energy mix (United Nations, 2013).[10] As a corollary, the initiative further intensified focused awareness about the dearth of electricity in the most economically impoverished regions in the world. Thereafter, in 2012 the UN Conference on Sustainable Development (Rio+20) delegates established a need for new global 2015 goals that build on the Millennium Development Goals (MGDs) and incorporate the objectives of Sustainable Energy For All. As a result, another major global initiative that looks towards 2030, the Sustainable Development Goals, is currently under development (United Nations, 2012).[11] The Sustainable Development Goals (SDGs) also assert that modern energy is critical for development and poverty alleviation. Furthermore, the Rio+20 delegation posits that in addition to electricity access the use of clean, low-emission electricity generation sources is essential to sustainable development. Ostensibly, the aid and energy agency approach to electrification is marked by a consequential series of comprehensive frameworks and initiatives that unequivocally assume that increases in electricity generation, access, consumption play a critical role in economic development and can be advanced in a manner that mitigates climate change. The perspectives are predominately manifesting as centralized large-scale power projects (McDonald, 2009; MEM, 2013b; USAID, 2014).

However, there is growing recognition by energy policy makers and practioners that conventional centralized generation, transmission and distribution least-cost-planning approaches may not make economic and environmental sense in developing countries (OECD/IEA, 2010; RECP, 2013). McDonald (2009) finds that least-cost-planning fails to account for the full costs of negative externalities, such as environmental damage and social impacts. For example, in the case of hydro dams McDonald (2009) finds that economic benefits are tenuous.[12] Based on this finding apropos Sub-Saharan Africa, a need for an alternative to least-cost-planning approaches is particularly true in the short-term (2013-2017).[13] Hence, mid-scale projects that serve not only households, but also business and public centers, present a more opportune and financially sustainable path, for producers and consumers, to electrification – particularly in regions where communities' geographic

[10] Modern energy includes access to household electricity and clean cooking facilities (e.g. fuels and stoves that do not cause air pollution in houses) (IEA, online, 2014).

[11] Sustainable Development Goals are an international framework to help nations establish goals within a three dimensional structure concerning economic, environmental and social development.

[12] Centralized large-scale hydro dams reportedly plunder river resources and have displaced 40 to 80 million people worldwide (McDonald, 2009).

[13] This thesis focuses on the short term (within 5 years) because the purpose is to address how policy makers and practioners might provide electricity services expediently since grid connectivity is a long-term process and small-scale off-grid solutions are nascent and struggling to scale. Moreover, the GOT's power sector management plan is defined in five-year increments so the case study seeks to provide consistency with this purview.

distance from one another and the national grid is hundreds of kilometers (km) (MEM, 2013a).

Localized Electricity Practioners

In parallel to the global, comprehensive IFI-aid posture on electrification in developing countries non-governmental organizations (NGOs) and private sector entrepreneurs are piloting decentralized, small-scale off-grid interventions. The small-scale off-grid ethos is a one household, one kilowatt at a time approach to electrification grounded in micro-economic theories of development (Clinton, William, Sachs, & Soloman, 2006; Easterly, 2006; Wilson & Zarsky, 2009). For instance, across Sub-Saharan Africa are hundreds of micro-economic electrification programs and enterprises that are working to address rural and urban electrification needs.[14] Essentially, the decentralized small-scale electrification perspectives emphasize the need for highly localized, incremental approaches to electrification.

THESIS INVESTIGATION

My thesis investigates the multi-dimensional point of intersection between electricity supply, access and consumption, and the electricity system scale at which electricity systems may be most effective, given the current political milieus, socio-economic and environmental conditions, in low-income Sub-Saharan African countries. The thesis explores the history of the architecture of electricity infrastructure. The history provides context for how globalization, technological innovation and the pursuit of economic development proliferated to developing countries, namely in Sub-Saharan Africa. Further, the thesis studies the confluence of the emerging theories and approaches to electrification towards an outcome of sustainable economic development through a specialized Sub-Saharan African perspective. Based on my study of government, IFI and international aid agency and energy agency approaches to electrification – primarily comprehensive, centralized large-scale initiatives – and conversely entrepreneurial and non-governmental interventions - decentralized small-scale off-grid solutions – as well as examinations of econometric data concerning the causal relationship between electricity consumption and economic growth, and modern planning approaches, I hypothesize that a *mid-scale opportunistic and pluralistic planning paradigm* presents a ready opportunity to address the dearth of electrification in communities within isolated rural regions in Sub-

[14] See Appendix-2: Sample list of small-scale off grid enterprises and programs operating in Sub-Saharan Africa.

Saharan African countries. Using Tanzania as a case study, given the degree of the country's electrification problem and the evolving, complex economic and governing ecosystem, my thesis analyzes my premise that promotes opportunistically leveraging available natural, financial and human resources in order to implement mid-scale electricity projects in isolated rural regions[15]. The aim of the thesis is to offer a specific reference point that questions and critically analyzes electrification in Sub-Saharan Africa and offers an alternative, novel path to generation and access in the short-term as centralized least-cost-planning approaches involve 15 to 20 year time horizons and small-scale off grid projects fail to keep apace with population growth, rising incomes, and increasing power demands. I suggest that a path to precipitously electrify communities within isolated rural regions, where the majority of Sub-Saharan Africans live, is plausibly through a mid-scale opportunistic and pluralistic planning paradigm.

Chapter 1 explores the broad historical and current theories and practices that led to the proliferation of frameworks that promote electricity development as a means to achieve economic development in developing countries with specialized Sub-Saharan Africa perspectives. Further, Chapter 1 investigates the econometric empirical evidence about the dynamic relationship between electricity consumption and economic growth, which acts as the basis upon which both centralized large-scale and decentralized small-scale off-grid electrification approaches are designed, developed and enabled in various Sub-Saharan African countries. Chapter 2 provides detailed context for the political, economic, social and environmental system (or lack thereof) in Tanzania that influenced the current state of the electricity sector. Building on Chapters 1 and 2, Chapter 3 discusses the mid-scale opportunistic and pluralistic planning paradigm in detail. Chapter 3 also discusses my hypothesis that best opportunity (as opposed to least-cost) involves a commitment to deep stakeholder engagement and policies that create a conducive operational environment for power developers and consumers in isolated rural regions. Finally, based on the Tanzanian case study, I offer concluding thoughts and recommendations to increase electricity generation and access in a manner that supports sustainable economic development.

[15] Examples of natural, financial and human resources, respectively: sun and wind for power production; private equity, debt, IFI and NGO funds for initial capital costs and working capital; and human capacities within a range of stakeholders and potential collaborators (e.g. academia, government, technical capacity within IFIs, localized knowledge from community members, etcetera.)

METHOLODLOGY

Case-Study Research | A paradigmatic, context-dependent case study

A paradigmatic case is research organized around a specific paradigm (Flyvbjerg, 2006). The paradigm of this thesis is *scale* in the context of electricity sector planning. Paradigmatic cases highlight interdisciplinary aspects of societies, for example economic, social and environmental constructs. Paradigmatic case studies do not follow standard rule-based criteria for research; rather, processes or methodologies are determined by the researcher and guided by intuition (Flyvbjerg, 2006).

I chose to structure the thesis as a paradigmatic case study because the ideologies, perspectives and practices around electricity sector planning and development in Sub-Saharan Africa (SSA) are structured around two paradigms. The dominant paradigm concerns centralized large-scale utility projects designed through a least-cost-planning approach. Secondly, a parallel nascent approach exists – decentralized small-scale off-grid initiatives designed through ad-hoc and experimental approaches.

The methodology used for the thesis includes the following: a case study research selection strategy; an iterative review of scholarly books, journals and reports; in-country field inquiries; and analytical interpretations. The methodology intends to question specific theories and practices of electricity sector development as well as advance specialized understanding for planning approaches for different electrification scales. The investigation is contextualized through a study of electrification in Tanzania.

Why Tanzania? | Information-oriented selection

Tanzania is the country in question based on the degree of the electrification problem, availability of information, in-country access to information, and personal interest – the opportunity to develop a keen understanding for the possible paths that may effectively advance electrification in low-income Sub-Saharan African countries. Tanzania is a reference point that I use to argue for *mid-scale opportunistic and pluralistic planning,* a paradigm and systematic process to advance electrification in low-income SSA countries.

Concept Formation | Midscale Opportunistic and Pluralistic Planning

This thesis suggests a new approach to electrification in Tanzania: *mid-scale opportunistic and pluralistic planning,* a term I developed based on research conducted for this thesis. The mid-scale opportunistic and pluralistic planning paradigm draws upon my investigative understanding of the critical *theoretical* threads that inform the complex fabric of electricity sector development – energy economics, social science, conceptualized and technical planning, and climate change theories. Additionally, the mid-scale opportunistic and pluralistic planning paradigm weaves in my *practical* understanding of the resources that are currently available in Tanzania, for example natural and financial, and can be leveraged to make normative conclusions and to take decisive actions. Moreover, the paradigm is holistic - appropriately reflecting the interdisciplinary complexities of economic growth, which is the ultimate aim electrification.

Scholarly review | Theoretical and Empirical

Electrification in Tanzania concerns the study of economic, social, political and environmental systems as well as the study of human affairs – the range of stakeholders working (or not) towards increasing electricity consumption and access in an environmentally conscious manner. As such, a review of scholarly materials aids in the illumination of these complex systems and activities.

Field Inquiry | Dar es Salaam, Lindi and Mtwara, Tanzania

The thesis is supported by a total of approximately eight weeks of in-country field inquiry in Tanzania. The location, date, nature of the field inquiries and reference listing is as follows:

Dar es Salaam, March 2012:

- Field inquiry included approximately two weeks in Dar es Salaam in March 2012. This period was prior to the start of academic work at Massachusetts Institute of Technology. This time in Dar es Salaam helped me understand matters related to land acquisition, land development, the government tax system and how multi-lateral development banks interact with government officials.
- Activities: making observations, engaging in scoping interviews for data and information (open ended, objective and subjective questions), and analyzing and synthesizing data and information ex ante, in situ and ex post.

- Scoping interview entities: See Appendix-1 for a full reference list of scoping interview entities
- Reference for thesis: In this thesis, this period of engagement is referenced as "Sarah Dimson (2012)."

Dar es Salaam, Lindi and Mtwara, January 2013:

- Field inquiry included four weeks in Tanzania. During this period I acted as an intern to the Regional Commissioner of Mtwara. The internship included travel to Dar es Salaam and Lindi. The primary objectives for the internship included the following: (i) working with the Regional Commission team on the Mtwara Development Corporation framework; (ii) gaining a broad understanding for the various sectors that might drive the future growth in the region; (iii) enhancing knowledge regarding Tanzanian development policies and laws; (iv) gaining a broad understanding for advancements in the energy sector; and (v) developing a general understanding for the region's geography and socio-cultural dynamics.
- Activities: making observations, engaging in scoping interviews for data and information (open ended, objective and subjective questions), and analyzing and synthesizing data and information ex ante, in situ and ex post.
- Scoping interview entities: See Appendix-1 for a full reference list of scoping interview entities
- Reference for thesis: In this thesis, this period of engagement is referenced as "Sarah Dimson (2013a)."

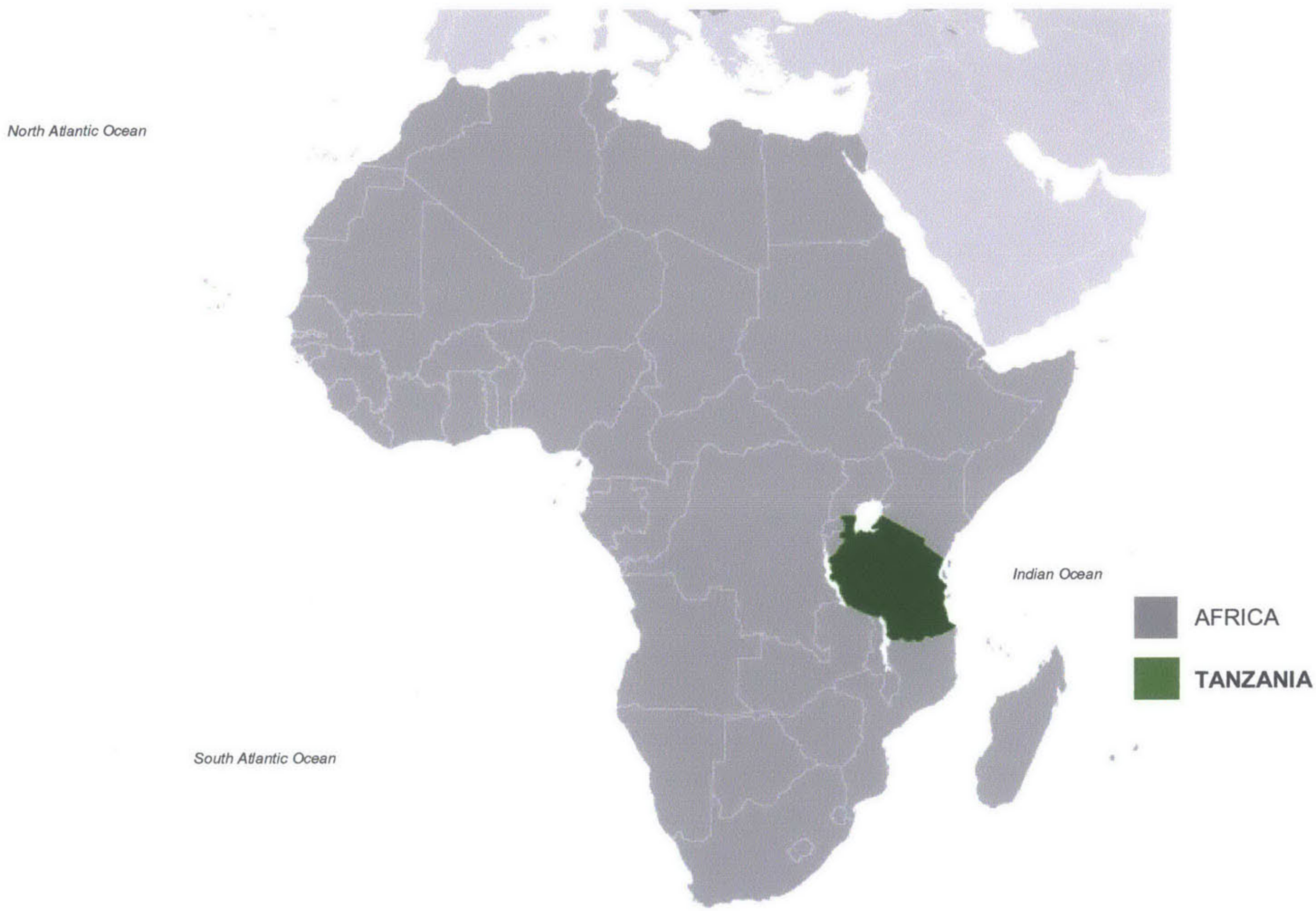
Dar es Salaam, July 2013:

- Field inquiry included approximately two weeks in Dar es Salaam in July 2013. This period focused on engagement with government electricity sector stakeholders.
- Activities: making observations, engaging in scoping interviews for data and information (open ended, objective and subjective questions), and analyzing and synthesizing data and information ex ante, in situ and ex post.
- Scoping interview entities: See Appendix-1 for a full reference list of scoping interview entities
- Reference for thesis: In this thesis, this period of engagement is referenced as "Sarah Dimson (2013b)."

Analytical Interpretations

Scholarly research and field inquiry are the foundation of the paradigm proposed in this thesis – mid-scale opportunistic and pluralistic planning. Further, my interpretations were also informed by an investigation of numerous perspectives apropos the energy sector in Tanzania.

MAP 1 | AFRICA (WITH TANZANIA HIGHLIGHTED)



Sources: Image, The World Factbook, April 15, 2014 (online); Google maps, April, 2014 (online)
Author: Sarah Dimson

CHAPTER 1 | ELECTRIFICATION AND DEVELOPMENT – HISTORY, THEORIES AND PRACTICES IN CONTEXT OF SUB-SAHARAN AFRICA

The policy and practice-based approaches to universal electrification across Sub-Saharan Africa (SSA) include comprehensive, centralized plans for large-scale power projects and decentralized small-scale off-grid approaches that have failed to address generation, access, and consumption in an expansive manner and that is apace with rapid changes in macro and micro-economies, population growth and climate change. There is an evidenced need for these parallel approaches to electrification given the scope of the electrification problem (IEA & World Bank Group, 2014; McCord & Sachs, 2013; Tenenbaum, Greacen, & Siyambalapitiya, 2014). However, I contend that the emphasis on centralized large-scale grid projects needs to be revisited in the context of the aforementioned socio-economic and environmental dynamism that is occurring in emerging Sub-Saharan African economies as well as geospatial considerations as the majority of Sub-Saharan Africans reside in communities within isolated rural regions. Moreover, the least-cost-planning time horizon for centralized grid-scale projects is 15 to 20 years. Africans need access to reliable, high quality electricity services today. As for small-scale off-grid approaches, existing business models are stuck in various stages of proof of concept or attempting to scale with limited resources – as such these efforts rarely translate into sustained electricity access. Hence, this thesis explores an alternative path to electrification, in the short-term, and for the communities within isolated rural regions: a *mid-scale opportunistic and pluralistic planning* paradigm.

Chapter 1 provides context for the electrification issues in Sub-Saharan Africa. Chapter 1 also reviews the prevailing historical and current planning approaches and paradigms apropos comprehensive, large-scale and small-scale off-grid approaches to electrification in Sub-Saharan Africa. In this review, the theoretical and empirical evidence concerning the correlation between electricity consumption and economic growth, the ultimate impetus for increasing generation and access, is detailed as the assumptions are part of the theoretical foundation of the mid-scale opportunistic and pluralistic paradigm.

Section 1.0 | Electrification in Sub-Saharan Africa (SSA)

Electricity is essential for economic growth and human development. Africa's critical lack of electricity generation and access is stifling economic progress (Arron, 2012). Nearly 600 million Sub-Saharan Africans live without a reliable source of electricity (IEA, 2013).[16] This large segment of the population, approximately 68%, depend on charcoal, wood, kerosene, diesel and candles to meet domestic and business power or lighting needs. The power sources have deleterious repercussions on health and the environment, the latter by means of greenhouse gas emissions (GHG) and deforestation. Moreover, the financial and opportunity costs are high for poor households, particularly given that nearly 40% of Sub-Saharan Africans live on USD $2 per day (PPP) (World Bank, 2013). As such, household levels of consumption are insufficient, at approximately 200 kWh per family, for any sort of meaningful economic prosperity. For populations who have access to modern (grid-connected) electricity supply is unreliable and erratic. For instance, an average of 10.5 power outages occur monthly and the average duration of an outage is 6.6 hours (World Bank, 2010). Andersen and Dalgaard (2013) assert that a one percent increase in electricity outages reduces long-run gross domestic product (GDP) by approximately three percent (Eberhard et al., 2008). Figure 3 details the electricity outage-GDP assertion across 12 countries in SSA.[17] Furthermore, electricity shortages and cuts are often supplemented by emergency diesel generators, which negatively affect electricity prices and the environment (Arron, 2012). Further, Sub-Saharan Africa (SSA) is not lacking in energy resources. In fact, the region is endowed with substantial hydrocarbon reserves and renewable energy resources.

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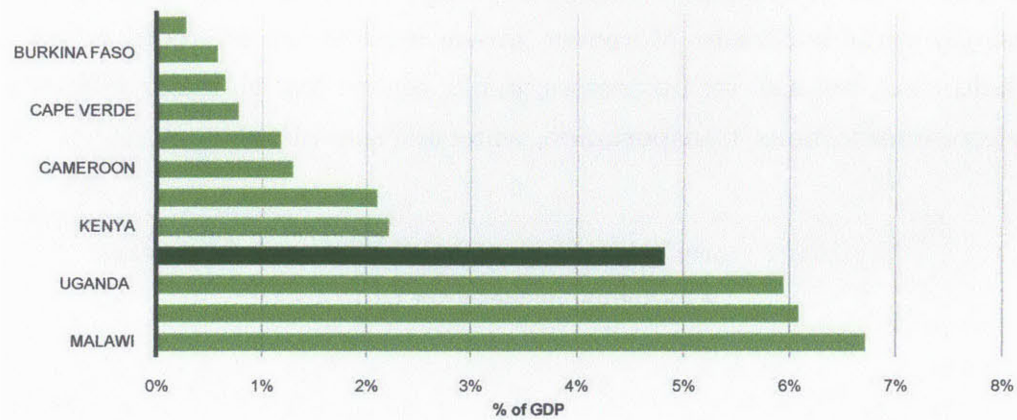
[16] See Appendix-3, Electricity Access in Africa, 2011.

[17] Actual percentages estimated based photocopy of Figure 11.11, Arron, John (2012).

FIGURE 3 | ECONOMIC COST OF POWER OUTAGES IN SELECT SSA COUNTRIES



Source: World Bank data; Eberhard et al. 2008 as cited by Arron, John (2012).[17]

Oil and gas production has increased four-fold since the 1960s. The value of energy resources is expected to surpass USD $300 billion by 2019 (based on 2011 prices) (Trajok, Way, & Robertson, 2012). Renewable energy sources are substantial in hydropower, solar, and moderate in wind and geothermal. At present, large-scale hydropower is a major least cost energy source in several SSA countries – Cameroon, Ghana, Kenya, Tanzania, Uganda and Zambia (McDonald, 2009).[18] However, large-scale hydro dam projects in SSA have historically experienced delays in construction, cost over-runs, often underperform in meeting power generation targets; and increasing droughts are prompting governments to rethink whether hydro dams are sound least-cost investments (IRENA, 2011; McDonald, 2009; MEM, 2013a, 2013b). Solar power has the greatest renewable energy potential, with high quality resources throughout much of the region. Onshore wind potential varies. High wind speeds are prevalent in the north-west coastal region, Horn of Africa and countries such as Mozambique, Namibia and Tanzania (IRENA, 2014). Geothermal sources (hot water and steam based) are primarily concentrated in the East African Rift (IRENA, 2011; Kahsai, Nondo, Schaeffer, & Gebremedhin, 2012).

For decades, developing SSA country governments have under-invested in the building and maintaining of electricity infrastructure irrespective of production source type (i.e. fossil fuels and renewables). The lack of investment does not align with dynamic socio-economic changes in SSA: rapid population growth (in urban and rural areas); geo-spatial

[18] In 2004 hydropower accounted for two-thirds of total electricity production in SSA, excluding South Africa (US EIA 2004 as cited by McDonald, 2009).

considerations (as 63% of the total SSA population reside in rural areas); rapid economic growth (see Figure 4, sustained 7% annual average GDP growth in SSA countries)[19]; and an increasingly variable climate. Moreover, power investments are requisite not only at the household level, but also for businesses, public centers and all major infrastructure areas (e.g. telecommunications, transportation, water and sanitation).

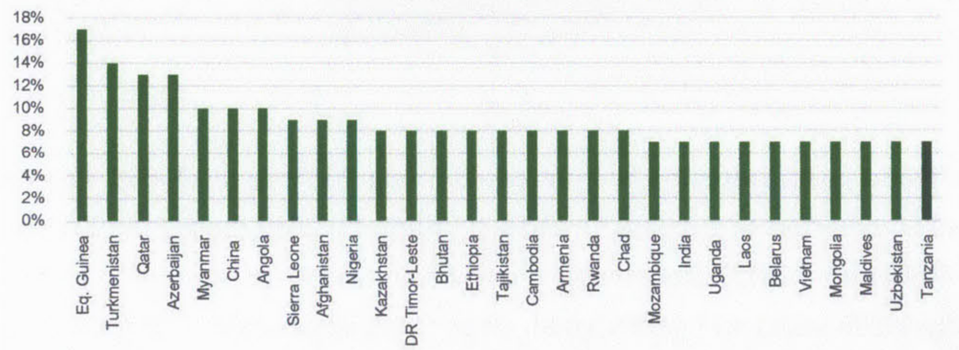


FIGURE 4 | "OVER 2000-11, 10 AFRICAN COUNTRIES ACHIEVED AT LEAST A 7% ANNUAL AVERAGE GDP GROWTH RATE

sufficient to double an economy's size every 10 years."

Source: IMF as cited by Arron, John (2012)[19]

According to economists Jeffery Sachs and McCord (2013), the path to sustainable, self-sustaining growth for low-income countries (those who have yet to pass the USD $2,000 threshold) is through, in part, an energy transformation at residential, commercial and industrial levels.[20] Energy transformation helped other regions around the world witness tremendous, tangible strides in economic growth, evidenced by extensive studies of developed economies that indicate a positive correlation between a nation's stock of infrastructure assets and economic growth (Bhattacharya, Romani, & Stern, 2012).[21] Electricity, specifically, is distinct in its ability to be used across the other infrastructure sectors, and unique in its correlation with real-Gross Domestic Product (GDP) growth, socio-economic indicators, such as the Human Development Index (HDI), and environmental impacts (Kamimoto, Maurice, Nyboer, Urama, & Weir, 2011). Yet, there is

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[19] Actual percentages estimated based photocopy of Figure 0.4, Arron, John (2012).

[20] McCord and Sachs (2013) contend that economic development involves five key structural transformations: from low to high inputs of energy; from traditional to modern agriculture; from traditional to produced knowledge; from low to high mortality rates; and from rural to urban life.

[21] Bhattacharya et al. (2012) suggests that temporary increases in investment for infrastructure development is necessary to move a country to a new, higher level of economic growth.

no consensus at present about electricity's relationship to economic growth and climate change among economic researchers (based on the existing body of theoretical and empirical evidence) nor is there a convincing planning approach or paradigm for achieving universal electrification among academics, policy makers, international financing institutions (IFIs), governments and citizens. The genesis of this electrification discord is rooted in history.

Section 1.1 | Electricity and Economic Growth – Key Historical Events and Theories

The strong electricity consumption-economic growth correlation was palpable in the late 1960s through the early 1970s as the rate of energy consumption closely followed the rate of economic growth (Iwayemi, 1998). The era was marked by rapid economic growth, rising incomes, higher living standards and a downward trend in energy prices, which was due to increased global energy demands (Iwayemi, 1998). As such, during the 1970s economic powerhouses, such as the United Kingdom (UK) and the United States (US), spread the ideology of electricity infrastructure development as an essential tool for economic prosperity to aid-dependent countries in Latin America, Asia and Africa.[22] However, the electricity-economic growth theory was tested with the 1973 Oil Embargo, which catapulted the global energy market into a new era of high energy prices (Iwayemi, 1998; Payne, 2010; US Department of State, Office of the Historian, 2013). The oil shocks created instability in global energy markets and catalyzed three separate but topically relevant events that informed the nascent network of electricity ecosystems around the world: (i) the shift from traditional to least-cost-planning[23]; (ii) a new wave of econometric investigations concerning the electricity consumption-economic growth nexus; and (iii) recognition of the limits to, and environmental repercussions of, the exploitation of non-renewable energy sources.[24]

In the late 1970s, western electric utility lobbyists advocated against traditional state-owned enterprise planning and for least-cost-planning (Hanson, Kidwell, Ray, &

[22] Roland, Gerald. "The Public Sector, Privatization, and Development in Sub-Saharan Africa." African Studies Quarterly, 2001, 5(1).
[23] In traditional planning, state-owned utility companies governed and executed the majority of the planning process without much oversight or engagement from third-party stakeholders. For example, a utility would forecast demand, screen supply-side options based on its own interests, objectives and technical and environmental constrains, etcetera (Hanson, Kidwell, Ray, & Stevenson, 1991).
[24] Rist (2008) asserts that the recognition of the limits to non-renewable energy exploitation arose in 1972 with the publication of the Meadows Report, *The Limits to Growth* and the oil price shocks. (Rist, 2008, p.184).

Stevenson, 1991). The least-cost-planning approach aligns with neo-classical and institutional economic theories and seeks to include a broader range of parties to institute more comprehensive supply and demand options for large-scale electricity projects with long time horizons (e.g. 20 years).[25] Regulatory commissions, urban and regional planners and a range of public, private emissaries sought to provide electricity services at minimum costs through diversified supply sources and demand-side options, which were detailed in exhaustive, long-term plans.[26] This was the advent of economies of scale for the electricity sector – big plans, big projects, big investments for affordable electricity. Around the same time, while neo-classical theories acted as the basis for least-cost planning, other electricity concepts sought to further explain the complex, dynamic relationship between electricity consumption and economics.

The groundbreaking work of Kraft and Kraft (1978) underscored the importance of empirical evidence concerning the *directional causality* between energy consumption and economic development. Directional causality investigations question whether increases in electricity consumption leads to economic growth, or if economic growth leads to greater electricity consumption. Such studies also explore the existence of a bi-directional relationship, or whether there is any causality.[27] Electricity consumption-economic growth studies matter, broadly and in the context of this thesis, because the empirical evidence has the power to profoundly influence the design of electricity-environment policies as well as guide essential investment decisions, particularly from IFIs to developing Sub-Saharan African countries (Ozturk, 2010; Payne, 2010). Since the seminal work of Kraft and Kraft (1978), a plethora of research investigations studied the energy (electricity) consumption-economic growth nexus in high and upper-middle income regions since data is more readily available and reliable compared to developing countries (Apergis & Tang, 2013; Payne, 2010).[28] In high-income countries, such as the US, the empirical findings for energy consumption-economic growth are diverse and the implications are convoluted. For example, while Kraft and Kraft (1978) find uni-directional causality from real-GDP to energy consumption in the US, Stern (1993, 2000) finds the opposite: energy consumption in the US indeed leads to increases in real-GDP.[29] Further, Akarca and Long (1980) assert

[25] Hanson et al. (1991) describe the change from traditional to least-cost-planning from an industrialized country perspective.
[26] Electricity supply options varied by technology, fuel type and the intended use (e.g. base-load, cycling or peak-load). Source: Hanson et al. (1991).
[27] See Box 1.
[28] Huang et al. (2008) used the World Banks classifications of high, middle (lower and upper middle income groups
[29] Time horizons for studies range from 1947 – 2006 with some studies overlapping in time periods.

that there is no causal link between energy consumption and real-GDP. Nonetheless, across hundreds of studies most empirical evidence suggests that for high and upper-middle income countries energy (electricity) consumption leads to economic growth (Apergis & Tang, 2013). As such, for the major part of the 20th century, high and upper-middle income countries adopted aggressive growth strategies for electricity. It was a least-cost-planning paradigm whereby planners, policy makers and investors took the position that if the benefits of real-GDP growth outweighed the cost of environmental damage, it was worth increasing electricity consumption to accelerate economic growth (Huang, Hwang, & Yang, 2008; Kamimoto, Maurice, Nyboer, Urama, & Weir, 2011).

Box 1 | Overview of the Energy (Electricity) Consumption-Economic Growth Hypotheses

Energy consumption- real gross domestic product (real-GDP) studies influence energy and environmental policies formation and decision-making. The studies predominately test four energy consumption-real-GDP hypotheses: "growth hypothesis," "conservation hypothesis," "feedback hypothesis," and the "neutrality hypothesis" (Ozturk, 2010; Payne, 2010).[30]

Growth hypothesis: (ec → y)
The uni-directional causality from energy consumption to real-GDP. The growth hypothesis contends that energy consumption leads to increases in real-GDP. The premise advances that energy consumption is a vital aspect of economic growth and is a complement to labor and capital. Therefore, policies that limit energy consumption and "shocks to energy supply" may have a deleterious impact on an economy (Ozturk, 2010).

Conservation hypothesis: (y → ec)
The uni-directional causality from real-GDP to energy consumption. The conservation hypothesis argues that energy conservation policies may have little or no adverse effect on real-GDP. The hypothesis is validated if increases in real-GDP cause increases in energy consumption.

Feedback hypothesis: (ec ↔ y)
The bi-directional causality flows from energy consumption to real-GDP and from real-GDP to energy consumption. The feedback hypothesis asserts that energy consumption and real-GDP growth are concurrently interdependent.

Neutrality hypothesis: (ec ---- y)
The neutrality position posits that there is no causal relationship between energy consumption and real-GDP. Therefore, energy consumption and/or conservation policies may have no adverse impact on real-GDP.

[30] Box 1 legend: ec = energy consumption; y = real-GDP; arrow indicates direction of causality (uni or bi-directional); dashed line indicates no causality.

Section 1.2 | Electricity and Climate Change – Towards Renewable Energy

Ambitious electricity expansion projects, in the name of economic growth, in high and upper-middle income nations has been at a great expense to the environment. GHG emissions associated with the provision of electricity are a major source of climate change as nearly 57% of all anthropogenic GHG emissions are due to the consumption of fossil fuels, the primary power source fueling global economies (Kamimoto et al., 2011). In the US, for example, the combustion of fossil fuels used to generate electricity accounts for the largest single source of carbon dioxide (CO2) emissions (US EPA, 2011). In the UK electricity generation accounted for the largest share, approximately 40%, of CO2 emissions in 2012 (DECC, 2013). In fact the UK realized a five percent increase in electricity generated CO2 emissions from 2011 to 2012 as a result of an increase in coal use even though demand for electricity was largely unchanged (DECC, 2013). Further, more than 90% of China's CO2 emissions stem from electricity, as coal is the main source fueling electricity generation (Zhang, Liu, Wang, & Zhou, 2013). The greatest driver of climate change, CO2, has increased by 40% since pre-industrial times primarily due to fossil fuel emissions released by the US, UK, China and other high and upper middle-income nation-states (IPCC, 2013). Hence, economic growth is at the forefront of electricity policy in high-income nations – arguably discounting the significance of environmental impacts. However, the impacts are serious - the warming of the climate is indisputable (IPCC, 2013).

International attention towards the warming of the climate heightened in the 1980s as global climate studies emerged to engender a broad, intergovernmental movement for greater sustainable development practices, notably for regions with major energy production and consumption. In 1987 the United Nations World Commission Environment and Development (UNCED) released *Our Common Future*, an exhaustive list of threats to the global ecosystem – the greenhouse effect, the hole in the ozone layer, urbanization, energy and other systemic environmental predators (Rist, 2008). By the early 1990s, the United Nations (UN), in partnership with the World Meteorological Organization, established the Intergovernmental Panel on Climate Change (IPCC) to provide a scientific perspective on climate change and its potential environmental, economic and social impacts (IPCC, 2014). Additionally, UNCED launched its first global conference in Rio de Janeiro (Earth Summit) to set an agenda for development and environment in the 21st century (United Nations, 2011). The Earth Summit acknowledged the importance of economic development for societal progress and emphasized the urgent need for nation-states to change production and consumption patterns to reflect more environmentally sustainable practices. Further, in 1997 the United Nations Framework Convention on Climate Change (UNFCC) established the Kyoto Protocol, an international agreement whereby developed nations, the countries principally responsible for the high level of GHG emissions, commit to binding emission reduction targets (United Nations, 2014). UNFCC later established the 2010 Cancun Agreements to expand the responsibility to reduce anthropogenic GHG emissions to developing countries and mobilize widespread use of clean technologies (UNFCC, 2014).

The Cancun Agreements are unique in the call for developing countries to also assume environmental responsibilities.[31] The most recent version of the Earth Summit, the 2012 UN Conference on Sustainable Development (Rio+20) followed suit by intensifying focus on developing countries apropos a new sustainable development framework that is based on more rigorous principles for economic growth, social development and environmental protection (United Nations, 2012). More poignantly, the Rio+20 outcomes include a provision to address the critical state of electricity access and climate change through policies and strategies that aggressively promote the use of low-carbon, renewable electricity sources and technologies. Further, the Rio+20 outcomes include a commitment to launch the Sustainable Development Goals (SDGs), a comprehensive, global 2030 vision that details a new ethos for sustainable development as the framework goes beyond the Human Development Index (HDI), which focuses on economic growth and social welfare, to include the environment (Jeffrey Sachs, 2014). Furthermore, the provisos of the SDG framework categorically promotes the use of low-carbon emitting and renewable electricity sources for universal electrification efforts (see Table 1, Overview of Renewable Energy Technologies by Maturity and Distribution Method).

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[31] The initial UNCED-Rio de Janeiro agenda and the Kyoto Protocol's Clean Development Mechanism, a pathway for developed nations to implement emission-reduction projects in developing countries, initially put the burden of environmental stewardship on developed nations (United Nations, 2014).

TABLE 1 | OVERVIEW OF RENEWABLE ENERGY TECHNOLOGIES: MATURITY AND DISTRIBUTION METHOD

	Technology Maturity				Primary Distribution Method	
	R & D	Demo & Pilot Project	Early- Stage Com'l	Later- Stage Com'l	Centralized	Decentralized
Bioenergy						
Anaerobic Digestion for Biogas Production				•	•	•
Combined Heat and Power (CHP)				•	•	•
Co-firing in Fossil Fuel Power Plant				•	•	•
Combustion-based Power Plant				•	•	•
Gasification-based Power Plant			•		•	•
Direct Solar						
Photovoltaic (PV)				•	•	•
Concentrating PV (CPV)			•		•	•
Concentrating Solar Thermal Power (CSP)			•		•	•
Geothermal						
Hydrothermal, Condensing Flash				•	•	
Hydrothermal, Binary Cycle				•	•	
Engineered Geothermal Systems (EGS)		•			•	
Submarine Geothermal	•				•	
Hydropower						
Run-of-River				•	•	•
Reservoirs				•	•	•
Pumped Storage				•	•	
Hydrokinetic Turbines		•			•	•
Ocean Energy						
Wave		?			?	
Tidal Range				?	?	
Tidal Currents		?			?	
Ocean Currents	?				?	
Ocean Thermal Energy Conversion		?			?	
Salinity Gradients		?			?	
Wind Energy						
Onshore, Large Turbines				•	•	
Offshore, Large Turbines			•		•	
Distributed, Small Turbines				•		•
Higher-Altitude Wind Generators	•				•	

Notes

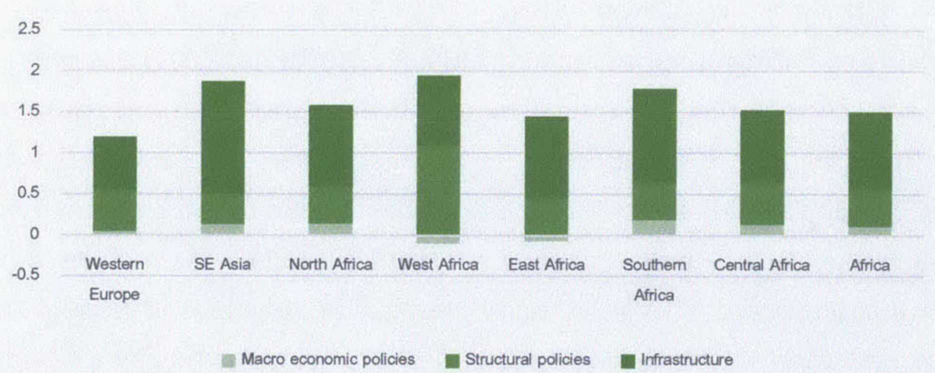
Com'l: Commercial; *Bioenergy technologies can also be combined with CCS, though CCS technology is at an earlier stage of maturity;

of maturity; ?: Information is unclear or unavailable

Source: Kamimoto et al. (2011)

While interest in renewable electricity generation is growing the recent, massive hydrocarbon discoveries of domestic natural gas in western, southern and eastern regions in Sub-Saharan Africa (Ghana, Mozambique, Uganda, and Tanzania) are shifting government and citizen perspectives about the need for significant investment in renewable electricity technologies.[32] The dominating perspective contends that natural gas will be a cheaper source of electricity in the long-run, and CO2 emissions from gas generation are less than emissions from the combustion of fossil fuels.[33] The hydrocarbon discoveries support the contention by economists that Africa's economic growth is positively surging forward with serious upticks in investment programs to catalyze infrastructure development, which is a major factor in per capita growth as indicated by Figure 5 (Robertson, 2012; World Bank, 2014c).[34]

FIGURE 5 | "CHANGES IN PER CAPITA GROWTH CAUSED BY CHANGES IN GROWTH FUNDAMENTALS,1990-2005."



Source: World Bank 2010 report; C'esar Calderon, "Infrastructure and Growth in Africa," 2008. as cited by Arron, John (2012).[34]

There is, however, reason for caution in the interpretation of rapid macro-economic growth and increases in foreign direct investment in SSA as such indicators are merely a subset of a complex development ecosystem, particularly with respect to building a reliable, clean electricity network. Economic growth does not guarantee increases in electricity consumption. For example, Wolde-Rufael's (2006) electricity investigation of 17 SSA countries, a rare study of the region, finds the following: positive unidirectional causality from real-GDP to electricity consumption in six countries; bi-directional causality between

32 Personal communication, Regional Commission of Mtwara, TZ, January 2013.

33 Personal communication, Regional Commission of Mtwara, TZ, TANESCO January 2013.

34 Actual percentages estimated based photocopy of Figure 11.2, Arron, John (2012).

energy and real-GDP in three countries; and unidirectional causality from energy consumption to real-GDP (Kahsai et al., 2012). Although the study is inconclusive, it suggests the conservation hypothesis[35] could be applied – electrification through low-carbon and renewable electricity sources may not have deleterious effects on economic growth or the environment. Furthermore, the assertion that SSA could devise an electricity approach that is environmentally advantageous and fundamentally different from the conventional centralized, large-scale power project paradigm is also theoretically and empirically supported by studies conducted by Apergis and Tang (2013), Kahsai et al. (2012), Sari & Soytas (2007) and the International Renewable Energy Agency (IRENA, 2011).

Section 1.3 | Electricity, Economic Development and Renewable Energy in Sub-Saharan Africa

According to an economics and policy study by Bhattacharya et al. (2012), sustainable electricity infrastructure development in SSA requires an increase in electricity infrastructure spending of approximately USD $40-210 billion (2008 prices)[36] per annum for low-emission, climate resilient infrastructure in the region (not including operation and maintenance) (see Figure 6 and 6.1).[37] This level of investment required for sustainable electricity development is far too great a financial burden for SSA governments to assume as country budgets are heavily reliant on aid (UNDP, 2011).[38] As such, in the coming years it is likely that advancing SSA's electricity plan will involve tens of billions of dollars in IFI assistance and foreign direct investment. Unsurprisingly, the foreign aid approach to mobilize extensive financial, technological and human capital resources for increased clean energy generation and access is grounded in comprehensive, utility-scale projects

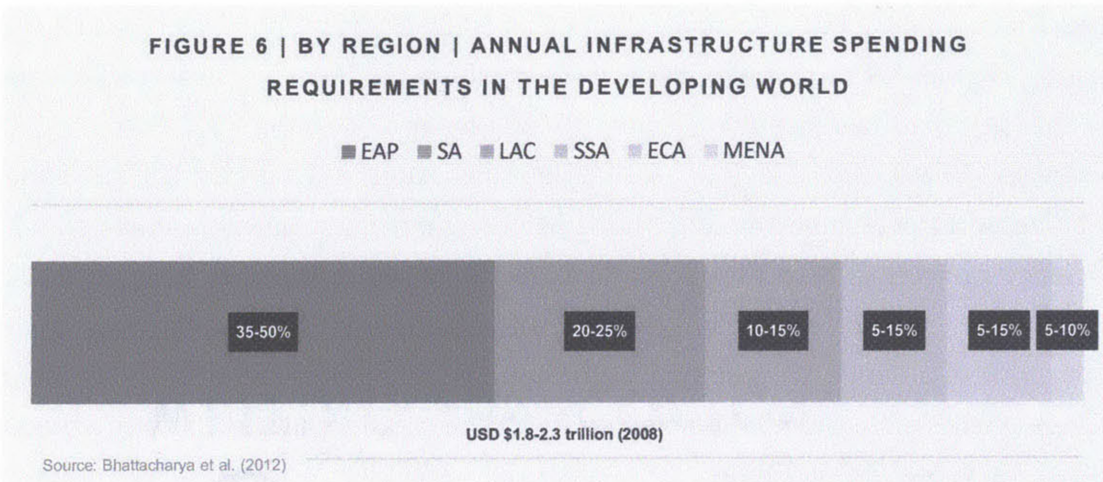
[35] See Box 1.

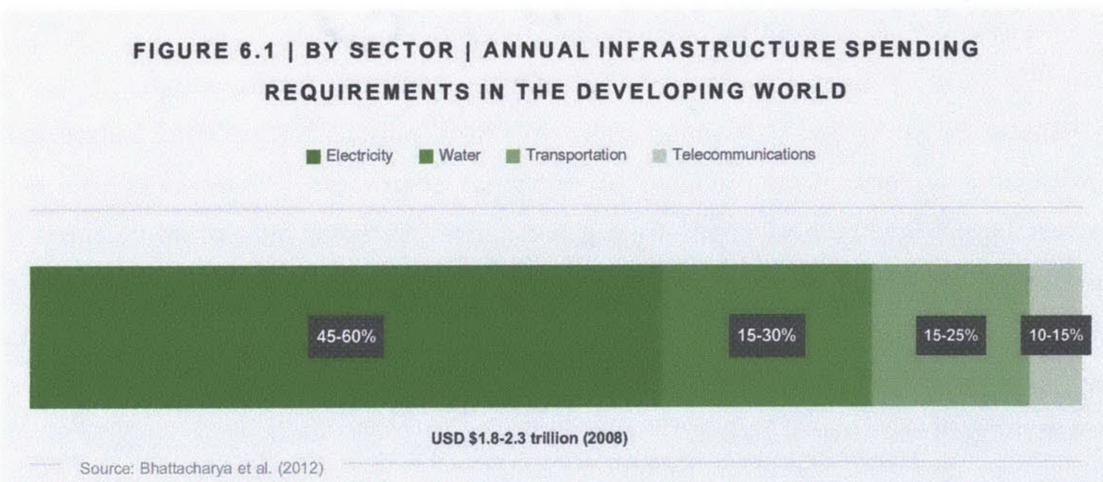
[36] Author's own calculations for SSA based on data from Bhattacharya et al. (2012).

[37]Bhattacharya et al. (2012) acknowledge the difficulty in making precise estimates due to data deficiencies in developing countries. Even so, IRENA's Africa Renewable Scenario, which assumes approximately 80% of all new capacity installed between 2010 and 2030 would be renewable, indicates a requisite increase in electricity expenditures (investment and fuel) of around USD $32 billion per year (IRENA, 2011). Renewable Scenario: "This scenario examines the impact of policies in Africa to actively promote the transition to a renewable-based electricity system to meet the growing needs of its citizens for electricity, to boost economic development, and improve electricity access. Importantly, this scenario achieves electricity access for all by 2030 and assumes concerted government action in the area of efficiency standards and programs." Source: IRENA, 2011.p. 3.

[38] SSA receives the largest volume of official aid assistance compared to other developing regions. In 2009 SSA received USD $42.2 billion (2011 prices), which accounted for the more than 25% of the total annual amount (UNDP, 2011).

organized through least-cost-planning (Clinton, William, Sachs, & Soloman, 2006; Sachs, 2013).





For example, in 2008, the World Bank , in partnership with four other multi-lateral development banks (MDBs)[39], launched the Climate Investment Fund (CIF), a USD $63 billion global MDB and private sector initiative created to provide developing and middle income countries with resources to reduce GHGs and mitigate climate change (World Bank, 2014b).[40] CIF funds clean technology, climate resilience and renewable energy programs in

[39] African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development and Inter-American Development Bank.

[40] Fourteen contributor countries have pledged a total of $8 billion to the CIF, which is expected to leverage an additional $55 billion from other sources. Funds per program: Clean Technology Fund, $5.5 billion; Forest Investment Program, $639 million; Pilot Program for Climate Resilience, $1.3 billion; and Scaling Up Renewable Energy in Low Income Countries Program, $551 million. Source: World Bank (2014a).

ten SSA countries.[41] The World Bank recently approved USD $115 million for a utility-scale renewable energy program to spur a global investment effort in renewable energy with a focus on geothermal (Lacerda & Hughes, 2013). In Kenya, for example, where the electrification rate is 19%, the government tapped USD $25 million from the CIF renewable energy program for the development of Menegai field, a 1600 megawatt (MW) geothermal site that is a step towards the country's 2030 vision to develop 5000 MW of geothermal energy (ADB, 2011; IEA, 2013).[42] Also, Nigeria is expected to utilize USD $100 million to mobilize additional investment of USD $455 million for renewable energy and energy efficiency projects to help fill its national electricity gap of 52% (IEA, 2013; World Bank, 2012). Finally, in Ethiopia, where the electrification rate is 23% and biomass accounts for nearly 90% of all energy consumed in the country the government is relying on USD $50 million in renewable energy financing for 75 MW of geothermal and 100 MW of wind power (IEA, 2013; World Bank, 2014a).

However, Sub-Saharan African large-scale, long-term, (clean) electricity projects have historically been challenged by market failures, multi-million dollar upfront investment requirements, financial risk, the time and cost to extend transmission and distribution systems, low incomes of potential customers, awareness and education barriers, weak utility and regulatory governance systems, lack of in-country technical knowledge capacity and rapid shifts in socio-demographic trends (Hammons et al., 2000; IPCC, 2012; Iwayemi, 1998; McDonald, 2009). The issues are complex, cross cutting and play a critical role in transforming the SSA ecosystem to improve viability of clean electricity generation and access.

The immense SSA clean energy electrification challenges for comprehensive, multi-megawatt projects, organized through least-cost-planning, arguably fueled an industry of decentralized, small-scale off-grid interventions – led by social enterprises, non-governmental organizations and foundations. The small-scale off-grid approaches typically operate in communities within isolated rural regions as grid connectivity continues to be an elusive aim. The underlying small-scale thinking suggests that large-scale, multi-

[41] Clean Technology Fund SSA countries: Nigeria and South Africa. Climate Resilience Fund SSA countries: Mozambique, Niger and Zambia. Renewable Energy Fund SSA countries: Ethiopia, Kenya, Liberia, Mali and Tanzania. Source: World Bank (2014a).

[42] The renewable energy program per the USD 25 million aims to support 500,000 households and 300,000 businesses. Kenya's total geothermal potential is 7,000MW, which three times Kenya's annual energy consumption. Currently, approximately 200 MW is currently utilized. (World Bank, 2014a).

development bank led policies, initiatives and investment strategies resemble tried market intervention concepts that fail to result in significant developmental improvements(McDonald, 2009). Economist William Easterly refers to the concept as "the big push déjá vu," whereby electricity as a tool for economic development features large increases in aid and complementary investments – an approach first made in the 1950s and 1960s (Easterly, 2006). In contrast, to utopian social and environmental engineering[43], economists suggest that incremental and piecemeal interventions are equipped to deftly respond to the aforementioned socio-economic issues that constrain the proliferation of clean electricity systems (Easterly, 2006). From 19th century theorists, such as Edmund Burke, to 21st century economists, such as Abhijit Banerjee and Ruimin He (2004), small-scale piecemeal interventions purportedly translate more effectively in local contexts that are often difficult to navigate (Easterly, 2006).

In practice, small-scale off-grid interventions are predominately driven by for-profit social enterprises and local informal businesses (Wilson et al., 2009). Social enterprises and local informal market players acutely recognize that eradication of electricity poverty, stimulation of economic growth, and mitigation of climate change differs greatly within and between villages and cities of a common geographic area. As a result, the development and diffusion of decentralized, small-scale off-grid renewable electricity generation and distribution systems is localized, ad hoc and erratic (Bellanca & Wilson, 2012; Wilson & Symons, 2013). The spectrum of small-scale off-grid projects range from household single LED light apparatuses to mini-grids for residences. The last decade realized a precipitous uptick in entrepreneurial offerings on the low-watt end of the spectrum, particularly in rural areas that lack access to grid-connected electricity services. In fact, there are hundreds of low-watt, solar powered LED lantern and battery charging residential and SME systems across SSA. For example, d.light solar produces LED solar powered lanterns and solar home systems that provide 8 and 15 hours of use (on a full battery), respectively, for Kenyan and Nigerian households (d.light solar, 2012). Other social enterprises such as Eight19, Solar Sister and Fenix International produce an array of low-watt, solar electricity products for low-income customers in Burundi, Rwanda, Senegal, Tanzania, Uganda, and other SSA countries. Beyond solar, other electricity generation sources, such bioenergy, are being used in rural areas to serve residences and businesses: Bio2Watt, a waste to electricity company

[43] Karl Reimund Popper, an early 20th century economist and philosopher of science, opposed "utopian social engineering," favored empirics over inductivist views (Easterly 2006, Stephen Thornton, "Karl Popper", in The Stanford Encyclopedia of Philosophy (Summer 2009 Edition), Edward N. Zalta (ed.).

operating single-digit MW projects in South Africa, and Husk Power Systems, a biomass mini power plant company that aims to provide electricity for 60,000 households in Tanzania.

However, many small-scale off-grid enterprises struggle to achieve scale and often fail at sustaining business operations (Bellanca & Wilson, 2012). Even though there is significant growth potential in SSA's clean energy sector the market is nascent. As a result, enterprises are hindered by a paucity of financial service providers (per the high risk of unproven business models, technologies and low rates of return on investment) and project development processes that fail to build apt, necessary strategic alliances and systems that allow for local buy-in and ownership (Bellanca & Wilson, 2012; Wilson & Symons, 2013). Hence, the bottom-up, "thinking small" approach to sustainable electrification development in SSA is evolving, highly fragmented and marked by semi-occasional stories of success.

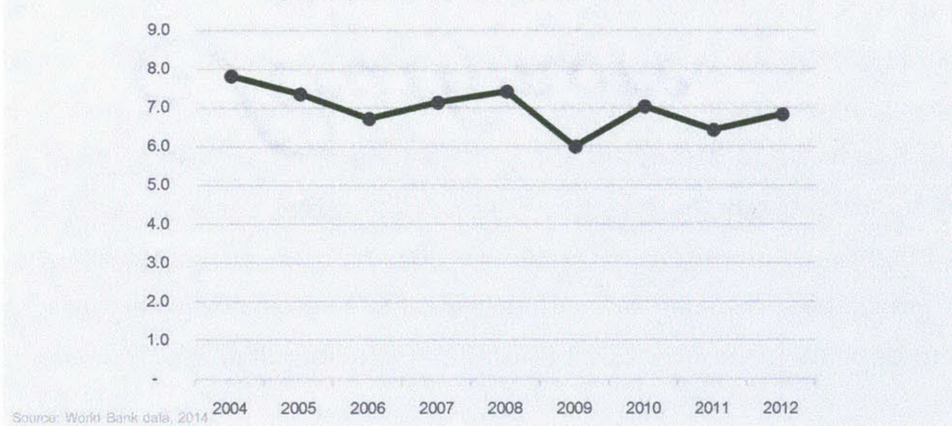
The critical electrification issue with the small-scale off-grid household level experimental pilots and the comprehensive, large-scale, least-cost-planning projects is that neither approach has been able to effectively meet the existing short-term demand in a way that supports entire socio-economic ecosystems – households, businesses, public entities and spaces – for communities within isolated rural regions.

The thesis is constructed around the premise that a sustainable development path to universal electrification in SSA is through an intensified focus on the middle of the development spectrum – mid-scale, community level electrification projects. Not the tried, conventional comprehensive, least-cost-planning approach nor the bottom-up, small-scale ad hoc method. History and econometric electricity consumption evidence demonstrate that these "large and small" mechanisms may not address generation and access in a sustainable development manner nor lead, absolutely, to sustained economic growth.

CHAPTER 2 |
TANZANIA

Tanzania is an east African sovereign nation. The country is geographically vast compared to the surrounding countries of Burundi, Rwanda, Uganda, Kenya and Malawi. Forty-four million Tanzanians live in largely underdeveloped peri-urban and isolated rural highland areas (United Republic of Tanzania, 2013a).[44] However, the main urban centers, such as Dar es Salaam and Mwanza, are advancing the country's economic growth, which since 2004 has been stable with an average rate of gross domestic product growth of seven percent (World Bank, 2014) (see Figure 7). Commerce in the urban centers is palpable and physical infrastructure is far more robust compared to the rest of the country.[45] In the rural areas, which constitute approximately 73% of the population, poverty is rampant and infrastructure, specifically electricity infrastructure is underdeveloped.

Figure 7 | Tanzania - GDP (annual %), 2004-20012



Section 2.0 | The Electrification Challenge – Historical Influences

Tanzania's insufficient and inadequate electricity infrastructure – defined by the low rate of electrification, intermittency and high technical losses – hinders national and per capita economic mobility. A mere 18% of the total population have access to electricity and only 4% of rural-dwelling Tanzanians have electricity access (MEM, 2013a). Those with access to the centralized main power grid experience frequent outages that prolong for

[44] Forty-four million is the population of mainland Tanzania. The Tanzania-Zanzibar includes an additional 1.3 million people. Source: (United Republic of Tanzania, 2013a).
[45] Sarah Dimson (2013a,b).

hours (Odhiambo, 2009). Furthermore, urbanization and rising incomes are straining not only the centralized main grid, but also the environment as rural populations are increasingly using kerosene and timber as power sources. Tanzania's current electricity sector deficiencies are steeped in its political economy. During the tenure of former President Julius Nyerere, from 1964 to 1985, the newly independent Tanzanian policies reflected an ideology of national unification and socialism. Nyerere's era of socialism took reign over all aspects of commerce and eventually resulted in scarce investment in electricity sector planning and development.

Today, Tanzania is still recovering from Nyerere's era of good intentions and misguided economic policies that significantly depressed the economy and failed to establish a conducive environment for investment in power infrastructure. Although policies are now in place to encourage investment in the electricity sector, institutional capacity is weak – evidenced, in part, by the insolvency of the state-owned utility company – and regulatory frameworks are only recently being developed to support alternative electricity paths, such as renewable energy (Eberhard & Kapika, 2013). Consideration for renewable energy in the future power generation mix is due, partially, to the evident cost of climate change, which has negatively effected Tanzania's GDP and livelihoods. The impacts of flooding and drought disproportionately affect Tanzania's poor as many are ill equipped to mitigate risk (Norrington-Davies & Thornton, 2011). As such, there is a critical need for heightened attention to Tanzania's extraordinary predicament – how to provide access to renewable power sources across Tanzania's vast, low-density geography apropos a poor, aid-dependent country that has limited institutional and technological capacity.

Section 2.1 | Geographic and Climate Considerations – Implications for the Electricity Sector

Tanzania's vast geography and evolving climate present economic, social and environmental challenges to implementing new power infrastructure, particularly for communities within isolated rural regions.[46] Tanzania is bordered by Uganda (northwest), Kenya (northeast), the Indian Ocean (east), Mozambique (south), Malawi (south), Zambia (southwest), Democratic Republic of Congo (west), Burundi (northwest) and Rwanda (northwest) (see Map 2).

[46] The total land area is 885,800 square kilometers (sq km) (CIA, 2014).

MAP 2 | TANZANIA

Source: Image, The World Factbook, online, April 15, 2014.

Tanzania's climate is tropical with regional variations and the majority of the country is highland except for along the 1,424 km coastline (McSweeney, New, & Lizcano, 2012; World Atlas, 2014).[47] From 1960 to 2012, the mean annual temperature increased by one degree Celsius and is estimated to increase to 2.7 degrees Celsius by the 2060s (McSweeney et al., 2012). Tanzania's expected climatic rise in temperature as well as changes in precipitation patterns have led climate researchers to forecast that severe bouts of drought, flooding, and tropical storms will increase in frequency (McSweeney et al., 2012; Norrington-Davies & Thornton, 2011). Such extreme weather conditions have adverse effects on Tanzania's economy, human development, and more specifically the development of its electricity sector. For example, in 2005/6 a major drought cost one percent of Tanzania's GDP (Norrington-Davies & Thornton, 2011). Another drought in 2012 led to power load-shedding, the acquisition of high-cost, high carbon emitting emergency power generation sources, and critically affected the financial health the

[47] The coastal regions are warm and humid and highland temperatures are moderate (McSweeney, New, & Lizcano, 2012).

primary state-owned electricity supplier, Tanzania Electricity Supply Company Limited (TANESCO) (MEM, 2013b). As indicated by IDIB (2012), with 80% of total employment based in the agricultural sector, the impacts of such severe changes in the climate can be devastating to rural communities and crippling the economy (as cited by Norrington-Davies & Thornton, 2011).

Further, the Intergovernmental Panel On Climate Change's (IPCC) most recent 2014 report suggests that poor, agricultural based communities are markedly vulnerable to climate change (United Nations, 2014). Therefore, in the context of energy poverty, the notion – purported by energy economists – that "energy poverty and climate change policies can be set independently from each other," is misguided in view of the IPCC's *very high confidence* that developing countries, for instance Tanzania, will realize substantial climate change impacts on account of economic dependence on agriculture, natural resources, low adaptive capacities and geographical locations (Chakravarty & Tavoni, 2013; Dodman et al., 2013).[48] Moreover, energy poverty scenarios that discount the importance of even the slightest affect that universal electricity access will have on the environment are perhaps missing a critical point. Given access to solid, scientific evidence (via the IPCC), available renewable energy technologies and scientific know-how, electricity sector policy makers and planners should make every effort to employ electricity systems that mitigate GHG emissions.

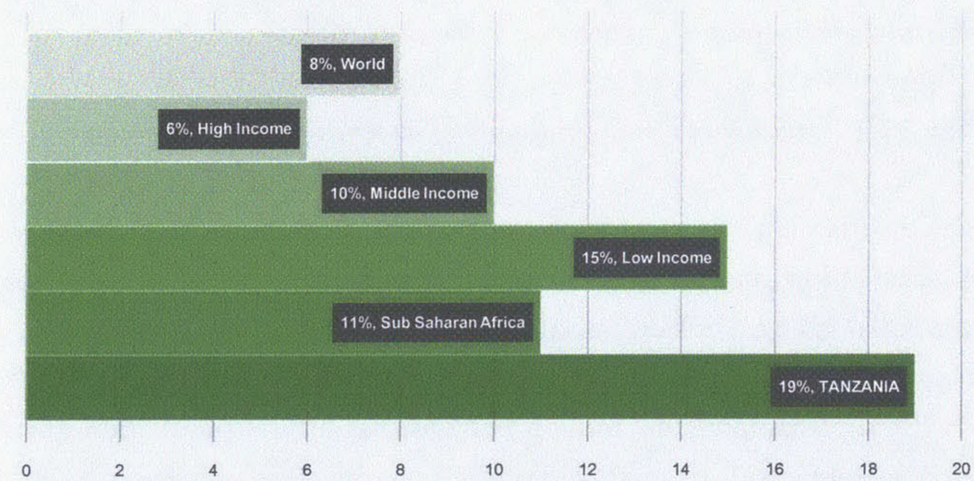
Tanzania's uncertain climate, geospatial arrangement between rural and urban communities and electricity poverty are some of the factors that prompted the government to include renewable energy sources (biomass, geothermal, wind and solar) in generation mix targets for improved energy security (MEM, 2013b).[49] The most recent policy target for renewable energy sources constitutes 14% of the total energy generation mix by 2015 (MEM, 2013b). However, this increased focus on renewables also aims toward

[48] Notes per methodologies and other per extrapolation IPPC Note: "The impacts of climate change on patterns of settlement, livelihoods and incomes in rural areas will be the result of multi-step causal chains of impact… One sort will involve extreme events, such as floods and storms, as they impact on rural infrastructure and cause direct loss of life. The other sort will involve impacts on agriculture or on ecosystems on which rural people depend. These impacts may themselves stem from extreme events, from changing patterns of extremes due to climate change, or from changes in mean conditions." See IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (Seneviratne et al.,2012).

[49] Tanzania does not have a national climate change strategy; however the Republic is a signatory to the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Also, Tanzania is an active participant in the Conference of Parties (COP), which is the decision making body for the UNFCCC (United Nations, 2014, See https://unfccc.int/bodies/body/6383.php (Norrington-Davies & Thornton, 2011).

strengthening reliability of supply through the main power grid, which suffers from high technical losses, at roughly 20%, and reaches only a fraction of the total population as many Tanzanians reside in rural, isolate areas (World Bank, 2013) (see Figure 8, Tanzania's technical losses compared to other regions, 2011).[50]

FIGURE 8 | TRANSMISSION AND DISTRIBUTION LOSSES % OF OUTPUT, 2011



Source: World Bank data, 2013.

In the short-term (2013-2017), the government of Tanzania (GOT) seeks to connect rural isolated regions to the main grid promptly and make use of Tanzania's ample renewable resources, particularly in view of climate change (MEM, 2013b). In order, to meet short to medium-term power needs that include a stock of renewable energy technologies, GOT needs to work expeditiously with a variety of stakeholders to improve the environment for renewable energy developers and investors and seek innovative financing solutions to cover high initial capital costs.[51] However, the renewable energy aims are seemingly quixotic as GOT lacks a national climate change strategy, which is important as the GOT is the initiator for the development of a climate change *paradigm* or *process* that can support access to necessary financial and technical assistance resources from IFIs and aid agencies (Norrington-Davies & Thornton, 2011). Extant research indicates that GOT is hesitant to develop broad climate change financing because financial aid assistance,

[50] The transmission and distribution losses of 20%, as reported in 2011 by the World Bank (2013), are of note because the government's generation mix plan is tailored towards centralized large-scale power sector planning.

[51] The Power Sector Management Plan (2013) investigates power supply in the short term (2013-2017) and finds that there is a shortage of power supply; further, a lack of immediate investment in generation may result in power load shedding.

pertinently for renewable energy generation, might shift away from other budgetary needs (Norrington-Davies & Thornton, 2011). However, GOT has taken tangible steps towards addressing renewable power and climate change mitigation, for instance through the finalization of the Scaling Up Renewable Energy program (SREP) (financed by various IFIs) (MEM, 2013b). Although SREP and other renewable energy programs (discussed herein) are steps in the right direction. Norrington-Davies and Thornton (2011) argue that Tanzania could take more aggressive steps towards climate mitigation and adaptation. But, the GOT is constrained by a lack of capacity and unclear processes.[52]

Section 2.2 | Population Demography and Geospatial Considerations

Tanzania's mainland population is approximately as 44 million persons with 73% of the population living in rural areas with low population densities, which poses a challenge for conventional grid expansion (as cited by World Bank, 2014). Moreover, the densities in rural and urban areas are changing rapidly. For example, Dar es Salaam, the largest urban area with approximately 4.4 million persons, has a high population growth rate at 5.6% (United Republic of Tanzania, 2013a). The electrification demands in Dar es Salaam often go unmet; as a result the Ministry of Housing Lands and Human Settlements developed a planning strategy to ease demands on urban infrastructure.[53]

Although urbanization is on the rise, the rural areas have about a two percent rate of population growth, very low densities as indicated in Table 2 and make up the greatest number of people living without access to modern electricity as most use costly and environmentally deleterious sources of power (i.e. small-scale off-grid options such as diesel, kerosene and timber).[54] For isolated rural grid-connected customers the grid is costly and dysfunctional – high unreliability due to inconsistencies in fuel availability, poor quality, frequent power outages and aged, dilapidated technologies.[55] More specifically apropos technology, the isolated grid is powered by diesel units with capacities of 1,500 kW or less, which are either out of service or in need of serious repair (MEM, 2013a). Accordingly, small-scale off-grid and isolated grid-connected power consumers lack

[52] See Appendix-4, TZ Renewable Energy Projects per the PSMP-13.
[53] Personal Communication, Ministry of Lands Housing and Human Settlements, March 2012.
[54] Four percent of Tanzania's rural population have access to electricity. The isolated rural grid system has a total nominal capacity of 81.5 MW (MEM, 2013).
[55] Sarah Dimson (2013b).

reliable, high quality sources of electricity, particularly of the type that is neither detrimental to the environment nor health.

TABLE 2 | TANZANIA'S REGIONS PER POPULATION DENSITY AND GROWTH RATE, 2012

	2012 Population	Land Area Sq. km	2012 Population Density	Growth Rate (%)
Mainland Regions*	43,625,354	883,343	50	2.7
Lindi*	**864,652**	**66,040**	**13**	**0.9**
Katavi	564,604	45,843	15	3.2
Ruvuma*	**1,376,891**	**63,669**	**22**	**2.1**
Iringa	941,238	35,503	27	1.1
Singida	1,370,637	49,340	28	2.3
Geita	1,739,530	20,054	28	2.6
Tabora	2,291,623	76,150	30	2.9
Morogoro	2,218,492	70,624	31	2.4
Manyara	1,425,131	44,522	32	3.2
Pwani	1,098,668	32,547	34	2.2
Rukwa*	**1,004,539**	**22,792**	**44**	**3.2**
Arusha	1,694,310	37,576	45	2.7
Mbeya	2,707,410	60,350	45	2.7
Dodoma	2,083,588	41,311	50	2.1
Kigoma*	**2,127,930**	**37,040**	**57**	**2.4**
Simiyu	1,584,157	25,212	63	1.8
Mtwara*	**1,270,854**	**16,710**	**76**	**1.2**
Tanga	2,045,205	26,677	77	2.2
Mara	1,743,830	21,760	80	2.5
Shinyanga	1,534,808	18,901	81	2.1
Njombe	702,097	21,347	81	0.8
Kagera*	**2,458,023**	**25,265**	**97**	**3.2**
Kilimanjaro	1,640,087	13,250	124	1.8
Mwanza	2,772,509	9,467	293	3.0
Dar es Salaam	4,364,541	1,393	3,133	5.6

Note: * indicates isolated rural load center per the Power Sector Management Plan, 2013.

Sources: MEM (2013); United Republic of Tanzania (2013).

Thus, given the dynamic nature of population growth, the distances of 100 km or more between isolated load centers as well as population densities, planning ministries are supporting the policies and plans for the development of small-to-medium sized cities in peri-urban and rural areas. The trend is evidenced by development plans in the low-density peri-urban and rural areas of Bunju, Kigamboni, Kimbigi, Pugu and communities within other isolated rural regions.[56] Essentially, Tanzania's population demography and settlement migration patterns reinforce an opportunity to decentralize power supply, reduce technical losses with shorter transmission and distribution distances and decrease dependence on costly, fossil fuel power systems, particularly in communities within isolated rural regions.

Section 2.3 | Political Structure and Economy

The fall and rise of Tanzania's economy is contextually relevant to the electricity sector because the need for fiscal reform catalyzed the inflow of official development assistance and marked a turning point for how electricity infrastructure was planned and financed in the ensuing decades. Following independence, former President Nyerere nationalized all imperative, functional dimensions of socio-economic progress: banking, education, land, public services, institutional systems, and the agricultural sector, which continues to be a major component of Tanzania's economic production.[57] More specifically, Nyerere's administration (1964-1985) promoted Ujamaa Socialism: inter-linked, self-governing village communities that sought to distribute wealth equitability. Nyerere focused on the need for communities to operate at an economically advantageous scale, to use advancing technologies and plan development in a practical, strategic manner:

> "We are not trying to go backwards into the traditional past; we are trying to retain the traditional values of human equality and dignity while taking advantage of modern knowledge about the advantages of *scale* and *improved tools*. But, inevitably this requires some adaptation in traditional social organization; it requires...a conscious effort to utilize the strength of united activity for social purposes. In the past we worked together because that was custom; now we have to do it *deliberately*..." (Nyerere, 1973).[58]

Fundamentally, Nyerere advocated for national unification by means of community-level planning. Nyerere espoused complete government control – in a manner that surpassed any other country in Sub-Saharan Africa at the time as the private sector was

[56] Personal Communication, Ministry of Lands Housing and Human Settlements, March 28, 2012.

[57] Nyerere expanded the authority of the government's rule over land, abrogated all freehold titles, and issued a series of conversion laws such that all land was vested with the President in perpetuity (Veit, Vhugen, & Miner, 2012).

[58] President Nyerere made the remarks on January 1, 1968 in a speech that aimed to expand principles outlined in a policy paper entitled "Socialism and Rural Development." Source: Nyerere, 1973, pp.5-11.

severely suppressed (Temu & Due, 2000).[59] State dominance, exercised through Ujamma Socialism, eventually led to profound, adverse effects on Tanzania's economy. On a micro level, domestic commodities became scarce and households lived without sufficient provisions (as cited by Temu & Due, 2000). The macro-economic structure also weakened under Ujamma Socialism: agricultural production declined; exports of cash crops dropped significantly and inflation was high (Nord et al., 2009). The World Bank (1990) reports that the economy declined 0.5 percent a year between 1965 to 1990 (as cited by Lewis, 1990). Moreover, social services, such as education and health declined (Temu & Due, 2000). By the time Nyerere appointed his successor, President Ali Hassan Mwinyi, in 1985 Tanzania's entire socio-economic structure was in need of major structural transformations (Mette Kjaer, 2004; Temu & Due, 2000).[60]

The International Monetary Fund (IMF) and the World Bank (WB) stepped in with economic reform programs, such as the Economic Recovery Programs I and II, to break down the GOT's controlling techniques, liberalize financial markets, civil service, state owned enterprises, parastatals, and promote private sector participation (Mette Kjaer, 2004; Temu & Due, 2000). The economy opened for serious growth through the following: removal of price, production and marketing controls; unification of the exchange rate, liberalization of foreign trade; privatization and reform of parastatals; and market-oriented regulatory reforms (Nord et al., 2009).[61]

Hence, liberalization of key sectors, the move towards a market-based economy and prolonged social concord is the foundation of Tanzania's present stable, emergent economic growth and social progress.

Today, Tanzania's economy is progressing steadily: GDP has remained above six percent since 2004; GNI per capita income has nearly doubled in the last ten years; and debt ratios are on the decline since 1986 (Nord et al., 2009; World Bank, 2014). During the 2008 global financial crisis, macro-economic stabilization mechanisms and fiscal reform

[59] Private sector business persons were considered to be capitalist exploiters. Source: Temu & Due (2000, p.3).
[60] Nyerere's TANU party merged with a Zanzibari party and in 1977 changed the political party name to Chama Cha Mapinduzi (CCM). Source: Mette Kjaer (2004).
[61] As a result of liberalization and macroeconomic reforms, Tanzania received widespread financial support from foreign aid agencies. Source (Nord, et al., 2009, p. 50). Serious socio-economic adjustments, reforms and changes in administrations occurred peacefully; this is notable given historical civil conflicts in the surrounding nation-states. The national accord is often credited to Nyerere's principles of political and social union (Mette Kjaer, 2004; Nord et al., 2009; Temu & Due, 2000).

strategies fortified the economy against a potential economic breakdown. Further, in 2012 the Economist and IMF reported that Tanzania is among sub-Saharan Africa's top three fastest-growing economies (The Economist, 2011). Services, industry and vital construction projects drove growth - much of which occurred in Dar es Salaam, Tanzania's predominant executive and commercial business center. In 2013, GDP (PPP) was roughly USD $80 billion (CIA, 2014). GDP consisted of services at 47.4%, agriculture at 27.6% and industry at 25% (CIA, 2014). The agricultural sector provides 85% of exports and employs 80% of Tanzania's workforce, which is predominately made of low-skilled youth and adults (CIA, 2014). Estimates of GDP per capita (PPP) range from USD $1,300-$1,600 (2012) – although per capita incomes are low, growth is occurring (CIA, 2014; United Nations, 2013; World Bank, 2014). Tanzanians are hopeful that the combination of improving economic conditions and recent discoveries of on and off-shore domestic natural gas will further advance socio-economic progress and catalyze increases in foreign direct investment (FDI).[62] Hydrocarbon and mineral exploration, exploitation, and supporting operational logistic services are expected to bring hundreds of billions of FDI dollars to Tanzania.[63] The most recent discoveries started in 2010 and by 2013 natural gas finds exceeded 40 trillion cubic feet (tcf) (Simbakalia, 2013).[64] The degree of natural gas resources is affecting the country's outlook on the critical areas of transformative growth, namely infrastructure development.[65]

However, the optimism is greatly tempered by Tanzania's ability to appropriately leverage hydrocarbon resources given its' lack of institutional capacity and human development (Simbakalia, 2013). Human development in Tanzania is low. Tanzania's 2012 Human Development Indicator (HDI) rank is 152 (out of a total of 187) with GNI per capital income of about USD $1,300, a mean year of adult schooling at approximately five years, and 65.6% of the population live in abject, multi-dimensional poverty.[66] Tanzania's current poverty policy, the National Strategy for Growth and Reduction of Poverty (NSGRP II), is

[62] Sarah Dimson (2013a); National Five Year Development Plan-2010/11-2015/16 the Tanzania Development Vision 2025.

[63] Current gas and oil exploration companies: BG Group, ExxonMobil, Maurel & Prom, Ndovu Resources, Ophir Energy, Petrobras, Statoil and Wentworth Resources. Logistics and support services enterprises: Halliburton, Schlumberger, and Solvochem. Sources: Personal communication, Regional Commission of Mtwara, Tanzania, January 2013; Simbakalia (2013).

[64] As a point of reference, U.S. proved reserved of wet natural gas as of December 31, 2010 is reported at a total of 49.9 tcf. Source: (EIA, 2013).

[65] Personal communication, Regional Commission of Mtwara, TZ, TANESCO, July 2013; Simbakalia (2013).

[66] The UN and the Oxford Poverty and Human Development Initiative developed the multi-dimensional poverty index in 2010. The index uses various indicators, other than income, to calculate a level of poverty. Source: UNDP (2014).

dependent on the national budget, which is financed, in large part, by foreign donor aid.[67] In 2009, aid financed 40% of the Tanzania's government operations (Nord et al., 2009). IFIs and aid development agencies are increasingly investing in financial and capacity building resources to support infrastructure development, particularly to address Tanzania's low Energy Development Index (EDI) ranking, an index developed by the International Energy Agency (IEA) to analyze to role that energy plays in human development per the HDI (IEA, 2012).[68] Tanzania's EDI ranking for household electrification and consumption are among the lowest in the world (IEA, 2012).

Section 2.4 | Electricity Sector – History and Current State

Tanzania's household as well as commercial and industrial electrification has been limited since post-colonial rule. The first public electricity entity was established under German colonial rule and transferred to Great Britain in 1920 (TANESCO, 2014). Great Britain established the Government Electricity Department (GED) in Dar es Salaam. In 1931, two private companies, Tanganyika Electric Supply Company Limited (TESC) and Dar es Salaam and District Electric Supply Company Ltd (DARESCO), purchased GED (TANESCO, 2014). Once Tanzania gained independence, former President Julius Nyerere nationalized the electricity sector. By 1975, the government owned all shares in TESC and DARESCO and the entity was renamed Tanzania Electric Supply Company Limited (TANESCO).[69] TANESCO was the sole parastatal organization responsible for electricity generation, transmission, distribution and sales to Tanzanian enterprises, households and industrial customers. Once markets were liberalized, in 1999 the government unbundled TANESCO and allowed private sector participation in the form of independent power producers (IPPs) (Mwasumbi & Tzoneva, 2007; TANESCO, 2014).[70]

[67] In 2005, Tanzania developed a poverty framework, Mpango wa Pili wa Kukuza Uchumi na Kuondoa Umaskini Tanzania (MKUKUTA I), to reduce poverty and improve living standards and social welfare. MKUKUTA II, also known as the National Strategy for Growth and Reduction of Poverty (NSGRP II), also focuses on poverty reduction and is aligned with Tanzania's development vision to reach middle-income status by 2025 (United Republic of Tanzania, 2010).

[68] EDI calculation: "is calculated in such a way as to mirror the UNDP's Human Development Index and is composed of four indicators, each of which captures a specific aspect of potential energy poverty: Per capita commercial energy consumption; per capita electricity consumption in the residential sector; share of modern fuels in total residential sector energy use; and share of population with access to electricity." (IEA, 2011).

[69] The name change from "Tanganyika" to "Tanzania" Electric Supply Company Limited after independence. The Government is the sole shareholder.

[70] As of 2014, the grid-connected (permanent and rental) IPPs in operation are Independent Power Tanzania Ltd (IPTL) and Songo Gas (SONGAS). Source: UNDP (2014).

Today, the Ministry of Energy and Minerals (MEM) oversees power (electricity) planning and development in Tanzania.[71] MEM provides oversight to electricity parastatals, works with various government agencies to produce the country's power sector management plans, and engages a broad range of public and private stakeholders to deliver electricity services. In the late 1990s through the early 2000s, Tanzania instituted a range of legal frameworks to guide MEM's activities and give proper structure to a fledgling electricity sector. For example, The National Energy Policy-2003 (NEP-03) revised the initial domineering energy policy of 1992 as it modified the role of government and provisions for IPPs.[72] NEP-03 was followed by seminal electricity policy, such as the establishment of the Rural Energy Act-2005, which established the Rural Energy Agency (REA). Also, the Energy and Water Utilities Regulatory Authority Act-2001 led to Tanzania's first independent regulator, EWURA, which commenced operations in 2005 (MEM, 2013a; Mwasumbi & Tzoneva, 2007). REA leads grid extension, generation and access initiatives, such as the Tanzania Energy Development and Access Expansion Program (TEDAP), as well as research and development activities for isolated rural regions (MEM, 2013a).

Tanzania's total installed generation capacity is 1,466 MW (MEM, 2013a).[73] The percentage of total installed capacity generated from thermal sources is 61.5% and hydro constitutes 38.5%.[74] Renewable electricity sources, other than hydro, are not currently part of Tanzania's electricity generation mix. The IEA (2011) reports that in years 2010 and 2011 electricity production was 5.106 billion kWh and 5.302 billion kWh, respectively (World Bank, 2014). Overall, MEM (2013) finds that the current electrification rate is 18.4% and 4% in rural areas. Moreover, the IEA (2010; 2011) finds that overall per capita electricity consumption in 2010 and 2011 was 91 kWh and 92 kWh, respectively (World Bank, 2014).[75] To put consumption in perspective note that throughout the 21st century Tanzania's annual per capita electricity consumption rates have ranked well below global, aggregate low-

[71] See Appendix-5, TZ Electricity Sector Organizational Chart; The first public electricity entity was established under German colonists and transferred to Great Britain in 1920. Great Britain formed a Government Electricity Department in Dar es Salaam (TANESCO, 2014).
[72] NEP-03 objective: "to provide an input in the development process by establishing an efficient energy production, procurement, transportation, distribution, and end-user systems in an environmentally sound manner and with due regard to gender issues" (United Republic of Tanzania, 2003).
[73] The MEM (2013) SREP report indicates an installed capacity of 1,564 MW as of March 2013.
[74] Percentages are author's own calculations based on MEM (2013) data for total installed capacity at 1,466 MW of which thermal is 900.7 MW and hydro is 565 MW.
[75] Electric power consumption definition: Measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants. Source: International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp), Energy Statistics and Balances of Non-OECD Countries and Energy Statistics of OECD Countries World Bank (2014).

income country averages. For instance, the IEA (2011) attests that in 2011 the per capita low-income country average was 233 kWh per capita (World Bank, 2013).[76] At the household level, fuel-wood and charcoal make up 85.5% of total energy consumption; electricity accounts for merely 6% of total energy use (MEM, 2013a). Electricity sources also include an array of decentralized small-scale low-watt solar photovoltaic methods, mini-hydro systems and diesel generators (MEM, 2013b).[77]

Section 2.5 – Electricity Sector Planning

In 2013, MEM released the latest Power Sector Management Plan (PSMP-13) to align electricity generation, access, energy security with poverty reduction and economic growth policies and plans for rural and urban areas (MEM, 2013a). The fundamental objectives of the plan are to accelerate nation-wide electrification from the 2013 level of 18.4% to 30% by 2025.[78] MEM is seeking to realize the aims in partnership with IFIs, aid agencies and social enterprises. For example, MEM partnered with the World Bank to develop SREP, a USD $720 million effort to increase electricity supply from renewable energy sources and demonstrate the viability of a clean energy pathway to electrification in urban and rural Tanzania (MEM, 2013b).[79] SREP is designed catalyze parallel investments in large-scale, main grid projects, such as geothermal (total potential capacity is 650MW), solar (total potential capacity is 800MW) wind (50MW – 100MW projects), and small-scale off-grid power projects powered by mini-hydro and solar (MEM, 2013b).[80] Further, Power Africa, a United States Agency for International Development (USAID) electricity initiative, aims to increase electricity access and reliability by through direct investment and technical assistance for policy enhancements. Similar to SREP, Power Africa also seeks to catalyze the development of an environment that is conducive for private sector investment in grid and off-grid electrification systems, particularly those that utilize clean energy sources (USAID, 2014). Power Africa differs from SREP in the degree to which the initiative calls upon resource support from other US agencies, US and European IFIs, private investment banks and companies. To date, the projects of public acclaim are notably large-scale

[76] Consumption in developed countries, such as the United States and the United Kingdom, is reportedly 13,246 kWh and 5,516 kWh, respectively for the 2011 period.
[77] Sarah Dimson (2013a).
[78] MEM's 2013 electrification estimate of 18.4% is up from the IEA, World Energy Outlook report, which reports a 2011 electrification rate of 15%.
[79] Solar potential calculated by MEM (2013): theoretical model assumes a 20% capacity factor and power demand of 27,000 GWh.
[80] Small power projects, which are under the purview of REA, are defined as those between 100kW and 10MW.

ventures, such as the Symbion Power-General Electric transaction for a 400MW gas generation plant and transmission infrastructure (USAID, 2014). Beyond projects that are resourced by deep pockets, there are a vast range of clean energy generation and distribution projects that provide small-scale off-grid power products and services to communities within rural isolated regions.[81] Decentralized mid-scale developments – those serving households, businesses and public centers and industrial customers – are most common in isolated rural regions, but are marked by high cost poor technology (e.g. dated diesel generators), unreliability and lack a robust codified development plan in the short-term.

Section 2. 5.1 | Electricity Sector Planning - Challenges and Opportunities

President Kiwete's current National Development Plan (Vision 2025) calls for 2,780 MW to be installed by 2015 – an increase of nearly 90%. Vision 2025 suggests, unequivocally, that the increases in electricity are paramount to economic growth and social welfare; therefore the long-term goal seeks electrification for at least 75% of the population by 2035 (MEM, 2013b). As such, the emphasis of the PSMP-13 is on generation and planning for a long-term, 2035 electricity plan, which includes coal (3800 MW), hydro (3304 MW), gas (995 MW) and renewables (solar, wind and biomass for a total of 260 MW) (MEM, 2013a), has an estimated investment cost of USD $27 billion for generation alone.[82] The PSMP-13 conclusions for the short-term, a 5-year time increment that is of interest apropos the *opportunistic* dimension of my proposed paradigm shift, state there "are very few options available to meet the expected demand for power" (MEM, 2013a). The short-term electricity assumption centers on a long-term plan to connect isolated, rural areas to the main grid. The load centers for the rural areas are more than 220 kilometers from the main grid (see Chapter 3) (MEM, 2013a). Therefore, through the long-term approach rural dwelling Tanzanians will likely continue, for another decade, to deforest land, use kerosene and low-watt household applications. In fact, studied universal access scenarios substantiate the above conjecture, as consumption assumptions through 2030 show modest increases from roughly 100 kWh per capita per year to 250 kWh per capita per year (IEA, 2013).

Further, for short-term planning and implementation, MEM advises the development of sustainable development plans that are based on the long-term base case

[81] Sarah Dimson (2013a).
[82] MEM notes that data and information used to inform the PSMP-13 was inconsistent and outdated (MEM, 2013).

and isolated regions should seek to be grid-connected "...as soon as it is feasible, " yet a detailed plan to do so, outside of the long-term, least cost planning approach, is absent (MEM, 2013a). As a result, programs such as SREP, and other small-scale private and non-governmental renewable electricity interventions seek to meet present household load demands. However, the ideologies of both the big projects, big investment approach and the household pilot interventions, have been practiced for decades and neither has been able to provide ready access to hundreds of thousands of Tanzanians. The a priori theory is sound – increases in electricity consumption lead to economic growth prima facie, but the practices fail to address the nexus of the constraints to renewable electricity generation, access and consumption.

CHAPTER 3 | MID SCALE OPPORTUNISTIC AND PLURALITIC PLANNING RESULTS & DISCUSSION - TANZANIA

The thesis presents the *mid-scale opportunistic and pluralistic planning paradigm* because modern power planning and implementation strategies for communities within Tanzania's isolated rural regions are lacking and incipient. The two dominate approaches to electrification - centralized, large-scale grid systems conceived through least-cost-planning (LCP); and decentralized, small-scale off-grid systems administered through entrepreneurial pilots – have not demonstrated an ability to address, in an expansive manner, the acute need for electricity services for communities within isolated rural regions.[83] As discussed in Chapter 2, the centralized least-cost-planning option is top-down and aged – derived in the 1970s by utility experts and instituted as a global best practice (Hanson, Kidwell, Ray, & Stevenson, 1991). Decentralized small-scale off-grid practices are bottom-up and nascent – gathering momentum in the 2000s but stymied by operational inefficiencies (Wilson et al., 2009).

A *mid-scale opportunistic and pluralistic planning* paradigm addresses the issues that have constrained the efficacy of extant electrification approaches. The paradigm brings together policy elements from least-cost-planning and strategies from entrepreneurial improvisations. Further, the paradigm promotes planning in-situ – electricity developers working from inside local communities to understand how to best leverage community resources and the most pertinent aspects of top-down and bottom-up methodologies.

Chapter 3 discusses the paradigm in detail and in context of communities within isolated rural regions, specifically the region of Mtwara. Chapter 3 also suggests that small power producers (SPPs), legally defined in Tanzania as developers that employ electricity systems with capacities between 100kW to 10MW, lead generation and access efforts for communities within isolated rural regions (EWURA, 2012).[84] This contention is analyzed in context of a Tanzanian SPP renewable energy scenario and in comparison to specific

[83] Isolated rural regions: the official term used by the Government of Tanzania that refers to administrative areas within the country that do not have access to the main / national grid system. There are a total of 25 official urban and rural regions in Tanzania (see Table 2).

[84] This case study suggests that in the short-term the most advantageous scenario is for SPPs to sell power directly to retail customers. In the medium to long-term and based on institutional, economic and technological factors, the other possible scenarios for mid-scale mini-grid systems in isolated rural regions is for power sales to the utility (TANESCO), or power sales to both retail customers and TANESCO once institutional and financial issues are resolved (see Chapter 3 recommendations).

aspects of the GOT Power Sector Management Plan (2013), which seeks to connect isolated rural regions, such as Mtwara, to the main grid in the short-term (2013-2017). Chapter 3 concludes with a discussion about Tanzania's key renewable electricity generation and access barriers and opportunities. This discussion is conducted in relation to the mid-scale opportunistic and pluralistic paradigm.

Section 3.0 | Paradigm definition and assumptions in context of Tanzania

In this thesis, *mid-scale* refers to the size of a renewable energy system (watts) and the corresponding financial investment.[85] The use of renewables is justified per Tanzania's evolving climate conditions as well as scientific conjectures concerning the need to develop policy that can mitigate, ex ante, CO2 emissions. Furthermore, the IFI and aid agency power bent is for clean energy technologies and as such, financial and technical assistance can be leveraged accordingly.[86] *Opportunistic planning* requires understanding of how a complex electricity system is affected by rapidly accelerating changes in population, production and technology. According to systems management engineer John Sterman (2000) comprehension of how the Law of Acceleration applies to a sector, country and problem is paramount to the development of good policy.[87] Based on this perspective, which is descriptive of Tanzania's emerging demography and economy, my contention is that planners and policy makers opportunistically leverage existing resources – natural, financial, political, human capital, and scientific knowledge – in real-time in order to understand how to meet current socio-economic demands and develop apt electrification policies. *Pluralistic planning*, an approach coined by Henry Davidoff (1965), posits that community-level policies and plans necessarily represent government and stakeholder interests, particularly minority interests – it is deep, focused and equitable stakeholder engagement.

Hence, the *mid-scale opportunistic and pluralistic planning* paradigm is a synthesis of established, intricate theories and practices as well as my own findings, based on specialized research and field experience, of how planners, policy makers and practioners might approach increasing electricity supply and access in complex, dynamic Sub-Saharan

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[85] Flexibility in the design of the technology is paramount per forecasted population growth, short to medium-term electricity demand and climate considerations.

[86] Refer to Chapters 1 and 2.

[87] Sterman's policy development process is called Systems Dynamics - an interdisciplinary (cognitive and social psychology, economics, and other social sciences) method to understand complex systems or the Law of Acceleration (founded by Henry Adams). Systems dynamics is grounded in the theory of nonlinear dynamics and based on mathematics, physics and engineering (Sterman, 2000).

African environments.[88] In Tanzania, the paradigm translates to providing electricity, in the short–term (within five years)[89], to communities within isolated rural regions through SPPs that use renewable energy on isolated mini-grid systems – providing access to clean and reliable electricity for communities: households, small and medium-sized enterprises, public centers and open spaces (e.g. health care centers, schools and street lighting).[90]

The underlying assumptions of the mid-scale opportunistic and pluralistic paradigm, specific to Tanzania, include the following:

- economic growth is catalyzed by a process that brings together institutions, technology the environment and culture (Sachs, 2013);

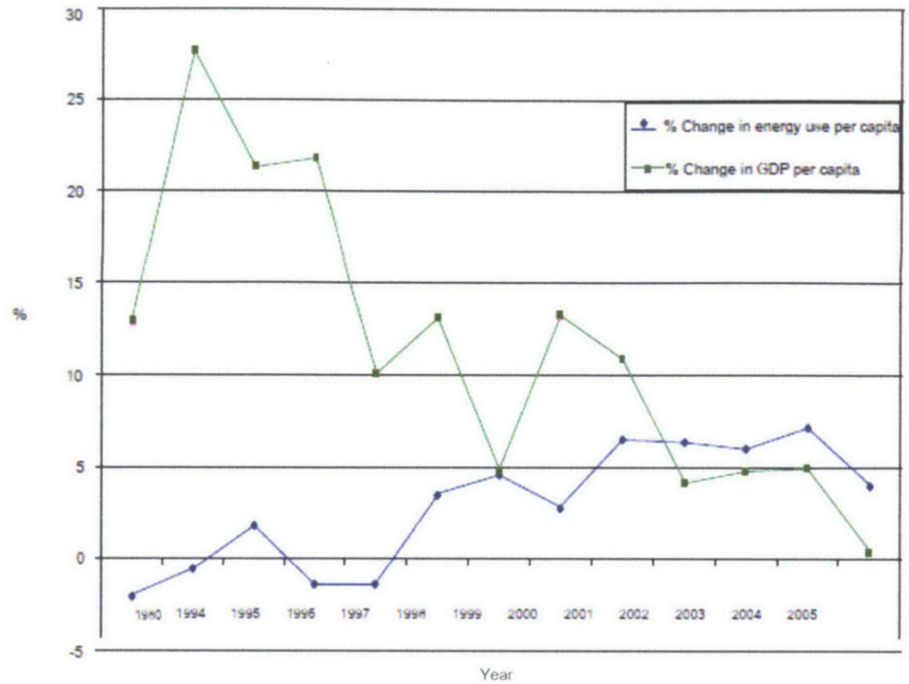
- increases in electricity consumption leads to economic growth in the short-run (prima-facie) in Tanzania (Odhiambo, 2009);[91] (see Figure 9, TZ Energy (electricity) Consumption-Economic Growth per capita, 1994-2005).

- in low-income countries substantial energy consumption is not likely to bring significant economic growth, but will increase CO_2 emissions; and as corollary, energy conservation and efficiency policies that support the use of renewables may have positive effects on the economy without putting considerable pressure on the environment (Apergis & Tang, 2013; Huang, Hwang, & Yang, 2008; Sari & Soytas, 2007); and

- confidence in the Intergovernmental Panel on Climate Change's claim that developing countries will realize substantial climate change impacts on account of economic dependence on agriculture, natural resources, low adaptive capacities and geographical locations (Chakravarty & Tavoni, 2013).

[88] See Methodology for information on specialized research and field experience.
[89] The five-year period is consistent with the PSMP-13 language per time periods (e.g. short-term is five years, 2013-2017). In addition, government administrations operate on five-year increments and as such PSMP plans may be subject to change.
[90] On a household level, renewable energy mini-grids provide service to Electricity Access Tiers 4 and 5, as defined by the IEA and World Bank (2014), and beyond. Tiers 4 and 5 in detail: peak available capacity (W) of more than 2,000 and use for at least 16 hours (Tier 4) or 22 hours (Tier 5) or more (4 or more hours during the evening). At Tiers 4 and 5 medium and high-powered appliances, respectively, can be utilized.
[91] See Box 1.

FIGURE 9 | Energy Consumption-Economic Growth Per Capita, 1994-2005



Notes: Trends of energy consumption per capita and economic growth during the period 1994–2005 as compared to 1980. *Source:* Odhiambo (2009) computation from the World Development Indicators CD-ROM, 2007; International Financial Statistics Yearbook, 2007.

Section 3.1 | Paradigm Shift from Least-Cost-Planning to Mid-scale Opportunistic and Pluralistic Planning

The thesis' premise for a paradigm shift - from the intense resource allocations on connecting isolated load centers to the main grid to decentralized renewable energy for communities within isolated rural regions – intends to create more alternative pathways for public and private resources to flow, to SPPs and communities, in order to expeditiously electrify households, businesses, public centers and spaces. The conviction and push for a shift emanates from the following barriers to electricity generation and access:

- low electrification rates;
- fledgling institutional operational and technical capacity;
- aged and dilapidated technology; and
- economic factors.[92]

In addition, the least-cost-planning (LCP) approach to short-term generation and access issues for isolated rural regions is ambiguous and confounding, evidenced in part by the

[92] Refer to Chapter 2.

planning conclusions made by the Ministry of Energy and Minerals in most recent Power Sector Management Plan (2013). The conclusions affirm: there is an "urgent need" to rectify the shortage of supply in the short-term (2013-2017); however, limited options are available to meet short-term demands; and yet, isolated rural load centers should be connected to the main grid in the short-term and "as soon as possible" (MEM, 2013a). The subsequent planning question that arises is: *what planning process can address high demand, with multiple supply options, limited in-country human, financial and technological resources, and fast?* I posit that the answer lay in opportunistic and pluralistic planning paradigm - administered by a planning agent on behalf of SPPs.

The government of Tanzania (GOT) aims to connect isolated rural load centers to the main grid by 2019 ("Isolated Load Plan"). The chief underlying assumptions driving the objective are that prices (tariffs) will be driven down with economies of scale, and improvements in access and increases in consumption will all work together to catalyze economic growth (MEM, 2013a). As such, the Isolated Load Plan is organized in accordance with least-cost-planning: energy services at a minimum cost and in consideration of relevant factors for the development of long-term (e.g. 20-year) plans (Hanson et al., 1991). Therefore, looking towards year 2035 the Isolated Load Plan suggests connecting five regions - Kagera, Kigoma, Lindi, Mtwara and Rukwa – as soon as the load capacity reaches a minimum economically feasible point, which is in the short-term (less than 5 years and by 2015) for all of the regions. (MEM, 2013a) (see Table 3, Tanzania Power Sector Management Plan (2013) Isolated Load Grid Connection Plan).

TABLE 3 | TZ POWER SECTOR MANAGEMENT PLAN (2013) ISOLATED LOAD GRID CONNECTION PLAN

Isolated Rural Region	Distance from grid (km)	Load in 2010 (MW)	Load minimum per grid connection feasibility (MW)	Projected year for grid connection	Projected Load in 2035 (MW)
Kagera	220	11.4	10	Now	383
Mtwara	**353**	**10.2**	**15**	**2013**	**271**
Rukwa	340	5.8	15	2015	134
Kigoma	280	5.4	10	2014	184
Lindi	353	1.2	15	2013	179

Note: Ruvuma - not listed because at advanced stage of grid connectivity

Source: MEM (2013)

The cost to grid-connect isolated rural regions ranges between USD $18 to $28 million (MEM, 2013a).[93] Mtwara's distance is the greatest at nearly 360 km from the main grid and scheduled for connection in 2013.[94] However, based on the aforementioned barriers to generation and access, Mtwara's population density and geospatial considerations, field observations, and the renewable energy SPP business framework by Tenenbaum et al. (2014), presented herein, I question the degree to which a conventional grid-connection LCP approach makes economic, social and environmental sense in Mtwara.[95]

Notably, small-scale off-grid solutions in Mtwara were neither visibly present nor were entrepreneurial pilots in operation during the field research period for this thesis.[96] Moreover, the GOT does not mention, in the Power Sector Management Plan (2013), small-scale off-grid initiatives as a pathway for extensive electrification in isolated rural regions, such as Mtwara, in the short-term. Consequently, the electrification analysis focuses on key points of comparison between the main grid LCP approach and the mid-scale opportunistic and planning paradigm.

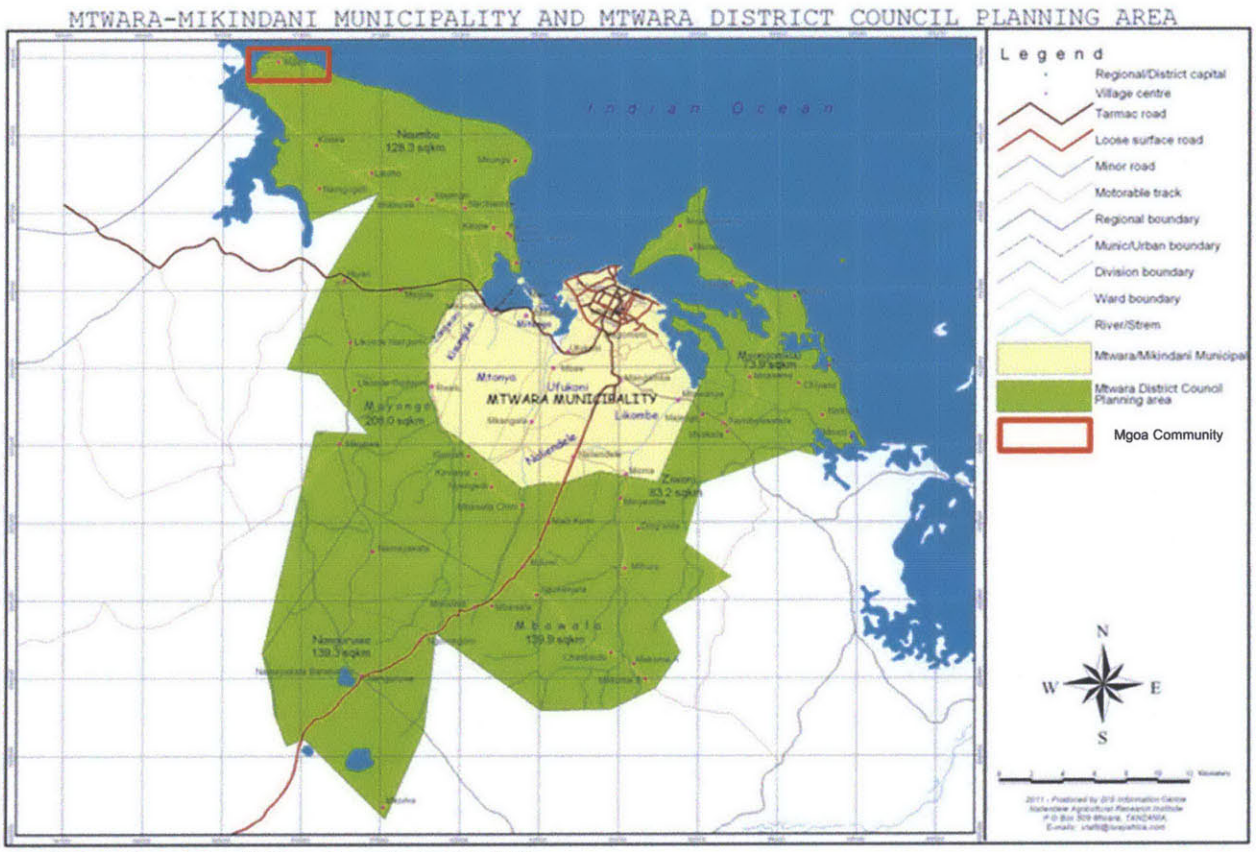
Section 3.2 | Mid-scale renewable energy systems in theory and practice – Mtwara, Tanzania

Mtwara, which is located in the southeastern area of Tanzania, has a total population (2012) of approximately 1.3 million and population density of 76 persons per sq km (United Republic of Tanzania, 2013). Residents of Mtwara are poor as reported GDP per capita (2010) was USD $437.00.[97] The primary electricity source is gas, which is generated through gas turbine plants that have a total capacity of 18MW, but consumption has been below capacity since 2010. The transmission lines are low voltage with capacities of less than 50kV. The transmission and distribution system reaches only a fraction of Mtwara's residents as the majority live in "Mtwara Rural" – well outside of the municipal area of commerce and beyond the reach of grid system as shown in Map 3.[98] However, in the long-term (2035) MEM and local government authorities anticipate serious socio-economic change in

[93] GOT economics of connecting six isolated load centers (inclusive of Mtwara): total switchgear and substation cost 132kV is USD $18 million to USD$ 28 million for 220kV. Mtwara's overall short-term (2013-2017) power sector plan assumes an installed capacity of 400MW, which equates to a $USD 481 million investment (MEM, 2013).
[94] As of January 2013, the majority of rural communities within Mtwara were not connected to the main grid. Source: Sarah Dimson (2013a).
[95] Sarah Dimson (2013a).
[96] Sarah Dimson (2013a).
[97] Mtwara Regional Commission (2013).
[98] Personal communication, Regional Commission of Mtwara (2013).

Mtwara given recent domestic discoveries of trillions of cubic feet of natural gas. Mtwara is the coastal gateway to massive amounts of off-shore hydrocarbons; a gas-turbine plant is currently under development in Mtwara and will serve power consumers as far north as Dar es Salaam.[99]

MAP 3 | MTWARA, TANZANIA WITH MGOA IDENTIFIED



Source: Regional Commission of Mtwara, Tanzania, January, 2013.

Notes: Local Government jurisdiction of Mtwara Mikindani Municipality: ~ 153 square kilometers; Local Government jurisdiction of Mtwara District Council ~ 768; Total proposed planning area: ~921; Designated as legal planning area August 11, 2013: Government Notice 404; The Urban Planning Act (CAP 355, Order (Made under section 8(1))

Yet, in the short-term (2013-2017), the period of focus for the mid-scale opportunistic and pluralistic planning paradigm, most residents in Mtwara do not have access to the main grid. Mtwara's current 18MW isolated gas-powered electricity system is within the boundaries of this thesis' definition of a mid-scale system in terms of system size; however, the thesis' focus is on mid-scale *renewable energy* systems. Moreover, Mtwara's gas

[99] Current gas and oil exploration companies: BG Group, ExxonMobil, Maurel & Prom, Ndovu Resources,Ophir Energy, Petrobras, Statoil and Wentworth Resources. Logistics and support services enterprises: Halliburton, Schlumberger, and Solvochem. Source: Regional Commission of Mtwara (2013).

production wells at Songosongo and Mnazi Bay generate limited fuel supplies specifically for power generation (Simbakalia, 2013).[100] In addition, the 18MW system has supply and demand side issues: the gas plants are operating below capacity, transmission and distribution infrastructure is severely dilapidated and underdeveloped; and consumption is low (Simbakalia, 2013).[101]

Mtwara's gas-powered mid-scale system is rife with problems, particularly with respect to the majority of residents living within Mtwara Rural – such as Mgoa, a fishing community of approximately 2,000 residents in northeastern Mtwara, rely on timber, kerosene and diesel for power (see Map 3). Mgoa's community consists of households, small businesses, schools and, increasingly commercial land developers.[102] Mgoa, like other rural communities within Mtwara, is experiencing growth in population and economic activity. As a result, access to a modern, reliable and affordable electricity system is requisite. Hence, the following section references Mgoa to provide context for analyzing and discussing the viability of mid-scale renewable energy projects as well as opportunistic and pluralistic planning.

Tenenbaum et al. (2014) conducted a theoretical scenario of a small power producer (SPP) operating in a community similar to Mgoa.[103] The SPP retails power directly to customers (households and businesses) through a mini-grid that utilizes hydropower (300kW plant capacity). In this scenario, Tenenbaum et al. (2014) find that a renewable energy mini-grid project is financial viable. More specifically, the Tenenbaum et al. (2014) scenario assumes a three-year project development timeline and a total capital investment requirement of USD $1.35 million (for generation, soft costs, mini- connection and extension). The majority of the total cost, 56%, is covered by grants: foreign aid (12%) and REA (44%). Debt and equity cover the remaining 44% of the total capital costs. Further, the tariff scheme is a cross-subsidy model whereby prices for business enterprises are set higher than the uniform national tariff in order to support lower tariffs for low-income residential customers. The Tenenbaum et al. (2014) SPP direct retail scenario is a theoretical financial success marked by an equity rate of return of 20% and debt coverage service ratio of 1.44.[104] However, SPP project feasibility for an Mgoa-like community heavily depends on

[100] Songosongo and Mnazi Bay have gas reserves of 880 bcf and 262 bcf, respectively (Simbakalia, 2014).
[101] Personal communication, Power System Manager, Mtwara, TZ, January 2013; Sarah Dimson (2013a).
[102] In January 2013 Mgoa community leaders were negotiating a land acquisition deal for a hotel. Personal communication, Mgoa community leaders, January 2013; Personal communication, Regional Commission of Mtwara, 2013; Sarah Dimson (2013a).
[103] See Appendix-5, SPP mini-hydro financial model by Tenenbaum et al (2014).
[104] Banks in Tanzania require a minimum DSCR of 1.4. (Tenenbaum et al., 2014).

institutional financing (i.e. donor aid and GOT-Rural Energy Agency), climate change financing (i.e. carbon revenues), sound regulatory mechanisms (e.g. feed-in-tariffs) and innovative socio-economic support systems for connection fees (i.e. per low-income households). Essentially, a SPP renewable energy mini-grid project (even at the low-end of the mid-scale range), requires a deep financing stack. More importantly, through the lens of the mid-scale opportunistic and pluralistic planning paradigm (and Mtwara power and economic development experts), an efficient *process* is requisite – one that is able to leverage various resources and represent the interests of all stakeholders, especially community members (Simbakalia, 2013).[105]

Section 3.3 | Barriers, opportunities and recommendations for a mid-scale renewable energy power project

Through the lens of the mid-scale opportunistic and pluralistic planning paradigm, the small power producer (SPP) direct retail scenario effectively addresses, in the short term, the chief barriers to electrifying communities within Tanzania's isolated rural regions: economic constraints, limited project financing, institutional hindrances, and lacking technological expertise. The opportunities for electricity sector progress in isolated rural regions are within the constraints and include novel ideas.

Interestingly, the barriers and opportunities (not inclusive of new, novel concepts) are indicative of consistent patterns, since liberalization of the electricity sector in 1985. The patterns reflect an economic-electricity infrastructure-society nexus that is replete with complexity (see Chapter 2). The patterns distinctively include the following premises: measurable, systemic change is catalyzed with the injection of financial and technical assistance resources (mostly by IFIs and aid agencies); poor electricity infrastructure is cited as a major problem and a solution to generation and access; poor institutional capacity is also cited as a significant problem and a solution to a lack of discernment and efficiency in the creation and implementation of power plans; and principally, the electricity sector has floundered forward under the least-cost-planning paradigm. The barriers, opportunities and patterns are explored herein categorically, with respect to the mid-scale opportunistic and pluralistic planning paradigm and in context of isolated rural regions.

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[105] Personal communication, Regional Commission of Mtwara, 2013; Sarah Dimson (2013a).

Section 3.3.1 | Economic and Financing Constraints

The GOT's estimated cost to connect the main grid to isolated rural regions, within the short-term, is over ten to twenty times greater than the SPP direct retail scenario. Moreover, the main grid connection emphasis will likely be on the municipal area of Mtwara where power demand is concentrated.[106] Ostensibly, a main grid connection to Mtwara in the short-term assumes ready access to USD tens of millions. The GOT revenue base is insufficient to cover the capital costs to support transmission and distribution infrastructure to connect the main grid to Mtwara; the effort will ultimately require support from IFIs, aid agencies and FDI (Nord et al., 2009). Moreover, although the PSMP-13 economic feasibility study indicates that isolated rural regions will be connected to the main grid within the short-term the costs are not aligned with specific sources (i.e. general categories of "equity" and "debt"). Such abstractness is a potential financial problem for implementation. Yet, the abstraction also presents an opportunity to rethink how to tangibly develop and finance electrification in isolated rural regions that are hundreds of kilometers away from the main grid, such as Mtwara.

The Tenenbaum et al. (2014) case provides an example of viable alternative SPP models that could conceivably scale to electrify multiple communities, like Mgoa, throughout the Mtwara region. Moreover, renewable energy mini-grid SPPs can opportunistically leverage available natural and financial resources that align with the current international policy posture that supports renewable power generation as a climate change mitigation mechanism (see Chapter 1). More specifically, natural resources refer to the power sources of biomass, hydro, geothermal, sun, wind – all of which are plentiful in Tanzania (see Chapter 2). Sustainable development financial resources, for renewable energy mid-scale mini-grid systems, are significant and easier to access by private sector developers (SPPs) and investors, NGOs and universities as compared to the GOT, which has yet to outline a climate change finance strategy (Norrington-Davies & Thornton, 2011).[107] For example, IFIs and aid agencies committed (2009-2015) a total of approximately USD $86 million, to public institutions, NGOs, private sector actors and governments, for climate change mitigation and adaptation activities, inclusive of rural-area renewable power programs (Norrington-Davies & Thornton, 2011) (see Table 4, Existing donor

[106] The likelihood of the main grid serving Mtwara's municipal area is deduced from the author's observation of the current transmission and distribution system in the municipal area through to the more remote rural areas. Sarah Dimson (2013a).

[107] GOT has to initiate certain processes to access climate change funds, such as the Clean Development Mechanism and Global Environment Facility Funds, which are primarily provided by UNDP, World Bank and the EU (Norrington-Davies & Thornton, 2011).

commitments for climate change activities). While Tanzania (via REA) has received a portion of the total funds for rural electrification, overall power sector planning agents lack the capacity to develop a robust climate change strategy whereby the allocation of funds to Tanzania might be higher and efficiently flow to apt rural area agencies and SPPs (Norrington-Davies & Thornton, 2011).[108]

TABLE 4 | EXISTING DONOR COMMITMENTS FOR CLIMATE CHANGE ACTIVITIES (USD $MILLION)

Donor	Timeframe	Committed	Planned
DFID	2009-2014	**1.3**	15.61
EU	2010-2014	**3.9**	N/A
Finland	2009-2015	**13.3**	14.52
Norway	20009 – 2013	**49.05**	52.28
One UN	2009 – 2015	**3.4**	14.36
UN REDD	2010 – 2012	**4.2**	N/A
UNDP/ UNEP	2009 – 2015	**8.4**	N/A
UNIDO	2011 – 2015	**N/A**	3.4
USAID	2010 – 2012	**2.5**	5
World Bank	2011	**N/A**	0.5
Totals	2009 – 2015	**86.05**	105.67

Notes: Donor mapping study, 2011; N/A: Not Available

Source: Norrington-Davies & Thornton (2011)

Generally, renewable energy SPPs operating in low-income communities within isolated rural regions need climate finance options for capital costs, insurance and other operating costs (Norrington-Davies & Thornton, 2011; Tenenbaum, Greacen, & Siyambalapitiya, 2014). Fortunately, renewable energy SPPs have a cadre of financial and technical assistance resources to leverage. For example, through top-down institutional means such as the Tanzania Energy Development and Access Expansion Project (TEDAP) (see Section 3.3.2) and the Clean Development Mechanism (see Chapter 2); and directly from entities such the Overseas Private Investment Corporation (OPIC). OPIC, for instance, offers renewable energy developers loan guarantees, political risk insurance and support for investment funds – all of which are plausible financial and operational resources for SPPs operating in isolated rural regions (OPIC, 2014).[109] Alternative, SPPs

[108] Tanzania's portion of the USD$86 million for rural area electrification is not listed through the data source – Norrington-Davies & Thornton (2011)-Annex A.

[109] In 2013 OPIC committed USD $1.2 billion for large-scale main grid and decentralized mid-scale renewable energy projects (biomass, geothermal, hydropower, solar and wind). OPIC (2014).

can leverage bottom-up financing and operational support from capital market players such as Spring Hill Partners (venture capital), or social venture entities such as Acumen (grants, capital, debt and technical assistance), or foundations such as Skoll (grants and technical assistance).[110] In addition, a renewable energy SPP business model may present a new way to advance local wealth by offering local communities an ownership stake, by way of land, in projects. Norrington-Davies & Thornton (2011) suggest that local ownership is fundamentally absent in Tanzania's least-cost-planning power paradigm.

Accordingly, in theory a SPP can effectively address economic and financing constraints through a host of resources; a deep and diverse financing stack is requisite. An improved planning process, for developers, local institutions and community members, is imperative in order to move a renewable energy mid-scale project from theory to practice in the short-term (RECP, 2013).[111]

Section 3.3.2 | Institutional Capacity: TANESCO, EWURA and REA

In the short-term, the SPP direct retail scenario addresses the institutional barrier in TANESCO, namely bankruptcy due to a historic lack of operational management capacity, by excluding TANESCO as a power off-taker. The SPP direct retail scenario mitigates the risk of non-payment by TANESCO, which is a real present risk (Eberhard & Kapika, 2013; Tenenbaum et al., 2014). Furthermore, power consumers benefit in terms of time to connect to a mini-grid versus the main grid – within a week as opposed to over 100 days, respectively (World Bank, 2014). Until TANESCO is able to rectify its financial and operational challenges, the SPP direct retail scenario presents a ready, financially viable option for generation and access in the short-term.

The most promising institutional opportunities that SPPs can leverage are through EWURA and REA. EWURA and REA are new entities that also face capacity challenges, with respect to small power projects, but both bodies have made positive strides in the past five years (Eberhard & Kapika, 2013; Tenenbaum et al., 2014).[112] For example, EWURA established the framework for small power projects, recently finalized a Standardized Power Purchase Agreement (2013) for SPPs; and developed a feed-in-tariff (FIT) mechanism

[110] See: http://springhillequity.com/investments; http://acumen.org/; http://www.skollfoundation.org/issue/sustainable-markets/
[111] Personal communication, Regional Commission of Mtwara, TZ, January 2013.
[112] Personal communication, EWURA, Dar es Salaam, TZ, July 2013.

(Eberhard & Kapika, 2013; EWURA, 2012; Tenenbaum et al., 2014).[113] However, renewable energy SPPs report that EWURA's FIT is problematic per the use of the avoided-cost calculation approach - all renewable energy generators receive the same FIT even though levelized costs vary. Because the initial capital costs are typically high for renewable energy SPPs, it is important for EWURA to continue to work on an acceptable FIT and research other mechanisms to drive down costs, particularly for SPPs serving low-income communities in isolated rural regions.

In addition, SPPs can leverage the existing EWURA (2012) decree that allows for cross-subsidized customer tariffs (as cited by Tenenbaum et al. (2014). In a cross-subsidy arrangement, low-income resident tariffs are lower than commercial tariffs, which helps the SPP sustain operations. However, extant research suggests that populations such as Mgoa may struggle not necessarily with tariff rates but with initial connection fees. As a result, Tenenbaum et al. (2014) record recommendations for pass-through lending: loans sponsored by foreign aid grants or loans that are passed through SPPs and on to low-income customers (Tenenbaum et al., 2014). On the contrary, African mini-grid rural development experts suggest that customers need reliable, high quality, safe electricity and not subsidies (RECP, 2013).

REA's position on connection fees is arguably evident through TEDAP, a financing and technical assistance program for renewable energy SPPs that provides USD $500 for each new client connection to an isolated mini-grid (REA, 2012).[114] REA is the executing agency for TEDAP's total credit line, which is USD $35.3 million and scheduled to close March 15, 2015 (REA, 2012).[115] REA's primary work is management of the Rural Energy Fund (REF), which provides grants for SPP capital costs, technical assistance, training and capacity building. In 2010/11 the REF financed projects worth USD$ 12.5 million (REA, 2011).[116] The majority of the REF projects were for grid-extension (see Figure 10, REF allocation by percentage and project type)

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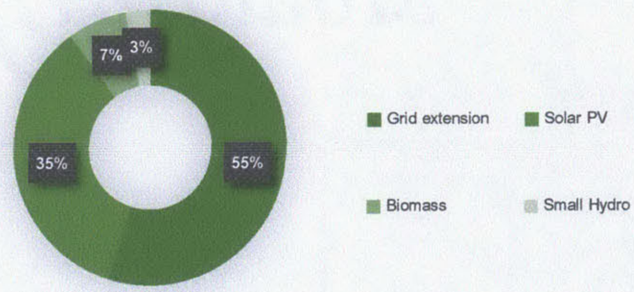
[113] Feed-in-tariff: an economic policy mechanism used to promote investment in the production and deployment of renewable electricity technologies. Power producers receive a set price, established by the regulator in the case of Tanzania, for all of the electricity the producer generates and provide to off-takers (e.g. direct retail to customers and/or to a utility). Through a contracts and guaranteed pricing, power producers mitigate inherent risks in renewable energy production (EIA, 2013; Investopedia, 2014).

[114] TEDAP also provides USD $500 per connection for the following systems: grid-connected generation combined with grid-connected mini-grids distribution network; and grid-connected mini-grids including distribution network.

[115] GOT is the borrower for TEDAP. The USD $35.3 million credit line for SPPs consists of: USD $24.0 million from IDA TEDAP Credit Line of which USD $3.0 million is earmarked for projects smaller than 3MW; USD $5.5 million from PFIs and developers; USD $5.85 million from Green Generation Performance Grants (REA, 2012).

[116] 2014 prices; Author's own calculation based on 2014 exchange rates.

FIGURE 10 | | REA-RURAL ENERGY FUND ALLOCATIONS BY % AND PROJECT TYPE



Source: REA (2011).

Section 3.3.3 | Institutional Capacity – Technological Know-How

The use of modern technology for sustainable electricity generation and access is a sine qua non for quality and reliability. To-date, TANESCO has demonstrated a lack of technical knowledge capacity. According to economist Jeffery Sachs (2013), technical know-how is a critical complementary to economic growth. As indicated in Chapter 2, the main grid suffers from high technical losses – transmission losses of five percent and distribution losses of 20% (MEM, 2013a). In addition, the isolated grid relies on dysfunctional diesel generators. The PSMP-13 indicates that moving forward, TANESCO will use technology that meets international standards; however, what arguably matters more is the capability to operate and maintain technologies post transfer. Planning policy research indicates that in the case of technology transfer, specifically from industrialized countries to developing countries, implementation needs to be paired with capacity building for sustained success (Banerjee, 2009).

Renewable energy SPPs have a tremendous opportunity to not only bring modern advanced technologies online in communities within isolated rural regions, but also develop and leverage local talent to support the operations and maintenance of mini-grid systems. While this is seemingly a business model decision, from a pluralistic perspective, local level engagement and training is a necessary continuation of stakeholder engagement that occurs throughout the life a small power project. Furthermore, technological advancements need not be made outside of communities and then transferred; research and development, particularly for renewable energy technologies, may realize benefits in efficacy if developed and tested locally. Moreover, there is widespread support in isolated rural regions, specifically Mtwara, for resources to improve human capital in order to progress economic development.[117] Figure 11 represents an idealized model, developed by planning expert Tridib Banerjee (2009), of how, SPPs for example, might work to improve the viability of scaling or diffusing mini-grid systems throughout isolated rural regions (Banerjee, 2009).

FIGURE 11 | PROCESS MODEL FOR KNOWLEDGE AND TECHNOLOGY TRANSFER

Image: Banerjee (2009); Source: Banerjee (2009)

Section 3.4 | Recommendations

1. *Develop a local (within isolated rural regions) public development corporation to streamline planning and development processes for SPPs; inclusive of stakeholder engagement, access to financing and project service delivery support.*

Correspondingly, Mtwara's local government recognizes the need to bring public, private and community stakeholders together in a novel way.[118] In January 2013, the Mtwara Regional Commission explored the concept of an Mtwara Development Corporation, a public corporation[119] that acts as a management conduit for city planning and development projects, such power projects to spur economic growth in the region.[120] The public corporation works in partnership with an associated development fund entity that reviews, approve and finances projects with public and private funds.[121] Essentially, a localized public corporation-fund venture represents a pluralistic planning agent: coordinating the interests of all stakeholders; and providing transparent streamlined processes for developers, access to

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117 Local skill levels and occupations in Mtwara mirror national statistics; more than 80 percent of the population consists of low-skilled workers with agricultural and elementary occupations (Regional Commission of Mtwara (2013), Sarah Dimson (2013a)); Tanzania policy framework for poverty reduction through improvements in human capital: the National Strategy for Growth and Reduction of Poverty II- Cluster I.

118 Personal communication, Regional Commission of Mtwara, TZ, January 2013.

119 The legal framework to support a development corporation for economic development activities in Tanzania is extant: Public Corporations Act-[R.E.] 2002 : "[a] corporation established under the [Public Corporations Act] ... in which the Government or its agent owns a majority of the shares or is the sole shareholder." Under the Public Corporations Act-[R.E.] 2002, "agent" means "an intermediary such as a public corporation, a company or any other body appointed by the Government which owns fifty-one percent or more of the shares in any public corporation and represents the Government directly or indirectly." Private investors are expected to contribute the remaining 49%.

120 Personal Communication, Regional Commission of Mtwara, TZ, January 2013.

121 A range of private investors, inclusive of local community members, and public entities, (theoretically) capitalize the development fund

financing and technical support.[122] The feasibility and viability of the public corporation-development fund concept is under research for the Mtwara region.[123] Notably, a public corporation does not replace the need for regulation; rather, it builds on the best practices of EWURA.

2. *In the short-term, until TANESCO is able to rectify bankruptcy related issues and improve operational capacity, resources for renewable energy SPPs that sell power directly to retail customers through a mini-grid should be prioritized.*

3. *EWURA should explore the economic viability of increasing the maximum capacity limit for small power projects from 10 MW to 20MW for isolated load regions that are hundreds of kilometers away from the main grid.*

Mtwara's isolated grid gas powered system has a capacity of 18MW, but only serves a fraction of the population and is replete with technological deficiencies. In this case, an independent mid-scale power producer could improve the system with cogeneration technologies (renewable energy and fossil fuel systems). A cogeneration power producer might be incentivized to redevelop Mtwara's system if the producer is able to leverage the cadre of financial and technical resources that are currently available to small power producers. Further, as demand increases in rural communities served by new renewable energy mini-grid systems, the power producers should be able to expand a system, up to 20MW, without losing the benefits and incentives allocated to small power producers under the current policy definition per capacity.

4. *In the short-term, REA should explore prioritizing renewable energy generation projects over grid extension efforts given institutional and technological capacity shortcomings within TANESCO.*

5. *Policy makers should develop mechanisms to support renewable energy vocational training for apt institutional staff and local community members.*

Section 3.4.1 | Complementary recommendations for consideration – addressing possible outstanding electricity policy issues and questions

The following two major complementary recommendations – for advancements in research and development (R&D) and education – are based on research for this thesis and work towards supporting the two aims of the mid-scale opportunistic and pluralistic paradigm.

[122] A local public development corporation differs from REA in its scope of work, and financing vehicles, which are structured with public and private funds.

[123] Personal Communication, Regional Commission of Mtwara, TZ, January 2013.

These secondary recommendations are complementarities to the specific suggestions made in Section 3.4. Further, an objective of the case study is to use Tanzania as a reference point for other developing, low-income countries in Sub-Saharan Africa. Accordingly, these secondary recommendations may be appropriate for other SSA countries, with socio-economic characteristics that are similar to Tanzania, apropos electricity generation, access and consumption. Each complementary recommendation includes a brief statement for context.

1. *Advance mid-scale power systems for isolated rural regions of SSA through R&D in two areas: Renewable Energy Systems and Electricity Economics.*

    - *(1-a): Renewable Energy Systems includes research for technology financing and grid integration.*
    - *(1-b): Electricity Economics includes research concerning the relationship between electricity consumption, economic growth and climate change, and Local Content Requirement policy.*

(1-a).Technology financing and grid integration:

High initial capital costs of renewable energy (RE) generation technologies is often cited as a major barrier for widespread adoption, specifically in Tanzania (Kamimoto, Maurice, Nyboer, Urama, & Weir, 2011; RECP, 2013).[124] Capital costs for renewables, for instance solar photovoltaic power systems and wind power, have fallen since the late 1990s (Boyle, 2010). However, for low-income SSA countries with ample natural resources, such as Tanzania with its natural gas resources, the initial price-tag is seen as a financial risk and is a socio-political concern (Kamimoto et al., 2011; RECP, 2013).[125] The financial investment risk issue is largely tied to confidence in the technology performance as some renewable energy technologies are in incipient development phases, which increases rate of return expectations in private capital markets (Gross et al., Bazilian and Roques, 2008 as cited by Kamimoto et al., 2011).

In addition, further research is needed around grid integration. If mid-scale renewable energy systems in isolated rural regions eventually connect to the main grid, there is extant concern, among energy technology researchers, investors and government officials, about

[124] The components of costs for renewable energy systems include the capital costs, operation and maintenance (O&M), and fuel costs, which are free in the case of most renewable energy technologies (i.e. solar, wind, etc.) Capital costs are amortized and interest is charged by an investor to achieve a healthy rate of return (Boyle, 2010); Sarah Dimson (2013b).
[125] Sarah Dimson (2013a,b).

how the addition of an intermittent source of power (e.g. solar, wave and wind) will affect the level of certainty or reliability of the main grid (Boyle, 2010; Kamimoto et al., 2011; Tenenbaum et al., 2014). However, Boyle (2010) argues that the additional level of uncertainty is small and depends on the level of renewable energy integrated into a main grid system. Further R&D will help provide clearer technical answers about how a mid-scale system might integrate with a main grid. Kamimoto et al. (2011) and Tenenbaum et al. (2014) suggest that there is a need to develop policies to support grid integration.[126]

(1-b).The relationship between electricity consumption, economic growth and climate change; and Local Content Requirement (LCR) policy.

More directional causality econometric research concerning the relationship between electricity consumption, economic growth and CO2 emissions on an SSA regional level, and for each developing SSA country is needed to create plausible and sustainable recommendations for electricity-environment policy. [127] Electricity consumption-economic growth research matters because the results are critical to informing allocation of resources and creating sound and sustainable short and long-term electricity-environment policies (Kahsai, Nondo, Schaeffer, & Gebremedhin, 2012; Ozturk, 2010; Payne, 2010). For SSA countries, less is understood in comparison to high and middle-income countries about electricity consumption patterns in relationship to economic growth, which is the fundamental aim of electrification/access. This is largely because econometric evidence concerning the directional causality between electricity consumption and economic growth is scant.[128] Findings that are available are conflicting due to small sample sizes and the lack of consideration for how unrecorded/informal economies may affect empirical results (Karanfil, 2008; Odhiambo, 2009). Further, in addition to directional causality, researchers suggest that investigations examine the electricity consumption-growth causality apropos CO_2 emissions, an emanating negative environmental externality (Huang et al., 2008). Extant recent studies connect energy consumption, economic growth and the implications for climate change (CO2 emissions); however, robust SSA data is lacking (Odhiambo, 2010; Payne, 2010; Sari & Soytas, 2007; Wolde-Rufael, 2009).[129]

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[126] See Tenenbaum et al. (2014) for grid-integration policy suggestions.
[127] See Box 1.
[128] Author's note: in my investigation of over 20 econometric studies concerning the relationship between energy and electricity consumption and economic growth only two studies reference Tanzania. The studies analyze data from many global regions and countries, and includes data from the 1940s to 2012.
[129] Kahsai et al. (2012) proposes that consumption in SSA increase while simultaneously mitigating environmental damage by using the abundance of renewable energy sources – geothermal, hydro, solar and wind – that exist across the continent; Sarah Dimson (2013,b).

LCR policy development for renewable energy technology manufacturing in situ may be an appropriate mechanism for economic growth. The purpose of LCR policy, in a developing country context, is to provide emergent governments with a mechanism to increase domestic employment, catalyze technology transfer, and regulate foreign direct investment (Qiu & Tao, 2001). In emerging market economies, this practice has been on the rise since the 1980s (UNIDO, 1986). For example, SSA policy makers might consider exploring Brazil's LCR policies for renewable energy technologies. Brazil started LCR policy practices with hydrocarbons in the late 1970s and has since expanded to include renewable energy technologies (Landu, 2008).

2. *Invest in demand-side management education and vocational training for communities within isolated rural regions.*

Demand-side management (DSM) education provides power consumers with incentives and information about how to use less energy during peak hours or shift energy use to off-peak hours. DSM also includes energy efficiency schemes. The term was introduced in the 1970s in response to the energy crisis (refer to Chapter 1).[130] However, DSM strategies are dependent on accurate data about consumption patterns, which is barrier in SSA countries, such as Tanzania, since data is limited (refer to R&D recommendation here within) (MEM, 2013b).

Section 3.5 | Conclusion

The ideas for how to practically exercise a *mid-scale opportunistic and pluralistic planning* paradigm in communities within isolated rural regions of Tanzania is undeniably complex in the need to consider a host of factors and incorporate the interests of a plethora of stakeholders. Yet, the paradigm corresponds to the dynamic nature of electricity sector development in low-income Sub Saharan African countries. The electrification challenge in Tanzania is emblematic of a systems dynamic framework – opportunistically and pluralistically levering multi-faceted resources that are available today, but may change in scope, purpose, etcetera tomorrow (Sterman, 2000). There is no one single approach to solving generation, access and consumption challenges faced by rural isolated regions in Tanzania. Parallel approaches are necessary; however, LCP is costly, takes a substantial

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[130] The Electric Power Research Institute publically introduced DSM as a power management tool in the 1980s. Short-term load management problems are referred to as Demand Response, which is defined by the Federal Energy Regulatory Commission as changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time (Balijepalli, Pradhan, Khaparde, & Shereef, 2011).

amount of time and conventionally relies on fuel sources that are depleting and negatively affecting the environment. Moreover, in Tanzania, small-scale off-grid approaches are nascent, meet the lowest range of possible consumption needs and are not part of serious discourse, amongst policy makers, researchers and economists, as a sustainable path towards economic growth.

Admittedly, the *mid-scale opportunistic and pluralistic planning paradigm* requires a specialized skill set – objective planning agents that are able to comprehend the institutional, economic and technological deficiencies that constrain progress as well as discern who are the relevant and necessary stakeholders from within and outside of a community in question (Davidoff, 1965). Therefore, a plausible way to enact and streamline the paradigm is through an agent that works within the proposed electricity development corporation, a local (within an isolated rural region) public corporation that uses planning agents to administer a codified process that benefits renewable energy mid-scale SPPs, public, private and citizen stakeholders (RECP, 2013).[131] In addition, the corporation is not only a process agent, but also a knowledge conduit for access to critical information that spurs investment in clean energy power projects for isolated rural regions. For example, information might include the following: consumption data, graphic information service data that provides geospatial statistics, climate and geography data for technology selection, or information concerning new climate change power project financing sources.

Hence, the core of the mid-scale opportunistic and pluralistic planning paradigm is fundamentally about developing a profoundly deep, localized understanding of the key factors that suppress electrification and perceiving a way forward that leverages the working aspects of a complex environment. The paradigm is meant to be discerning, agile and deliberate towards an objective to help create (i) rigorous and modern policies that reflect rapidly changing environments in Sub-Saharan Africa; and (ii) a pathway to advance sound mid-scale renewable energy business models. More specifically, Tanzania's electricity sector past and present is an indication that neither conventional large-scale nor experimental small-scale paradigmatic approaches have translated into marked expansive improvements in generation, access and consumption, particularly in isolated rural regions. Hence, the future of electrification in the immediate through short-term depends on reimagining electricity delivery systems and processes in consideration of the best opportunities that represent sustainable development and spur local knowledge about

[131] Sarah Dimson (2013a).

advancements in clean electricity technologies, which are tools to forward economic and human development .

APPENDIX

Appendix-1	List of scoping interviews by entity
Appendix-2	Sample list of small-scale off-grid enterprises
Appendix-3	Electricity Access in Africa, 2011
Appendix-4	Tanzania Renewable Energy Projects
Appendix-5	GOT Electricity Sector Organizational Chart
Appendix-6	Tenenbaum et al. (2014) small power producer mini-hydro financial model

Appendix-1 | List of scoping interviews in Tanzania (by time period)

Personal Communication, March 2012

National Housing Corporation
Private affordable housing real-estate developer
Dar es Salaam residents
Ministry of Lands Housing and Human Settlements
World Bank Specialist

Personal Communication, January 2013

Regional Commission of Mtwara, Tanzania
MEM
NDC
Commercial bank
Mgoa residents
Mtwara education administrators
Oil and gas operators
Tanzania Port Authority

Personal Communication, July 2013

EWURA
TANESCO
NDC
MEM

Appendix-2 | Sample list of small scale off-grid companies / organizations

Company /Org Type	Company / Organization	Program	Country(s)	Product / Service	Website
NGO	Energia/ETC International	Energy SME	Senegal, Mali, Ghana, Nigeria, Kenya, Uganda, Tanzania, Zambia, Lesotho, Zimbabwe, Swaziland, South Africa Asia	Technical assistance	http://www.etc-international.org/about-2/about-etc/
NGO	S3IDF	Social merchant bank approach	Kenya, Uganda	Financing	www.s3idf.org
NGO	Pima Gas	LPG	Kenya	LPG in 1kg cylinders	TBD
NGO	Global Alliance for Clean Cook stoves	N/A	East Africa	Financing and Technical Assistance	Global Alliance for Clean Cook stoves: The Global Alliance for Clean Cook stoves
Private	Solar Century	Solar Aid & Sunny Money School Programme	Kenya, Malawi, Tanzania	Solar lamps & Micro-franchising	http://www.solar-aid.org/; http://www.solarcentury.com/uk/
Private	Devergy	N/A	Tanzania	Solar Micro-grid systems	http://www.devergy.com/
Private	D.Light	N/A	Kenya, Nigeria	LED lamps & battery chargers	http://www.dlightdesign.com/
Private	Energiebau	Energibau+InWEnt	Tanzania	Off-grid solar (biomass-jatropha)	http://www.energiebau.us.com/Energiebau-International.3574.0.html
Private	Clean Star Ventures + Novozymes (biotech) + ICM (ethanol tech) + Merrill Lynch (carbon finance)	CleanStarMozambique	Mozambique	Food & bioenergy and forest production	www.cleanstarmozambique.com
Private	Eight19	Pay as you go solar	Kenya	Solar panel home system	www.eight19.com
Private	Solar Sister	N/A	Nigeria, South Sudan, Rwanda, Uganda, Tanzania	Solar lamps	www.solarsister.org
Private	Little Sun	N/A	Zimbabwe, Uganda, Kenya, Burundi, Senegal, Ethiopia, South Africa	LED lamp	http://www.littlesun.com/index.php?sec=home
Private	Fenix International	N/A	Tanzania, Uganda	Solar panel (75W), Battery chargers, LED lights 3w-5w	http://fenixintl.com/
Private	Schneider Electric	BipBop	Nigeria, Tanzania, Senegal, Burkina Faso, Cameroon, Kenya, Madagascar, South Africa, Uganda	Lamps, chargers, Micro-grid solar and water systems	http://www2.schneider-electric.com/sites/corporate/en/group/sustainable-development-and-foundation/access-to-energy/presentation.page
Private	Greenlight Planet	N/A	Uganda, Tanzania, Kenya	Solar powered batteries, LED lamps	http://greenlightplanet.com/
Private	Global Cycle Solutions		Tanzania	Solar powered batteries, LED lamps	http://gcstz.com/

Appendix-3 | Electricity access in Africa, 2011

Region	Population without electricity (millions)	Electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)
Sub-Saharan Africa	**599**	**32**	**55**	**18**
Angola	12	38	58	8
Benin	7	28	55	6
Botswana	1	46	68	10
Burkina Faso	14	13	39	4
Cameroon	9	54	88	17
Congo, Rep	3	38	54	10
Cote d'Ivoire	8	59	85	32
DR of Congo	62	9	26	-
Eritrea	4	32	86	17
Ethiopia	65	23	85	11
Gabon	1	60	64	34
Ghana	7	72	90	52
Kenya	34	19	58	7
Lesotho	2	19	45	9
Madagascar	18	14	62	(9)
Malawi	14	7	37	1
Mauritius	-	99	100	99
Mozambique	19	20	55	5
Namibia	1	60	83	46
Nigeria	85	48	35	61
Senegal	6	57	88	33
South Africa	8	85	96	67
Sudan	25	29	57	14
Tanzania	**39**	**15**	**46**	**4**
Togo	5	27	35	21
Uganda	30	15	55	7
Zambia	11	22	51	3
Zimbabwe	8	37	83	8
Other sub-Saharan Africa	105	13	34	4
North Africa	**1**	**99**	**100**	**99**
Algeria	0	99	100	98
Egypt	0	100	100	99
Libya	-	100	100	99
Morocco	0	99	100	97
Tunisia	0	100	100	99
Africa	600	43	65	28

APPENDIX-4 | TABLE 2 | TANZANIA RENEWABLE ENERGY PROJECTS

	Technology[1]	Time[2]	Primary Distribution Method	
	Capacity (MW)	**Expected Year On-line**	**Centralized**	**Decentralized**
Bioenergy				
Biomass-Steam I**	30	Short-term	•	
Biomass-Steam II**	10	Short-term		?
Biomass III*	9	2010	•	
Biomass IV*	1.5	2013		•
Direct Solar				
Solar I**	60	Early 2016	?	
Solar II**	60	•	?	
Geothermal[3]				
Hydropower				
Hydro I*	4	2012	•	
Hydro II*	7.5	2014		•
Hydro III*	1	2015		•
Hydro IV*	10	2015	•	
Ocean Energy-N/A				
Wind Energy				
Turbine I**	50	Early 2016	•	
Turbine II**	50	Early 2017	•	

Notes

1: Specific technology type information unavailable; each project is referred to generally and distinguished by numbers (i.e. I, II, etc.)

2: Short-term refers to a period of time: 2013-2017

3: MEM (2013) reports that data is insufficient to consider geothermal under the PSMP-13. There are approximately 50 potential sites with an estimated

?: Information is unclear or unavailable

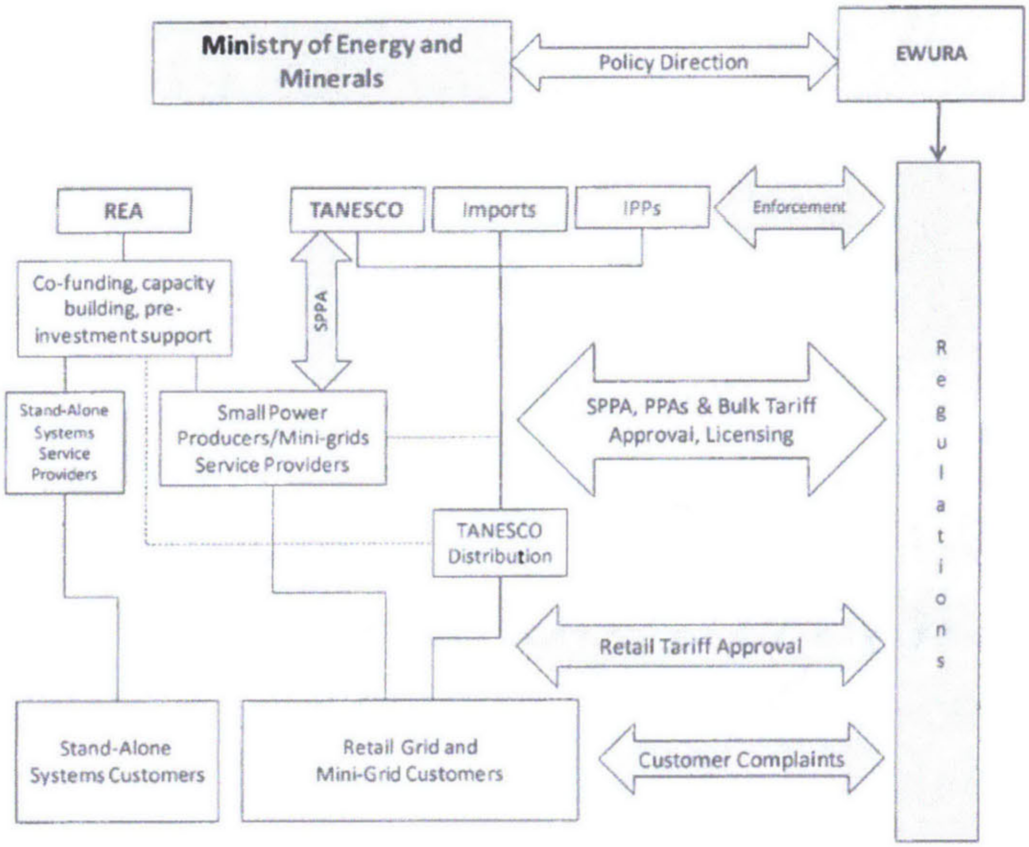
* SPPA Signed

**Renewable energy candidate projects

N/A: Not applicable - technology type not under consideration

Sources: MEM (2013); Personal communication, TANESCO, July 2013.

Appendix-5



Source: Personal Communication, EWURA, July 2013.

Appendix 6 | Simple Project Financial Analysis Spreadsheet, Tenenbaum et al. (2014)

Inputs

Project inputs			
Plant capacity	300 kW		
Capacity factor	40%		
Annual generation	1,051 MWh		
Number of connections	1,200		

Generation costs	*USD 000s*	*T Sh Mn*	
Generation	600	900	44%
Soft costs	150	225	11%
Grid connection	400	600	30%
Grid extension	200	300	15%
Total investment costs	1,350	2,025	100%
REA grants	600	900	44%
Other donor grants	160	240	12%
Total grants	760	1,140	56%
Investment (excluding grants)	590	1,125	44%

Revenues		*T Sh/kWh*	*US c/kWh*
Residential <50 kWh/month	40%	100.0	6.7
Residential >50 kWh/month	10%	273.0	18.2
Business	50%	360.0	24.0
Average tariff		247.3	16.5
Carbon revenues		9.0	0.6

Operating costs	*USD 000s*	*T Sh Mn*	*US c/kWh*
Salaries	25	38	2.38
Maintenance	14	20	1.28
Fuel costs	0	0	0.00
Other	15	23	1.43
Total	53.5	80.3	5.1

Other inputs	
Construction time	3 years
Collection efficiency	90%
Distribution losses	5%
Tariff inflation	4.0%
Consumer price index	6.0%
Terminal value	0.0 times exit FCF
Exchange rate	1,500 T Sh/USD

Capital structure			*USD 000s*	*T Sh Mn*
Equity share	15%	Equity	203	304
Debt share	29%	REA grant	600	900
Required returns	14%	Other grants	160	240
Equity including REA	59%	Loan	388	581
Loan rate	12%			
Loan grace period	3			
Loan term	10			
WACC[c]	9.2%			

Outputs

Project returns	
Project IRR[a]	4.8%
Equity IRR[b]	19.7%
Project NPV	($286)
Equity NPV	$73

Cost recovery tariff	
Capital investment	4.50 $/W
Operating costs	5.1 c/kWh
Output per watt	3.50 kWh/W
Capital recovery	20.22 c/kWh
Total	25.3 c/kWh
	380 T Sh/kWh

Schedule	*Year 1*	*2*	*3*	*4*
Construction	33%	33%	33%	0%
Operations	0%	0%	0%	100%

Other assumptions	
Depreciation period	25 years
Corporate tax rate	30%
Tax holiday	0 years

table continues next page

Appendix 6 | Simple Project Financial Analysis Spreadsheet *(continued)*

Cash flow USD 000s	*Year*															*Residual*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*value*[d]
Investment	$450	$450	$450	$0	$0											
Increase in working capital	$0	$0	$14	$0	$0											
Grants	$253	$253	$253	$0	$0											
Equity	$68	$68	$68	$0	$0											
Debt	$129	$129	$129	$0	$0											
Revenue (c/kWh)	17.1	17.7	18.4	19.1	19.9	20.7	21.5	22.3	23.2	24.1	25.0	26.0	27.0	28.1	29.1	
Total revenues	$0	$0	$0	$201	$209	$217	$226	$234	$243	$253	$263	$273	$284	$295	$306	
Operating costs	$0	$0	$0	$64	$68	$72	$76	$80	$85	$90	$96	$102	$108	$114	$121	
Operating cash flow	($197)	($197)	($197)	$138	$142	$146	$150	$154	$158	$163	$167	$172	$176	$181	$185	
Cash flow if no grant	($450)	($450)	($450)	$138	$142	$146	$150	$154	$158	$163	$167	$172	$176	$181	$185	
Depreciation[e]	$0	$0	$54	$54	$54	$54	$54	$54	$54	$54	$54	$54	$54	$54	$54	
Loan payments	$0	$0	$0	$96	$96	$96	$96	$96	$96	$96	$0	$0	$0	$0	$0	$0
Interest	$0	$16	$33	$52	$47	$41	$35	$28	$19	$10	$0	$0	$0	$0	$0	$0
Principal	$0	($16)	($33)	$43	$48	$54	$61	$68	$76	$85	$0	$0	$0	$0	$0	$0
Loan balance	$129	$274	$436	$393	$344	$290	$229	$161	$85	$0	$0	$0	$0	$0	$0	$0
Effective tax[f]	$0	$0	$0	$9	$12	$15	$18	$22	$25	$30	$34	$35	$37	$38	$39	$0
SPP's total costs	$197	$212	$230	$125	$127	$128	$129	$130	$130	$130	$130	$137	$144	$152	$160	
Equity cash flow	($68)	($68)	($68)	$33	$34	$35	$36	$37	$37	$38	$133	$136	$139	$143	$146	$0
Debt service coverage ratio	0.00	0.00	0.00	1.44	1.48	1.52	1.57	1.61	1.66	1.70	0.00	0.00	0.00	0.00	0.00	0.00

Source: http://[illegible] evaluator.

Note: c/kWh = cents per kilowatt hour; FCF = free cash flow; IRR = internal rate of return; kW = kilowatt; kWh = kilowatt hour; MWh = megawatt hour; NPV = net present value; REA = rural electrification agency; SPP = small power producer; TSh Mn = million Tanzanian shillings; WACC = weighted average cost of capital.

a. The project IRR is low, but this is mitigated somewhat by the presence of REA grants, which do not need a return or repayment.

b. An equity return is allowed only on the equity supplied by the developer (not on the REA and donor grants).

c. WACC = equity share × return on equity + debt share × loan rate × (1 – tax rate).

d. Present value of residual value at year 15 is for revenues from year 16–25.

e. Depreciation is allowed on the total investment (SPP developer equity plus donor funds).

f. A project like this would typically collect value added tax (VAT) and perhaps other duties (for example, in Tanzania VAT on power sales = 18 percent, and there is an additional 3 percent duty collected to fund the REA and 1 percent collected to fund the Energy and Water Utilities Regulatory Authority). These charges are not included in this spreadsheet because, while they affect ratepayers' finances, they are passed through directly to the government and do not affect cash flows from the developer's perspective.

(IEA), I. E. A. (IEA) I. E. A., & World Bank Group. (2014). *Sustainable Energy for All 2013-2014: Global Tracking Framework Report*. World Bank Publications.

ADB. (2011, December 16). ADF geothermal project to boost affordable, clean energy supply in Kenya. *Africa Development Bank*. Retrieved March 16, 2014, from http://www.afdb.org/en/news-and-events/article/adf-geothermal-project-to-boost-affordable-clean-energy-supply-in-kenya-8743/

Apergis, N., & Tang, C. F. (2013). Is the energy-led growth hypothesis valid? New evidence from a sample of 85 countries. *Energy Economics*, *38*, 24–31. doi:10.1016/j.eneco.2013.02.007

Arron, J. (2012). Infrastructure: The Beauty of Starting Afresh. In *The Fastest Billion The Story Behind Africa's Economic Revolution* (p. 17). Renaissance Capital Securities Limited.

Balijepalli, V. M., Pradhan, V., Khaparde, S. A., & Shereef, R. M. (2011). Review of demand response under smart grid paradigm. In *Innovative Smart Grid Technologies-India (ISGT India), 2011 IEEE PES* (pp. 236–243). IEEE. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6145388

Banerjee, T. (2009). U.S. Planning Expeditions to Postcolonial India: From Ideology to Innovation in Technical Assistance. *Journal of the American Planning Association*, *75*(2), 193–208. doi:10.1080/01944360902790711

Bellanca, R., & Wilson, E. (2012, June). Sustainable Energy and the private Sector. International Institute for Environment & Development.

Bhattacharya, A., Romani, M., & Stern, N. (2012). Infrastructure for development: meeting the challenge. In *Centre for Climate Change Economics and Policy, Londres. www. cccep. ac. uk/Publications/Policy/docs/PP-infrastructure-for-development-meeting-the-challenge. pdf. Consultado el* (Vol. 15). Retrieved from http://www.cccep.ac.uk/publications/policy/docs/pp-infrastructure-for-development-meeting-the-challenge.pdf

Boyle, G. (2010). *Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy.* (B. Moselle, J. Padilla, & R. Schmalensee, Eds.). Earthscan.

Chakravarty, S., & Tavoni, M. (2013). Energy poverty alleviation and climate change mitigation: Is there a trade off? *Energy Economics*, *40*, S67–S73. doi:10.1016/j.eneco.2013.09.022

CIA. (2014, March 11). The World Factbook. *Central Intellegence Agency: Library, Publications.* Retrieved March 26, 2014, from https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Clinton, B., William, E., Sachs, J., & Soloman, P. (2006, September 21). Authors Analyze, Criticize Foreign Aid Agencies in New Books. *PBS Newshour*. Transcript. Retrieved from http://www.pbs.org/newshour/bb/social_issues-july-dec06-foreignaid_09-21/

d.light solar. (2012). Products | d.light. Retrieved from http://www.dlightdesign.com/productline/

Davidoff, P. (1965). Advocacy and Pluralism in Planning. *Journal of the American Institute of Planners, 31*(4), 331–338.

DECC. (2013). *2012 UK Greenhouse Gas Emissions, Provisional Figures and 2011 Greenhouse Gas Emissions, Final Figurs by Fuel Type and End User* (Statistical Release) (p. 33). Department of Energy and Climate Change. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193414/280313_ghg_national_statistics_release_2012_provisional.pdf

Dodman, D., Karapinar, B., Meza, F., Rivera-Ferre, M. G., Sarr, A. T., & Vincent, K. (2013). *IPPC WGII AR5 Chapter 9.Rural Areas* (p. 74). Retrieved from http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap9_FGDall.pdf

Easterly, W. (2006). The big push déjà vu: A review of jeffrey sachs's the end of poverty: Economic possibilities for our time. *Journal of Economic Literature, 44*(1), 96–105.

Eberhard, A., & Kapika, J. (2013). *Power Sector Reform and Regulation In Africa: Lessons from Kenya, Tanzania, Uganda, Namibia and Ghana*. HSRC Press. Retrieved from http://www.hsrcpress.ac.za/downloadpdf.php?pdffile=files%2FPDF%2F2305%2FPSPrelims.pdf&downloadfilename=Power-sector%20reform%20and%20regulation%20in%20Africa%20-%20Prelims

EIA. (2013a). *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Proved Reserves, 2011* (p. 54). Washington, DC: U.S. Department of Energy, Energy Information Administration. Retrieved from http://www.eia.gov/naturalgas/crudeoilreserves/

EIA. (2013b, May 30). Feed-in tariffs. Retrieved May 16, 2014, from http://www.eia.gov/todayinenergy/detail.cfm?id=11471

EWURA. (2012). Development of Small Power Projects (SPP) in Tanzania. Retrieved April 23, 2014, from http://www.ewura.go.tz/newsite/index.php/sppmenu?highlight=WyJzbWFsbCIsIn Bvd2VyIiwic21hbGwgcG93ZXIiXQ==

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry, 12*(2), 219–245. doi:10.1177/1077800405284363

Hammons, T. J., Blyden, B. K., Calitz, A. C., Gulstone, A. B., Isekemanga, E., Johnstone, R., … Taher, F. (2000). African electricity infrastructure interconnections and electricity exchanges. *IEEE Transactions on Energy Conversion, 15*(4), 470–480. doi:10.1109/60.900510

Hanson, M., Kidwell, S., Ray, D., & Stevenson, R. (1991). Electric Utility Least-Cost Planning Making It Work within a Multiattribute Decision-Making Framework. *Journal of the American Planning Association, 57*(1), 34–43. doi:10.1080/01944369108975470

Huang, B.-N., Hwang, M. J., & Yang, C. W. (2008). Causal relationship between energy consumption and GDP growth revisited: A dynamic panel data approach. *Ecological Economics, 67*(1), 41–54. doi:10.1016/j.ecolecon.2007.11.006

IEA. (2002). *Energy and Poverty* (pp. 365–404). International Energy Agency. Retrieved from http://www.worldenergyoutlook.org/media/weowebsite/energydevelopment/WE O2002Chapter13.pdf

IEA. (2012). IEA - The Energy Development Index. *The Energy Development Index*. Retrieved May 14, 2014, from http://www.iea.org/publications/worldenergyoutlook/resources/energydevelopme nt/theenergydevelopmentindex/

IEA. (2013). *World Energy Outlook 2013* (No. 10.1787/weo-2013-en) (p. 700). International Energy Agency. Retrieved from http://www.oecd-ilibrary.org/energy/world-energy-outlook-2013_weo-2013-en

Investopedia. (2014). Feed-In Tariff Definition. *Investopedia*. Retrieved May 16, 2014, from http://www.investopedia.com/terms/f/feed-in-tariff.asp

IPCC. (2012). *Renewable Energy Sources and Climate Change Mitigation: Special Report of the IPCC* (Special Report). Cambridge University Press: Intergovernmental Panel on Climate Change. Retrieved from http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf

IPCC. (2013). *Climate Change 2013: The Physical Science Basis: Summary for Policymakers* (Working Group: Contribution to the 5th Assessment Report of the IPCC) (p. 33).

Switzerland: Intergovernmental Panel on Climate Change. Retrieved from http://www.ipcc.ch/report/ar5/wg1/docs/WGIAR5_SPM_brochure_en.pdf

IPCC. (2014). IPCC - Intergovernmental Panel on Climate Change. *IPCC: Organization.* Retrieved March 14, 2014, from http://www.ipcc.ch/organization/organization.shtml

IRENA. (2011). *Prospects for the African Power Sector* (pp. 1–60). International Renewable Energy Agency. Retrieved from http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=244

IRENA. (2014). Renewable Energy Country Profiles: Mozambique, Namibia, Tanzania. International Renewable Energy Agency. Retrieved from http://www.irena.org/REmaps/africamap.aspx

Iwayemi, A. (1998). *Energy sector development in Africa.* African Development Bank Group. Retrieved from http://core.kmi.open.ac.uk/download/pdf/6424032.pdf

Jeffrey Sachs. (2014). *Live Chat with Jeffrey Sachs on "The Age of Sustainable Development."* Earth Institute, Columbia University. Retrieved from https://www.coursera.org/course/susdev

Kahsai, M. S., Nondo, C., Schaeffer, P. V., & Gebremedhin, T. G. (2012). Income level and the energy consumption–GDP nexus: Evidence from Sub-Saharan Africa. *Energy Economics, 34*(3), 739–746. doi:10.1016/j.eneco.2011.06.006

Kamimoto, M., Maurice, L., Nyboer, J., Urama, K., & Weir, T. (2011). *Renewable Energy and Climate Change: Introduction. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation.* Cambridge University Press.

Karanfil, F. (2008). Energy consumption and economic growth revisited: Does the size of unrecorded economy matter? *Energy Policy, 36*(8), 3029–3035. doi:10.1016/j.enpol.2008.04.002

Lacerda, A. C. de, & Hughes, K. (2013). Climate Investment Funds (p. 7). World Bank. Retrieved from https://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Summary_of_Co_Chairs_CTF_TFC_October_2013_final.pdf

Landu, G. D. (2008, May). Local Content in Brazil. Brazil Focus.

McCord, G. C., & Sachs, J. D. (2013). *Development, Structure, and Transformation: Some Evidence on Comparative Economic Growth*. National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w19512

McDonald, D. (2009). *Electric Capitalism: Recolonising Africa on the Power Grid*. South Africa: HSRC Press.

McSweeney, C., New, M., & Lizcano, G. (2012). *UNDP Climate Change Country Profiles: Tanzania* (p. 27). United Nations Development Programme. Retrieved from http://country-profiles.geog.ox.ac.uk

MEM. (2013a). *Power Sector Master Plan, 2012 Update* (p. 154). Tanzania: Ministry of Energy and Minerals, United Republic of Tanzania.

MEM. (2013b). *Scaling Up Renewable Energy Program: Tanzania Investment Plan* (p. 146). Ministry of Energy and Minerals, United Republic of Tanzania. Retrieved from https://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/SREP_Tanzania_Investment_Plan_Design.pdf

Mette Kjaer, A. (2004). "Old brooms can sweep too!" An overview of rulers and public sector reforms in Uganda, Tanzania and Kenya. *The Journal of Modern African Studies*, *42*(03). doi:10.1017/S0022278X04000242

Mwasumbi, H. A., & Tzoneva, R. (2007). Power sector in Tanzania: Performance, trends and reforms. In *AFRICON 2007* (pp. 1–7). doi:10.1109/AFRCON.2007.4401511

NDC, TZ, & Dimson, S. (2014, January). Wind Engery Potential in Tanzania. Retrieved from http://www.ndc.go.tz/about-us

Nord, R., Sobolev, Y., Dunn, D., Hajdenberg, A., Hobdari, N., Maziad, S., & Roudet, S. (2009). INTERNATIONALMONETARY FUND. *Washington, DC*. Retrieved from http://204.180.229.152/external/pubs/ft/books/2009/tanzania/tanzania.pdf

Norrington-Davies, G., & Thornton, N. (2011). *Climate Change Financing and Aid Effectiveness: Tanzania Case Study* (Case Study). Agulhas; Organisation of Economic Cooperation and Development; Africa Development Bank. Retrieved from http://www.oecd.org/countries/tanzania/TZA.JPG

Nyerere, J. (1973). *Nyerere: Freedom and Development - Uhuru Na Maendeleo*. Dar es Salaam, Tanzania: Oxford University press.

Odhiambo, N. M. (2009). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy, 37*(2), 617–622. doi:10.1016/j.enpol.2008.09.077

Odhiambo, N. M. (2010). Energy consumption, prices and economic growth in three SSA countries: A comparative study. *Energy Policy, 38*(5), 2463–2469. doi:10.1016/j.enpol.2009.12.040

OECD/IEA. (2010). *Energy Poverty: How to make modern energy access universal?* (Excerpt of World Energy Outlook 2010) (pp. 1–38). International Energy Agency, United Nations (UNDP & UNIDO). Retrieved from http://www.worldenergyoutlook.org/media/weowebsite/2010/weo2010_poverty.pdf

OPIC. (2014). How OPIC supports renewable resources in the developing world | OPIC : Overseas Private Investment Corporation. Retrieved May 15, 2014, from http://www.opic.gov/opic-action/renewable-resources/how-opic-supports-renewable-resources-developing-world

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy Policy, 38*(1), 340–349. doi:10.1016/j.enpol.2009.09.024

Payne, J. E. (2010). Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies, 37*(1), 53–95. doi:10.1108/01443581011012261

Qiu, L. D., & Tao, Z. (2001). Export, foreign direct investment, and local content requirement. *Journal of Development Economics, 66*(1), 101–125.

REA. (2011). REA Annual Report. Tanzania Rural Energy Agency.

REA. (2012, August 1). Operating Guidelines. Credit Line: Tanzania Energy Development and Access Expansion Project (TEDAP)-Off Grid Component. United Republic of Tanzania-Rural Energy Agency.

RECP. (2013). Mini-grids: Opportunities for Rural Development in Africa (p. 24). Arusha, Tanzania: Africa-EU Renewable energy Cooperation Programme.

Rist, G. (2008). *The History of Development: From Western Origins to Global Faith* (3rd ed.). London, UK: Zed Books.

Robertson, C. (2012). *The Fastest Billion: The Story Behind Africa's Economic Evolution*. London, UK: Renaissance Capital Securities Limited.

Sachs, J. D. (2013, September 24). The End of Poverty, Soon. *The New York Times*. Retrieved from http://www.nytimes.com/2013/09/25/opinion/the-end-of-poverty-soon.html

Sari, R., & Soytas, U. (2007). The growth of income and energy consumption in six developing countries. *Energy Policy*, *35*(2), 889–898. doi:10.1016/j.enpol.2006.01.021

Simbakalia, J. L. (2013). The Preparedness of Tanzania to Accommodate the Natrual Gas Economy (p. 22). Presented at the Economic and Social Research Foundation: Unleashing Growth Potentials in Tanzania - Making Natural Gas Guarantee Sustainable Human Development.

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Jeffrey J. Shelstad, Irwin McGraw-Hill.

TANESCO. (2014). Historical Background. *Tanzania Electric Supply Company: We light up your life*. Retrieved March 26, 2014, from http://www.tanesco.co.tz/index.php?option=com_content&view=article&id=38&Itemid=126

Temu, A. E., & Due, J. M. (2000). The business environment in Tanzania after socialism: challenges of reforming banks, parastatals, taxation and the civil service. *The Journal of Modern African Studies*, *38*(4), 683–712.

Tenenbaum, B., Greacen, C., & Siyambalapitiya, T. (2014). *From the Bottom Up: How Small Power Producers and Mini-grids Can Deliver Electrification and Renewable Energy in Africa.* World Bank Publications. Retrieved from http://books.google.com/books?hl=en&lr=&id=N0afAgAAQBAJ&oi=fnd&pg=PP2&dq=%22cite+the+work+as+follows:+Tenenbaum,+Bernard,+Chris+Greacen,+Tilak%22+%22James+Knuckles.+2014.+From+the+Bottom+Up:+How+Small+Power+Producers+and+Mini-Grids+Can%22+%22Bank+translation.+The+World+Bank+shall+not+be+liable+for+any+content+or+error+in+this%22+&ots=W7UnE2Nc3T&sig=Mk3SOBItzJdFmilRmgEwthwY2qI

The Economist. (2011, January 6). Africa's impressive growth. *The Economist Online*. Retrieved from http://www.economist.com/blogs/dailychart/2011/01/daily_chart

Trajok, D., Way, B., & Robertson, C. (2012). Oil and Gas in the Africa Boom. In *The* (p. 14). Renaissance Capital Securities Limited.

UNDP. (2011). *Towards Human Resilience: Sustainaing MDG Progress in an Age of Economic Uncertainty* (p. Chapter 5). Retrieved from http://www.undp.org/content/dam/undp/library/Poverty%20Reduction/Inclusive%20development/Towards%20Human%20Resilience/Towards_SustainingMDGProgress_Ch5.pdf

UNFCC. (2014). UNFCCC : The Cancun Agreements. Retrieved March 12, 2014, from http://cancun.unfccc.int/cancun-agreements/main-objectives-of-the-agreements/#c33

UNIDO. (1986, February 3). Industrial Policy and the Developing Countries: An Analysis of Local Content Regulations. UNIDO/IS.606.

United Nations. (2011). Rio+20 - United Nations Conference on Sustainable Development. Retrieved March 12, 2014, from http://www.uncsd2012.org/history.html

United Nations. (2012a, September 11). Resolution Adopted by the General Assembly on 27 July 2012: The Future We want. United Nations. Retrieved from http://sustainabledevelopment.un.org/futurewewant.html

United Nations. (2012b, September 11). Resolution adopted by the General Assumbply on 27 July 2012: 66/288: The Future We Want. Retrieved from http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N11/476/10/PDF/N1147610.pdf?OpenElement

United Nations. (2013a). *Human Development Report 2013. The Rise of the South: Human Progress in a Diverse World - Tanzania (United Republic of)* (p. 5). United Nations Development Programme. Retrieved from http://hdr.undp.org/sites/default/files/Country-Profiles/TZA.pdf

United Nations. (2013b). Sustainable Energy For All. *Sustainable Energy for All*. Retrieved February 24, 2014, from http://www.se4all.org/about-us/

United Nations. (2014a). Kyoto Protocol. *United Nations Framework Convention on Climate Change*. Retrieved March 12, 2014, from https://unfccc.int/kyoto_protocol/items/2830.php

United Nations. (2014b, March 31). UN News - Climate change impacting entire planet, raising risk of hunger, floods, conflict – UN report. *UN News Service Section*. Retrieved April 9, 2014, from http://www.un.org/apps/news/story.asp?NewsID=47471&Cr=climate+change&Cr1=#.U0Vx4FehFo3

United Republic of Tanzania. The National Energy Policy, § 1-6 (2003).

United Republic of Tanzania. (2013a). *Tanzania In Figures 2012* (p. 81). National Bureau of Statistics, Ministry of Finance. Retrieved from http://www.nbs.go.tz/takwimu/references/Tanzania_in_figures2012.pdf

United Republic of Tanzania. (2013b). *The United Republic of Tanzania: Population Distribution by Age and Sex* (p. 499). Dar es Salaam, Tanzania: Ministry of Finance, National Bureau of Statistics.

US Department of State, Office of the Historian. (2013, October 31). Milestones: 1969-1976, Oil Embargo, 1973-1974. Retrieved January 21, 2014, from http://history.state.gov/milestones/1969-1976/oil-embargo

US EPA, C. C. D. (2011). Carbon Dioxide Emissions. Overviews & Factsheets,. Retrieved March 10, 2014, from http://www.epa.gov/climatechange/ghgemissions/gases/co2.html

USAID. (2014, March 26). Power Africa. Retrieved March 27, 2014, from http://www.usaid.gov/powerafrica

Wilson, E., MacGregor, G., Macqueen, D., Vermeulen, S., Vorley, B., & Zarsky, L. (2009). Innovating for environment and society: an overview. *IIED Briefing Business Models for Sustainable Development*. Retrieved from http://dlc.dlib.indiana.edu/dlc/handle/10535/6141

Wilson, E., & Symons, L. (2013, May). Stimulating quality investment in sustainable energy for all. International Institute for Environment & Development.

Wilson, E., & Zarsky, L. (2009, November). Power to the Poor. International Institute for Environment & Development. Retrieved from www.iied.org/pubs/display.php?o=17058IIED

Wolde-Rufael, Y. (2009). Energy consumption and economic growth: The experience of African countries revisited. *Energy Economics*, *31*(2), 217–224. doi:10.1016/j.eneco.2008.11.005

World Atlas. (2014). World Atlas: Tanzania Land Statistics. *World Atlas*. Retrieved March 29, 2014, from http://www.worldatlas.com/webimage/countrys/africa/tanzania/tzlandst.htm

World Bank. (2012). Clean Technology Fund: Nigeria. Retrieved from https://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/CTF_Nigeria.pdf

World Bank. (2013a). World Development Indicators | Power and communications. Retrieved March 27, 2014, from http://wdi.worldbank.org/table/5.11

World Bank. (2013b). World Development Indicators: Poverty rates at international poverty lines. Retrieved March 31, 2014, from http://wdi.worldbank.org/table/2.8

World Bank. (2014a). Clean Investment Fund: Ethiopia. Retrieved March 16, 2014, from https://www.climateinvestmentfunds.org/cifnet/?q=country/ethiopia

World Bank. (2014b). Climate Investment Fund. *About Climate Investment Funds.* Retrieved March 16, 2014, from https://www.climateinvestmentfunds.org/cif/aboutus

World Bank. (2014c). Sub-Saharan Africa (developing only) | Data. Retrieved May 5, 2014, from http://data.worldbank.org/region/SSA

World Bank. (2014d). The World Bank Data Bank - Tanzania. *World Development Indicators.* Retrieved March 25, 2014, from http://databank.worldbank.org/data/views/reports/tableview.aspx

World Bank. (2014e, January). Global Economic Prospects: Sub-Saharan Africa. Retrieved January 23, 2014, from http://www.worldbank.org/en/publication/global-economic-prospects/regional-outlooks/ssa

Zhang, M., Liu, X., Wang, W., & Zhou, M. (2013). Decomposition analysis of CO2 emissions from electricity generation in China. *Energy Policy, 52*, 159–165. doi:10.1016/j.enpol.2012.10.013