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The transition to 100% renewable energy societies in Central Africa - a Kasese District case study

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supervised by
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Affidavit

I, **Philip Jones**, hereby declare

1. that I am the sole author of the present Master's Thesis, "The transition to 100% renewable energy societies in Central Africa - a Uganda case-study", 56 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

This dissertation examines the pathways to 100% renewable energy communities, including both electrical and cooking energy sources. By focusing in Sub-Saharan Africa, where only a tiny fraction of the population has access to electricity and where biomass is still the overwhelming source of energy, the paper concerns itself with the concept of 'leap-frogging' carbon-based development. It outlines and assesses the existing literature on 100% renewable communities, before introducing a tailored model focused on Kasese District in south-west Uganda. Kasese District has set itself the bold target of using 100% renewable energy by 2020. By utilising the Long-Range Energy Alternatives Planning (LEAP) software, two scenarios ('Business-as-usual' and 'potential') are constructed to model progress in Kasese District from today through to 2025. These scenarios are outlined and their findings combined with knowledge found in the literature to produce a set of recommendations and identify bottle-necks in the process. Whilst the target of reaching 100% renewable energy in Kasese by 2020 is deemed highly unlikely, a set of policies theoretically implemented in 2016 to form the 'potential' scenario show how 100% renewable energy is possible in Kasese by 2025. These policies include maintaining the $5.5 USD per watt subsidy on solar panels, increasing access to finance for pico-power suppliers, investment in the harvesting of agricultural residues for use in cooking and the targeted afforestation of 10,000 hectares of deforested land in Kasese District. The results show that Kasese District has the potential to become an example of sustainable growth for the entire region, attracting both tourism and investment as it successfully decouples growth from carbon emissions and leap-frogs the 'traditional' carbon-based development model.

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1. Introduction

Why Kasese, why Uganda, and why now?

No radios crackling with news or music, no mobile phones to connect to the rest of the world, no electric lights to see by once the sun sets. An economy in tatters and with little prospect of improvement: farmers without access to markets or water pumps; schools unable to properly prepare children for the world beyond the community. Work finishes at sundown, with no option to add productivity by working in hours of darkness. The night is lit only by kerosene lamps, cooking fires and the moon. This is, for 1.1 billion people globally, the daily reality. Sub-Saharan Africa combined, excluding South Africa, uses less electricity than New York state. Population growth continues at a staggering pace, and currently 600m people are without electricity in the region. With the rate of population growth continuing to outstrip the rate of electrification, the number of people in Sub-Saharan Africa living without electricity is projected to rise through to 2030 (Economist, 2016).

The inspiration for this Master Thesis has come in large part from the "Go100%Percent" campaign launched by the Mayor of Kasese District, Uganda, with the aim of reaching 100% renewable energy in the district by 2020. This bold project is setting an example for other regions and states across Africa to follow, empowering communities and improving the living standards of the population. Godfrey Baluku Kime, the Mayor of Kasese, has chosen to work closely with the WWF and international donors to get the project moving, but as the project moves into its second half, the direction and ideas have begun to dry up (Oketcho, 2016). This paper will assess what has been achieved to date, introducing ideas and modelling from a recent WWF report looking at 100% renewable pathways for the whole of Uganda, as well as drawing lessons from the state-of-the-art, in order to breathe fresh life into the project and offer a timely reminder of the potential benefits and barriers to be addressed between now and 2020. Furthermore, whilst situated in the broader '100% renewable' literature, special attention is given to financial and political aspects that are otherwise often overlooked in the highly technically-based literature.

The "Go100%Percent" movement is not limited to Uganda, or indeed to Africa, with projects ranging from rural Vietnam, through India to Vermont in the United States and other developed countries. Uganda has been selected specifically, however, for the wider applicability of the lessons learnt. Solar radiation conditions, socio-economic development, deforestation and the issue of sustainable Biomass are all common factors that are prescient across Sub-Saharan Africa. Uganda has also made encouraging first steps towards a sustainable energy future, and whilst electrification is still on a rudimentary level, the potential for sustainable growth is enormous. Such is the small size of the existing electricity grid, and the abundant solar energy potential, that a relatively small area with installed solar PV or Concentrated Solar Power (CSP) could theoretically power all of the Ugandan grid. A solar PV array of four square kilometres could produce over 1,000 MW which is more than the current output of the Uganda grid. (WWF, 2015) Furthermore, the concept of 'leap-frogging' carbon based development has entered the lexicon of Ugandan politics, with policies designed to increase access to renewable energy being pushed not just for their environmental merits, but also the potential economic, health and politics improvements associated with cheap, plentiful energy (Baluku Kime, 2015).

Despite recent oil discoveries in Uganda, local and central government have reaffirmed their commitments to renewable energies (WWF, 2015). Historically, one of the greatest barriers to the large-scale deployment of renewable energies has been a belief that it would be costly, rather than cost saving. However, we are currently seeing the gradual blossoming of understanding that future prosperity depends on making the leap to a low-carbon economy. Developing states even have a particular advantage in this respect, with energy and other infrastructure not yet locked in to high emissions and inefficient centralised grids (Leach, 2015). Uganda and other developing states find themselves in a position whereby, with strategic thinking and effective management, flexible and interoperable grids can develop, including battery storage, demand-side management technologies and dynamic pricing. The ability to learn from the mistakes of developed nations, leap-frogging design flaws and the outdated assumption of needing single large baseload producers, leaves Uganda and others in a uniquely promising position (Ghatikar, 2015).

One advantage developing states have, apart from the almost blank slate upon which to design a modern energy system, is the rise of mobile technologies (especially mobile money) over the last decade. Mobile phones have allowed poorer communities to leapfrog traditional branch-based banking services and the need for landline telephones;

instead, benefiting from the latest in micro-credit financing and access to information and markets without the need for expensive data infrastructures. This model is already being introduced in the energy sector, allowing even those living on less than $1 USD a day to afford electric lights, a radio and a charging kit for a mobile phone. As with the advances in mobile communications technology over the last decade, the hope here is to do away with costly grid-construction and maintenance, harvesting solar power locally rather than relying on fossil fuel plants hundreds of kilometres away.

Broader context this paper is situated in

The push towards 100% renewable energy societies is one that is driven by the need to move away, globally, from greenhouse gas emitting fossil fuels and towards an energy mix which is sustainable in our attempt to avoid catastrophic climate change. With carbon dioxide concentrations rising above 400ppm permanently in 2016, time is running out to reverse the damage already done. Whilst the overwhelming majority of emissions have historically come from developed states, as developing countries move towards more advanced economies, it has become an expectation that their emissions must necessarily rise with their economic output. In the case of China, India, and other states which have developed quickly over the last few decades, much of their power has come from coal, the cheapest and most polluting of the fossil fuels. Were countries in Sub-Saharan Africa, or other G77 nations looking to move up the industrial ladder, to take the same decisions and utilise coal for their development, no amount of efficiencies and emissions cuts in the developed world would stave off the worst effects of climate change. The Paris Agreement, drafted in November 2015 and signed in April 2016, sets out the most ambitious framework for tackling climate change ever agreed upon, and includes specific provisions relevant to developing countries as well as developed. These provisions include forestry, where countries in East Africa stand to receive support from the group of developed states to combat deforestation. East Africa is particularly dependent on its forestry, with more than 95% of the population using solid biomass fuels for cooking and heating (Jagger & Shively, 2014).

Uganda also finds itself facing considerable challenges in its energy sector. Despite goals to increase access to renewable energy from 4% in 2007 to 61% in 2017 (G0100Percent.org, 2015), brownouts (decreases in voltage) on the grid are still common place as demand rises and new power-generation projects fail to come to fruition. Climate change is already impacting Uganda's Hydropower production, while investment in other forms of renewable energy is hamstrung by capital shortages and a lack of grid-level storage capacity and knowhow (Tumwesigye, Twebaze, Makuregye, & Muyambi, 2011). Electricity prices for customers on the grid have recently increased dramatically, from $0.12 per kWh in 2013 to $0.18 per kWh by the end of 2015. Uganda's constitution ensures that the Government pursue "energy policies for meeting people's energy needs in an environmentally friendly manner" (KDLG, 2012), and to this aim the Electricity Act (1999) was passed, establishing the Electricity Regulatory Authority (ERA). The ERA has gone a long way to ensuring financial viability in the sector, and the formerly state-owned Uganda Electricity Board has been unbundled to form independent entities responsible for generation, transmission and distribution (Tumwesigye, Twebaze, Makuregye, & Muyambi, 2011). Furthermore, the 2001 established Rural Electrification Agency is mandated to work towards rural electrification rates of at least 22% by 2020, up from 1% in 2010 (Rural Electrification Agency, 2012). Ultimately, whilst much of the framework now exists in Uganda, sixty years of global efforts towards mass electrification have thus far failed to deliver reliable access to even a small fraction of the world's poor, and Uganda is no exception. This is still a pressing issue as we move towards 2020, with health issues and environmental damage becoming more and more prevalent, and analysis of the existing literature and practical recommendations as to how best to move forward are always welcome (Oketcho, 2016). Of the UN's 17 Sustainable Development Goals, Goal 7 – ensuring access to affordable, reliable, sustainable and modern energy for all by 2030 – is arguably capable of achieving many of the other goals simultaneously. As United Nations Secretary General Ban Ki-Moon has extolled, "energy is a golden thread that connects economic growth, increased social equity, and an environment that allows the planet to thrive." (WGSI, 2015)

Statistics outlining Ugandan renewable energy potential

As much of this paper focuses on potential for renewable energy generation in East Africa, Uganda and Kasese specifically, it will be helpful to have an overview of the statistics and technical potential that the various pathways and policies are striving to best exploit. A recent report by the International Renewable Energy Agency (IRENA) outlines the technical potential of renewable energy generation in Africa as a whole, and the World

Wildlife Fund (WWF) report on 100% renewable pathways for Uganda elaborates in more detail for Uganda specifically (IRENA, 2014; WWF, 2015). The following statistics are taken, unless otherwise stated, from these two reports:

The Ugandan Electricity Grid:

- Electricity demand in Uganda was 3.1 TWh in 2014, which includes 0.94 TWh of losses due to distribution and transmission (UBoS, 2015). This compares to 60 TWh consumed in Austria.
- The Ugandan grid power is primarily generated by Hydropower plants. Whilst accounting for <2% of the energy demand in Uganda, Hydropower remains a crucial part of the energy mix.
- The Ugandan grid is made up of roughly 15,000 km of cables, split between transmission (33kV and above) and distribution (below 33kV). Estimated losses for the last available year, 2011, showed 30% losses in transmission and distribution despite the relatively small size of the grid.
- ~18% of the Ugandan population has access to grid electricity, almost all of whom are found in Kampala and the district capitals. The grid operator supplies approximately 650,000 customers.
- In Kasese district, Kilembe Investments Limited is implementing Grid Based Extension programs. A total of 2,800 new connections were completed in the Financial Year 2013/14, with another 5,000 completed in Financial Year 2014/15 (Kasese District Government, 2016).
- In 2014, the total installed capacity of power plants connected to the grid was 867 MW. This included 695 MW of Hydropower, and 136 MW of thermal power plant (Natural Gas). This compares to ~22 GW in Austria.
- Government plans are to increase per capita consumption of electricity. Today demand is at 80 kWh per capita, which the government wants to increase 588 kWh by 2020 and 3,668 kWh per capita in 2040. This compares to ~8,500 kWh per capita in Austria.
- The cost of electricity from the grid is unusually high, especially for a low-income country. Grid electricity prices now sit at ~650 Ugandan Shilling per kWh ($0.18 USD).

Solar:

- Given Uganda's area (236,040 km2), and over 5 kWh/m2/day, Uganda has more than 400,000 TWh of solar energy arriving each year on its surface area.
- Solar and battery based off-grid sites already provide hundreds of thousands of remote customers with electricity services. Whilst exact numbers are unknown, there is an active private-sector driven market in place and a burgeoning 'over-the-counter' market for small PV systems.
- 'Pico-solar' systems, small solar systems designed to power electric lights, a phone charger or small DC appliances, are currently priced at $0.39 per day, paid over 18-months, for a 10w system plus accessories.

Wind:

- The wind resource in Uganda is estimated as sufficient only for small-scale electricity generation, and only in select regions.
- Whilst more data needs to be collected, the ERA is yet to receive any formal expressions of interest in the generation of electricity from wind (Tumwesigye, Twebaze, Makuregye, & Muyambi, 2011).

Biomass:

- Uganda's biomass production potential means that it could produce biofuels based purely on domestically sourced, sustainable biomass, and replace demand for petroleum products within 50 years.
- Firewood, charcoal and agricultural residues used for cooking (respectively, 86%, 5.8% and 7.0%) constitute the bulk of household energy use.
- Deforestation pressures have reduced forest cover from over one-fifth of land area at independence in the 1960s to 7% today (Lee, 2013).

Structure

This paper will begin with an assessment of the state-of-the-art in 100% renewable energy pathways, highlighting areas relevant to Uganda and Kasese, as well as investigating areas in which the literature has failed to provide compelling arguments or evidence. The aforementioned WWF report from 2015 will then be assessed in greater detail, with special attention given to the financial assertions and implications of the pathway recommended by the report. A political and socio-economic assessment of Uganda and its readiness for the changes that would be required to reach 100% renewable energy is then presented, outlining information gathered through interviews and reports.

This is followed by a case study of Kasese district, in which each of the aspects mentioned above is brought together to form an holistic approach to the challenges ahead for the district. Following a short introduction to the district and its unique circumstances, the Long-range Energy Alternatives Planning system is employed to generate a pathway to 100% renewable energy for Kasese district. This pathway, and the necessary policy steps and financing required to achieve it, are then assessed in a system-wide approach; focusing on technical capacity and feasibility. Finally, an analysis for each renewable energy source is given for the specific circumstances of Kasese district. Cost analyses, including announced tariff levels and potential income returns, as well as political and social feasibility for grid-extension, solar (grid-connected and pico-power), geothermal, hydropower and biomass are generated in order to provide an easy-to-grasp overview for policymakers and potential investors alike looking to move Kasese closer to its 100% renewable energy goal.

2. Research Chapters

Assessment of the state-of-the-art (100% renewable energy pathways)

To begin with, it is essential to clarify that '100% renewable' can have two separate meanings. A narrower definition referring solely to electricity supply is predominantly used in Europe and the USA. For instance, so long as an electricity grid is powered 100% from renewable sources, the fossil fuels burnt in the heating and transportation sectors are ignored. Other definitions work towards a broader approach, encompassing both heating and transportation, as well as electricity supply. For the purposes of this paper, and in line with the literature reviewed and pathways assessed the definition of "100% renewable" is defined as including electricity supply and heating/cooking energies, but excluding transportation. The transportation sector in Uganda is relatively small, and whilst it will certainly be affected by developments in other areas, any progress here is seen as a side-effect of transformation in other areas and as such will not be included as a core goal of the 100% renewable project. For the project in Kasese district, which is the subject of a subsequent case study, rural electrification with renewable power sources and a fully sustainable use of biomass suffice as the definition for '100% renewable'.

Broadly speaking, the term '100% renewable' being used as a goal for communities, regions or even entire countries to aspire to is a comparatively new phenomenon. One of the first large-scale studies to be conducted was undertaken by Jacobsen and Delucchi at Stanford University in 2011. Looking on a global scale, they concluded that producing all new energy from hydropower, wind and solar by 2030 was both technically and financially feasible (Jacobsen & Delucchi, 2011). Existing fossil fuel and nuclear plant should be allowed to finish their life-cycles, and would be fully taken off the grid by 2050. Financially, Jacobsen and Delucchi predicted that 2015 would be the year in which their envisaged energy system would become cost competitive with existing fossil-fuel based systems. Although the recent slump in oil prices has partly dented this assertion, the faster-than-expected fall in cost per MW of solar and wind plant means that Levelised Costs of Electricity (LCOE) for these technologies are now competitive with gas and coal (Hill, 2016).

Indeed, the literature is almost unanimous in its findings when referring to the most significant barriers to widespread uptake of renewable energy, especially in the developed world. Rather than financial barriers or high capital requirements holding back progress, or technical challenges with regards to intermittent supply, a marked lack of political will is most commonly identified as the main obstacle. A 2013 report entitled 'Post Carbon Pathways', which brought together and reviewed dozens of international studies in the area, identified climate change denial, political apathy, outdated energy infrastructure, the fossil fuels lobby and unsustainable energy consumption as the most important roadblocks hindering renewables progress (Wiseman, Edwards, & Luckins, 2013). However, the interaction between politics and the technical feasibility of 100% renewable pathways is potentially even more interesting. Whilst study after study produce models showing the best possible path to a renewable energy mix in 2050, they all appear to have one common flaw. Whilst the formulae, economics and even the technological capacity and investment parameters are all worked out; they are optimised. Optimising pathways to a renewable energy mix means bearing the unavoidable flaw that it is almost certainly unrealistic. Whilst political decision-making and inconsistencies are often built-in through inefficiencies or the need to meet arbitrary targets in the model, the reality is that policy decisions taken in the energy sphere happen on election cycles and are impossible to delineate from these cycles. If politicians are not motivated by election cycles - as for example in the case of dictatorships - the pressure to remain as popular as possible remains the same.

This inability to factor in political decision-making or forecast societal reactions and uptake of new technologies is reflected in a common phenomenon amongst modelling outcomes. Many energy models, especially those looking towards reaching 100% renewable by 2050, show slow progress through the 2020s, ramping up a little in the 2030s, until finally there is a huge leap in the 2040s in order to achieve the target and reach the predefined goal (Wiseman, Edwards, & Luckins, 2013; WWF, 2015). In reality, such progress is not sustainable for the decision-makers who need results and outcomes sooner rather than later. Rarely does a government get to survive pointing to a plan, whether economic, social or energy-based, in which progress moves slowly through to 2040 before the vast majority of the benefit is realised in the final decade. The issue of modelling and its potential will be revisited in a later section dealing with the recent WWF report, and again as part of the case study. However, for now it is important to highlight that previous studies and literature relied heavily upon pathway optimization, without adequately assessing and analysing its shortcomings (Welsch, 2013).

Where the literature has conducted a multi-faceted investigation, however, is the various indicators that both drive the need to leap-frog carbon based development and provide the basis for the potential benefits of doing so. Whilst each of these areas could command a dedicated study into the effects of switching from fossil fuels, space requirements limit this section to a brief precis of the assorted literature on each topic.

Agriculture

Regions of the world suffering from energy poverty coincide with those areas where agriculture provides for 65% of the labour force and 29% of GDP (Economist, 2016). Lack of access to reliable, cheap, clean energy significantly hampers agricultural yields. An inability to properly irrigate land, operate or maintain equipment, or include any post-harvest processing on-site forces profit margins down and labour intensity up. By providing the agricultural sector in areas suffering from energy poverty with modern, reliable energy services, the immediate benefits would include increased yields, the ability to better manage supply chains and connect directly with new markets, and the implementation of cold-storage to reduce waste in the supply chain (REA, 2007).

Education

Decreasing the labour intensity of agriculture has a knock-on effect on education. Whilst school attendance has been rising steadily throughout the 21st Century, only half of the children from families in Least Developed Countries (LDCs) attend primary schools that are connected to the grid (WGSI, 2015). Whilst rural schools have been some of the earliest movers towards electrification, a vast majority remain without access to reliable electricity. Without it, schools are unable to offer after-school programs, or teach classes either before sunrise or after sunset (GOGLA, 2015). They are also unable to provide access to computers, the internet, or associated information technologies which have been shown to dramatically improve education and a student's readiness for work (WGSI, 2015). Whilst studies that show the use of information technologies improving educational attainment and job prospects have been mostly focused in the developed world, offering the same access to education in developing countries will help the whole society to develop quicker.

Women

Women are, much like children in the case of education, unequally burdened by the impacts of relying on traditional energy sources such as kerosene lamps, three-stone cook stoves and open fires. "*Surveys show that in many parts of the developing world women spend 2–8 hours per day collecting wood for cooking, and cleaning soot from household items*" (WGSI, 2015). Furthermore, women are faced with greater exposure to indoor air pollution, as the burning of biomass and kerosene in the home has shown to be a leading cause of blindness amongst women in the developing world (WHO, 2012).

Health

With regards to health, recent studies have shown a drastic and under-reported link between the over-reliance on biomass (especially non-forest acquired biomass) and acute health problems across Sub-Saharan Africa. According to a WHO-sponsored study from 2012, "*the indoor air pollution that results from using traditional sources of cooking and lighting fuel such as kerosene causes an estimated 1.5 million premature deaths per year – including half of all deaths of children under the age of five"* (Janssen, 2012). Indeed, were the combustion of biomass and kerosene to continue at present rates until 2030, resultant particulate matter and black carbon emitted is projected to directly lead to more premature deaths than AIDS, tuberculosis and malaria combined (Janssen, 2012). Contributing to this prognosis is the rate of deforestation. Separate studies have found that the quality of the biomass burned has a strong impact on health implications. Households reliant on biomass from non-forest areas (fallows or brushland) are at a significantly higher risk of suffering from Acute Respiratory Infection (ARI) (Jagger & Shively, 2014). Finally, the lack of access to reliable electricity has been shown to lead to approximately half of all vaccinations, as well as valuable blood and medicine, being wasted due to a lack of cold storage availability in Sub-Saharan Africa (WGSI, 2015).

Environmental

Deforestation, and the resultant goal of sustainable forestry management, is intrinsically tied to the question of renewable energy. Whilst rural Uganda, for example, obtains 98% of its end-use energy from biomass, the collection of biomass for firewood has been attributed to causing up to 75% of deforestation in the region (Cerutti, 2015). Although efficiencies can, and will, be improved through the introduction of new stoves and solar water heaters, woody biomass is projected to continue playing a significant role through to 2050, whichever scenario is used. As such, the issue of sustainable forestry management and the afforestation of the worst affected areas should be seen as a key pillar of any renewable energy strategy. Unfortunately, to date, assessments of the environmental and socio-economic impact of over-reliance on wood energy use have been unsystematic and failed to properly highlight its significance (Cerutti, 2015). In the case of Uganda, if current rates of deforestation are maintained, all forests outside of protected areas will become cropland by 2020, rendering woody biomass either more expensive or simply unattainable for many rural Ugandans (Jagger & Shively, 2014).

Political

Political disenfranchisement has been found to correlate strongly with energy-poverty in rural regions. Without access to electricity to power a radio or mobile phone, engagement with politics is sparse, allowing disenchantment with the political situation to grow easily. However, community-based ‘micro-grids’ and the rise of pico-power solar systems, have been shown to be reversing this trend (WGSI, 2015). Those communities which have seen the establishment of micro-grids or other electrification projects have been shown to greatly improve active participation and ‘buy-in’ to both local and regional government politics (Oketcho, 2016). An increase in access to information technologies has allowed rural villages to become more aware of their rights and the opportunities they can avail themselves of. This process not only helps to organically spread government initiatives, it also helps to improve governance and tackle corruption, which has been identified as one of the most severe hindrances to development in the region (KDLG, 2012).

Technologies

Pico-power, sometimes referred to as Single Home Systems (SHS), is one of the fastest growing markets in East Africa and South-East Asia. The market is predicted to continue to grow as prices come down, quality and reliability of the products rises and awareness and trust spreads. One of the leading companies in this area, M-KOPA, is having success by allowing customers to bypass large upfront costs and pay in small installments over a 12 or 18-month period. Their business model is based on the fact that currently, up to 80% of Ugandans utilize Kerosene lamps for light in the hours of darkness; a luxury which costs at least $0.50 per day. By offering packages of one solar panel, two or three LED lamps, a mobile phone charger and a radio for $0.40 a day (M-KOPA, 2015), these SHS are bringing modern technologies to rural communities in an economically sustainable manner, without the need for government subsidies (Leach, 2015).

Pico-power systems are not without their pitfalls, however, and are currently in danger of suffering from a surge of unregulated and inferior products on the market. At present, companies developing SHS are operating outside of any defined legal structures for SHS, without any system of mandatory testing or licensing to minimal standards. Whilst this influx of competition suggests that a market does indeed exist and could push prices for consumers even lower, there is a risk that poor quality products seriously harm public trust in the systems (Banning-lover, 2015). Part of the issue is that governments do not currently have the capacity to effectively enforce existing standards, and the aforementioned issues with corruption make efforts even more difficult. Whilst the technology, and the companies selling them, will require local government and community cooperation to reach remote areas, as well as extended access to finance to cope with the burgeoning demand, the future is generally considered bright for SHS (Leach, 2015).

Lessons from the literature to be applied in Uganda and Kasese

As far as rural electrification is concerned, the literature on 100% renewable energy pathways places an emphasis on centralised planning for a decentralised grid. Whilst grid-extension is currently the responsibility of the grid operator and the large utility companies, micro-grids and SHS are developing at a much faster rate, producing potential spare capacity in areas the national grid has not included in its planning (Oketcho, 2016). Instead, as a senior energy economist from the Department for International Development in London has stated, there is no reason for off-grid energy and grid energy to compete (Towers, 2015). The demand for electricity is outstripping supply, and as such a variety of solutions and a more diverse energy mix will only benefit national energy security. Rather than having to decide between grid-extension or a series of decentralised mini-grids powered by solar and small hydro, a well-planned and integrated system can provide both, whilst simultaneously addressing the weaknesses of either system on its own. The director of ‘Power for all’ recently listed her requirements for a successful transition to universal clean energy access in Africa as a mixture of: political will, sustained institutional capacity, market understanding, solid business operating environments, quality standards and reduced fossil fuel subsidies (Banning-lover, 2015). Each of these areas will be addressed in the case study, as Kasese District local government attempts to both enact the required programmes itself and create the environment for others to contribute towards their end goal.

The majority of the reports produced to date have focused on the technical possibilities and challenges, as opposed to the financial and political feasibility of transitions. Those that do include a financial element (the recent WWF Uganda report included), do so in a limited way and without detailed justification or explanation. A report touching upon both financial and societal aspects of a transition to 100% renewable energy is very difficult to come upon, although the subsequent case study will attempt to do just that. As far as the financial aspect of a transition goes, it is clear that with substantial government capital injections and subsidies, a transition is technically possible very quickly and cheaply for the consumer (Jacobsen & Delucchi, 2011). This, however, is neither politically feasible nor sustainable. Instead, the key is to move as far away as possible from government or donor grant funding, and instead provide energy solutions that are sustainable for both the consumer and the providers of renewable energy. The Overseas Development Institute in London has identified access to finance as being potentially the single most important constraint preventing renewable energy providers in developing states from expanding sufficiently. “*In terms of banks, the sector definitely needs more local currency lending”* (ODI, 2016).

One source of finance, albeit not in the form of credit, that is regularly discussed in developing states is the opportunity available to access funding from developed states through the ‘Clean Development Mechanism’ (CDM) and ‘Global Environmental Facility’ (KDLG, 2012). New hydropower projects provide traditional investment opportunities for developed states looking to partake in the CDM, with 30% of all carbon offset projects registered to date (Carbon Market Watch, 2016). As Uganda’s grid looks to expand rapidly, the 100% renewable pathway outlined in the recent WWF report suggests that at least 80% of Uganda’s technical hydropower potential will need to be exploited. As the most cost-effective projects are completed, the marginal return on later projects will make private sector finance harder to come by, and at this stage CDM investments from developed states will prove essential.

Analysis of the WWF’s “Energy Report for Uganda: A 100% renewable energy future by 2050”

Utilising a combination of the ‘Long Range Energy Alternative Planning’ (LEAP) tool and a qualitative study of the current energy market in Uganda, the WWF has produced a report on what it considers to be the optimum path to a 100% renewable energy future for Uganda by 2050 (WWF, 2015). Despite the report including a relatively detailed financial breakdown of the investment required for its recommended renewable pathway, it fails to investigate the economic and political feasibility of its model. To be specific, the report calls for 11 billion USD of extra investment from central government and ‘other large stakeholders’ in order to realise its pathway, a figure which amounts to roughly 50% of Uganda’s GDP. Whilst this level of investment might be potentially feasible, a more holistic and market-friendly approach could yield the same positive results for a fraction of the cost to the government. By regulating the SHS and solar powered micro-grid market to ensure quality products, whilst at the same time fostering access to finance for businesses in the sector, much of the burden of the costly rural electrification program can be transferred to a willing consumer market (ODI, 2016). Whilst the Ugandan government, and the WWF report, have to-date seen rural electrification as the task of the central government, the growth of off-grid solar and small hydropower plants has demonstrated a ready and willing consumer market even amongst Uganda’s extreme poor (Lee, 2013).

As a piece of software utilized in both the WWF report and other scenarios for the region, the relative utility of LEAP should also be briefly discussed. The Long-range

Energy Alternatives Planning System has been developed by the Community for Energy, Environment and Development, with assistance from the KTH Royal Institute of Technology in Stockholm. With the ability to assess a wide variety of data, including Raw potential data (such as hours of sunlight), demographic data and policy options, LEAP is commonly used to model climate change mitigation strategies and evaluate energy policies for their effectiveness in reducing carbon emissions. As such, LEAP is most effective when comparing scenarios for potential future pathways against a reference ‘business as usual’ scenario, in order to demonstrate marginal benefits. Whilst LEAP claims to produce bottom-up energy models, in reality energy demands are calculated using top-down macroeconomic assumptions. The scale of future capacity expansions has to be predefined by the analyst, with all significant factors exogenously specified by the user (Welsch, 2013). As such, instead of the model optimizing a pathway to a 100% renewable goal, LEAP allows the user to input politically and socially realistic developments in technology expansion. In this respect, the LEAP model helps the user to understand the implications of the pathways they design, rather than a mathematically idealised model. The WWF report chose to place an unnecessary emphasis on government and donor capital spending on larger, centralised systems, depriving rural populations of reliable electricity access well into the 2030s.

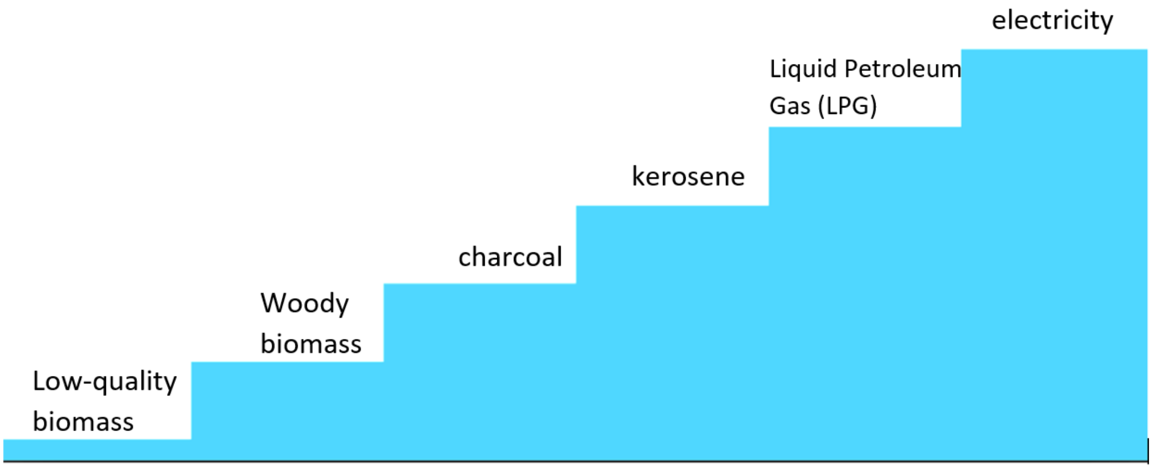
Despite this, the scenario produced in the report did provide almost universal energy access by 2050, albeit at the cost of significantly higher capital and operational costs than the ‘business-as-usual’ reference scenario. These costs are discounted in the report by the “*large amounts of unsustainable wood fuel, electricity imports and high emission levels*” avoided in comparison to the reference scenario (WWF, 2015). The costs of these negatives are found to far outweigh those of increased transmission and grid costs associated with the renewable pathway (see Table 1). Whilst the inclusion of a monetary value for ‘Environmental Externalities’ may not be of concern to a government which has not agreed to any compensation payments for emissions, the extra costs of fuel resources and wood imports alone guarantee that the renewable scenario is the economically more prudent choice. An area that the scenario relies heavily on is the enforcement of a fuel switch amongst the vast majority of Ugandan households; away from biomass for cooking and kerosene for light. Rather than supporting markets to enable this transition, the scenario envisages substantial central government investment; aggressively expanding the electricity grid and access to centralised energy production to curb unsustainable biomass use. Whilst this investment would certainly trigger new employment opportunities and benefit the livelihoods of some in Uganda, as well as reducing deforestation and environmental degradation, issues of corruption have overshadowed central government infrastructure projects in the past. There is certainly a risk of this recurring. Furthermore, the top-down approach is not entirely compatible with a recent study into the household energy mix in Uganda, which suggests that Ugandan households will make the transition to modern fuels once a turning point in income is reached (Lee, 2013). A turning point which can be lowered through easier access to the fuels and technologies in question. Indeed, whilst the WWF report makes macro-level predictions based on certain micro-level assumptions about consumer behaviour, this household energy study calls those assumptions into question.

As opposed to the working theory that Ugandan households will continue to utilise biomass and kerosene as their primary fuels until access to the electricity grid is enabled, Lee finds that Ugandans view "*energy as normal goods*" (Lee, 2013). As income increases, households switch to modern fuels, moving away from traditional or transitional fuels such as charcoal. This energy ladder theory, to which Ugandan households appear to fit, allows the energy mix to be influenced from both a bottom-up and top-down perspective.

Table 1 – Net Present Value calculations for Reference vs Renewable Scenario (WWF, 2015).

	REFERENCE	RENEWABLE	COMMENTS
Demand	-	-	There are no system costs (i.e. use costs or technology costs) defined in the demand sector. Therefore there are no costs in the NPV calculation for this section. This part is paid more by the consumer than by the system operator.
Household	-	-	
Commercial	-	-	
Transport	-	-	
Industrial Sector	-	-	
Transformation	6.12	17.32	The transformation sector contains mainly costs related to the electricity generation sector. There are no extra investment costs taken into account in the charcoal making for example as data was difficult to come by. Was subject to some assessment in the charcoal NAMA study.
Pelletisation	-	-	
Briquetting	-	-	
Charcoal Making	-	-	
Wood Harvesting	-	-	
Transmission and Distribution	4.29	7.74	This section is more expensive in the Renewable energy scenario because of the development of a stronger centralised electricity generation system.
Electricity Grid	1.74	9.32	
Electricity Mini Grid	0.10	0.25	
Electricity Off Grid			
Oil Refinery	-	-	
Natural Gas Extraction	-	-	
Biogas Digester	-	-	
Resources	105.40	65.69	This takes into account all extraction costs for fuel resources as well as import and export costs and benefits.
Production	17.55	17.51	Improvements could include adding the sales price for commodities produced by the refineries that are not used in the country.
Imports	87.85	48.18	This shows however that high levels of wood imports in the reference energy scenario are slashed in the renewable case.
Exports	-	-	
Unmet Requirements	-	12.29	
Environmental Externalities	15.29	3.01	This represents the total cost of all emissions in the model over the entire period between the two scenarios.
Net Present Value	**126.82**	**86.01**	Overall, the NPV of the renewable energy scenario is markedly lower: i.e. if you had to pay upfront today to make one scenario happen, the renewable energy scenario would be your best bet. This remains true even if you remove the CO_2 financing.
GHG Emissions (Mill Tonnes CO_2e)	3,301	1,233	

To extend the analogy of an energy ladder, each rung on that ladder represents a more modern, less polluting form of energy for the household.



In Uganda’s case, low-quality biomass would represent the bottom step, followed by forest extracted woody biomass, charcoal, kerosene, Liquid Petroleum Gas (LPG) and electricity. This has been taken to mean that more income brings electricity, with the approach taken in the WWF scenario being to bring electricity to the people in the form of the grid. Although effective by 2050, this approach leaves serious questions unanswered about deforestation and hampered economic development in rural areas until the grid arrives. The relationship between income levels and electricity is, however, not necessarily causal in only one direction. Studies cited above have shown how electricity access lower down the economic ladder can accelerate access to new income – suggesting that the relationship goes both ways. The ability to offer electricity access further down the economic ladder has also been assessed, with pico-power systems available for cheaper than kerosene. Referred to earlier as the ‘turning point’, there is a projected income level at which households will switch from one fuel to the next, with findings in 2013 suggesting a relatively high turning point for kerosene. This high turning point is, however, misleading. The research for Lee’s paper was conducted at a time before SHS had become statistically significant, and such systems now represent a real alternative to lighting at a much lower price point. Indeed, her paper asserts that “*a move up the ladder is conditional on the provision of public infrastructure [grid]*” (Lee, 2013), which has already proven to be an outdated concept. Whilst easier access to electricity is removing kerosene from the energy ladder, even in high income brackets, solid fuels are still the cooking fuel of choice in the vast majority of households. For cooking, the cost of importing LPG is still prohibitively high, and it is projected that households will continue to rely on biomass for decades. As such, when looking at securing energy security for Ugandan households as well as moving towards a renewable future, it is clear that the dissemination of improved cook stoves to increase the efficiency of cooking will be necessary. Furthermore, strategies for reforestation, staggered payment options to lower the capital barrier to accessing electricity services as well as relieving supply side constraints on modern fuels (SHS and LPG) will be necessary to achieve a more holistic and inclusive approach to energy transition.

A political and institutional assessment of Uganda and its readiness for the changes that would be required to reach 100% renewable energy

Whilst the technical and financial elements of a transition have been addressed, without an adequate institutional structure and political will to push ahead with necessary policies, the potential will remain purely academic. As such, an appraisal of the current legal and political framework in Uganda will help to understand not only what lessons can be learnt from previous initiatives, but also what will need to be done in order to capitalise on the growing market forces that are beginning to emerge in the renewable sector.

Legal and Political Framework

Beginning with the Constitution of the Republic of Uganda, from which the legal direction of the state is derived, Article 45 states that electricity is a public good. Access and utilisation of electricity by Ugandans is a right that must be "*recognised and protected at whatever cost"* (REA, 2007). In the case of renewable energy, this has been supplemented in 2007 by the introduction of the 'Renewable Energy Policy for Uganda'. This comprehensive document, whose stated aim is to reach 61% renewable total energy consumption by 2017 (from 4% in 2010), is seen as the main framework for action from a government perspective (Oketcho, 2016). The document includes a detailed breakdown of renewable energy potential in Uganda, as well as other objectives for increasing sustainability. Most importantly for investors and small-scale renewable energy producers, it introduced feed-in tariffs for renewable electricity generation under 20MW. External investment is identified as a key pillar to achieving a renewable transition, and as such attracting said investment will prove vital. To this end, Uganda has in place a number of safeguards and is party to several agreements to protect foreign investments. Safeguards enshrined in the constitution and the 'Investment Code 1991' protect foreign investors from a domestic legal perspective, and as a signatory to the main international investment related institutions, the Multilateral Investment Guarantee Agency as well as GATS, TRIMS and TRIPS, Uganda has attempted to make itself a safe-harbour for international investment.

Programmes and Plans

Domestically, Uganda has a series of overlapping and at times overly-complicated series of programs and initiatives in place to promote rural electrification and the sustainable use of biomass. As of 2001, a 'concessions programme' was launched, aiming to grant concessions to private developers willing to take over isolated generation and distribution facilities with a mandate for adding generation capacity and expanding the reach of the connected grid. With only small-hydro a financially feasible undertaking at the time, and doubts about the reliability of rural populations to pay relatively high prices, the programme was scaled back dramatically. In its place came the 'Energy for Rural Transformation' programme, which managed to attract some $400 million in backing from the World Bank, and was under the direct control of the Ministry of Energy and Mineral Development. This money has, however, mostly been spent on planning projects which have failed to be initiated as well as on the maintenance and extension of existing small hydropower projects (Tumwesigye, Twebaze, Makuregye, & Muyambi, 2011). Since 2011, a 'Modern Energy Service Programme' has been implemented with the aim to promote renewable energy for households, small-scale industries and commercial buildings. By focusing primarily on priority projects off-grid, this programme has delivered tangible results in areas that have been neglected by other, Kampala-based, funding mechanisms (Oketcho, 2016).

'Cogen for Africa' was a seven-year initiative from the African Development Bank, along with UNEP (funded by the GEF), designed to support cogeneration in the agricultural industry. By supporting pre-feasibility studies and assistance in accessing international finance arrangements, the programme sought to help generate power and additional income from agricultural wastes and sustainable biomass management. In Uganda, this resulted in one 30MWe Bagasse plant being constructed, as well as a much smaller plant utilising the waste from tea production.

Institutional Framework

Both the laws and programmes outlined above are the mandate and actions respectively of the various ministries and agencies tasked with improving reliable, clean energy access in Uganda. The most important of these is the Ministry of Energy and Mineral Development (MEMD). Responsible for energy policy as a whole, MEMD oversees the operations of the electric power sub-sector. MEMD's mandate includes energy efficiency, which is a key pillar often overlooked in any energy transition. Despite having overall responsibility for the mandate to improve energy access, the majority of programmes and projects are undertaken by a series of specialised agencies under it. Most notable amongst these is the Rural Electrification Agency, established in 2003. Originally, it's mandate was to increase the electricity grid coverage to 10% by 2010. Having only achieved 4% coverage by 2010, this mandate was extended to 2017. As established earlier, however, grid extension is proving costly and slow, despite steps in the right direction since part-privatisation. The Rural Electrification Agency has, instead, begun to focus on planning provisions for micro-grids; making these projects simpler to get off the ground, and ensuring that they are incorporated into longer-term plans for the national grid (Kasese District Government, 2016).

Of particular importance to international investors are the Uganda Investment Authority (UIA) and the National Environmental Management Authority (NEMA). The UIA, an autonomous regulatory body setup to promote and facilitate investments in Uganda, has since 2007 been given the explicit task of promoting foreign investment in clean energy projects. By providing free advice and essential information, licences can be obtained quicker and investment is allowed to flow smoother. NEMA, on the other hand, has a mandate to ensure quality and environmental protection where investments are concerned. As mentioned above, the quality of renewable energy technology entering Uganda will play a large part in determining its long-term success, and NEMA has a strong role to play in this area.

The challenges facing attempted transition in the sector

The socio-economic challenges to Uganda's energy sector are already great, without attempts to revolutionise the way people go about their daily energy needs on top of this. Whilst it is clear that something must change, with rates of deforestation unsustainable and energy prices rising across the spectrum, any such transition is easier said than done; especially in relation to convincing a population often sceptical of change originating from the centre of government (KDLG, 2012). Indeed, whilst electricity from the grid continues to get more expensive, rising almost 30% in 2015 alone (Muhumuza, 2015), the wood fuel industry continues to flourish. Especially in Western Uganda, on the borders of the vast tropical rainforests of the Democratic Republic of Congo, wood fuel and charcoal production are a particularly lucrative industry. Deforestation provides income, job security and a source of revenue for local governments. Whilst electricity consumption in households remains low, and "*the majority of the population is not aware about solar technology use…*" (WWF, 2012), sourcing fuel wood for cooking and kerosene to provide light has become second-nature. The issue of awareness is blamed on a lack of necessary information; as local governments lack structures to disseminate information or impose a functioning regulatory framework (WWF, 2012).

The issue of a lack of awareness is not just an issue for local governments, but also for those firms looking to bring solar power to rural communities and households. Adam Molleson of SolarNigeria has stated that

> "*…we find that many customers do not know what they are willing to pay for power as they have never had it. It is very difficult to assess affordability levels before you provide a product. Often, once a reliable power source is available people will pay far more than originally thought*" (Banning-lover, 2015).

Once customers were introduced to solar power, either through SHS or larger systems such as schools, both interest and willingness to pay spiked upwards. As one report into the solar industry in East Africa found, knowledge and trust in the product being sold is often a greater barrier than the ability to pay (Alstone, Gershenson, Kammen, & Jacobson, 2015). Issues of trust and the removal of entry barriers to electrical energy are beginning to be addressed by the private sector in a much more proactive way than can be achieved by central or local government. By switching to a 'Pay-As-You-Go' (PAYG) model, as opposed to selling appliances with one up-front payment, consumers are more inclined to trust the seller. Because PAYG systems are effectively a form of financing, consumers can return the product to the seller if it is faulty or not operating at the promised level. This shows confidence in the equipment, which in turn had immediate results in a pilot trial of solar study lamps. In schools that offered PAYG financing, adoption levels were as high as 50%. Schools where PAYG financing was not offered saw adoption levels closer to 10-15%. Whilst solar study lamps are often the cheapest product on offer, larger systems (where up-front capital investment is higher) have the potential to benefit even more from the ability to offer consumers PAYG business models (Hansen, Pedersen, & Nygaard, 2015).

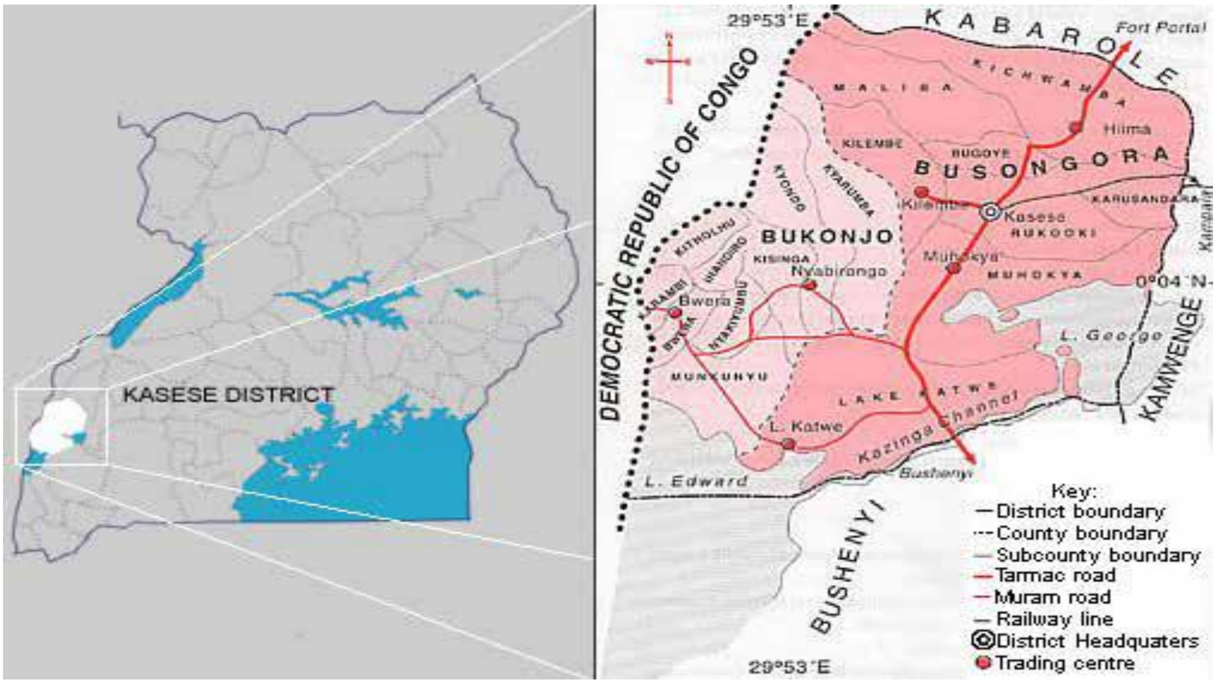
The recent successes of companies offering SHS has been built upon two main pillars; the ability to offer micro-finance in the form of PAYG systems, and the mobile technologies required to make them possible. Information and communication technology has been accelerating and reshaping off-grid solar, increasing connectivity throughout the supply chain and allowing businesses to offer innovative services in a region that ten years ago had extremely limited contact to the nearest town, let alone mobile money services. As previously stated, the ability to develop pricing strategies that closely match current kerosene spending patterns overcomes issues of high-capital requirements and a lack of trust in the new technology. Instead, the barrier has been shifted from the consumer-side to the supplier, with access to capital for suppliers now a potentially serious limiting factor. Like the broader renewable energy market, a significant barrier to scale is access to appropriate working capital financing, especially in the local currency. Greater access to working capital would allow suppliers to stock more product, provide retailers and sales agents with a larger inventory and offer better finance terms to end-users. Issues of a bottleneck on the supply-side are currently hampering distribution, despite more than $70 million in equity and debt investment in these firms (Alstone, Gershenson, Kammen, & Jacobson, 2015). The Global Off-Grid Lighting Association have claimed there is a sector-wide demand for over $1.5 billion in order to support consumer finance, and that would cover potential demand for only the next two years (GOGLA, 2015). Bridging this gap, allowing private sector actors to provide clean, cheap energy to millions across Africa, should be a priority for government policy-making.

Political will vs. Public distrust in the political class

Whilst government policy-making will play a crucial role in any energy transition, they must be wary of a potentially equal backlash against government 'interference'. The political situation across much of East Africa is less-than-stable and a history of colonial regimes and the institutions they left behind have eroded public trust in authority. Corruption is rife in Uganda, and has the potential to act as a handbrake on any initiative too closely associated with the government or in which officials are used as gatekeepers to investment opportunities (Uneke, 2010). Political instability and uncertainty caused by corruption increase the costs and risks involved for international investors, especially with regards to large, centralised energy projects involving longer term returns on investment. This has perhaps already been witnessed in renewable energy investments which, along with the reasons outlined above for a concentration on smaller-scale rural projects, has been seen to be heavily favouring more agile projects in the last decade. A review of the solar market landscape in East Africa has shown two major trends: a movement away from government and donor-based support towards a market-driven dissemination of solar PV, and an investment move away from small-scale off-grid systems and towards pico-power and mini-grids able to eventually connect to the grid. The Ugandan government in particular has been active in stimulating this trend towards SHS, implementing in 2015 exemptions from VAT or duties on PV products. Furthermore, a subsidy of $5.5USD/Wp has been introduced on small-solar systems, further helping to reduce the financial burden on consumers looking to move up the energy ladder and away from kerosene (Hansen, Pedersen, & Nygaard, 2015).

3. Case Study – Kasese District

In this section, data and assessments made by the WWF for Uganda as a whole will be combined with statistics and reports from the Kasese District in order to draw up scenarios and recommendations that take into account the [theoretical] technical, financial, political and social complexities of leap-frogging carbon-based development in Kasese.



Map of Kasese District

Located in the West of Uganda, Kasese is a district of 700,000 inhabitants. As of 2012, just under 50% of the population lived in poverty – defined as living on less than $2 a day - with the vast majority (75%) of the population living in rural settlements (Kasese District Government, 2016a). Agriculture and tourism are two of the major sources of income for the region, known for its nature reserves and passion fruit production. The national electricity grid is confined to the capital, Kasese, with the exception of a few outlier towns; meaning that only 7.6% of the 134,000 households in the district have access to grid electricity. In 2011, Godfrey Baluku Kime was elected as Mayor, on the promise to expand access to modern energy services. His declared mission aim was to transform Kasese into a poverty-free district by 2025. As one of the first steps to make this vision a reality, Kasese Local District Government (KDLG) applied to work together with WWF Uganda on a pilot project to achieve 100% renewable energy in the district by 2020.

Tourist map of Kasese District, highlighting Queen Elizabeth National Park and Mount Rwenzori as the main tourist highlights in the district. The electricity grid runs along the main roads, with no connections along smaller (non-bold) roads.

Introduction to the "Champion District on Energy Access" Campaign in Kasese

Beginning in 2012, WWF Uganda and the KLDG announced their four key outputs that this pilot project should achieve:

1. "*A functional institutional framework to oversee the implementation of the strategy*
2. *A socio-economically empowered community accessing and utilising renewable energy technologies*
3. *Management efforts of the biomass resource base strengthened for sustainability*
4. *A paradigm shift from the use of Kerosene lamp (tadooba) and the traditional 3-stone cook stove to solar for lighting and other energy saving cook stoves.*" (KDLG, 2012)

Progress on these objectives has to-date been admirable, with up to 26% of the population now having access to modern energy services and sales of kerosene having shrunk dramatically. Modern cook stoves have been introduced in over 28,000 households, with corresponding falls in woody biomass consumption (Kasese District Government, 2016b). Solar powered micro grids have been established in three pilot villages to demonstrate their potential. The pilot villages and parishes were chosen based on their high visitation numbers, either due to hosting markets or being tourist destinations. These micro grids have allowed all three villages to become hubs for medical treatment and access to national markets, partly due to the introduction of refrigeration possibilities for vaccines as well as mobile money terminals. All government-funded projects and institutions in the district have been tasked with delivering renewable energy as a key deliverable (Kasese District Government, 2016b). Schools, health centres and other public infrastructure must now incorporate strategies to extend access to modern energy services. As a recognised project under the 'Go100%Percent' movement, Kasese district has received international attention, with articles in major newspapers and energy periodicals appearing globally[1]. As investors became increasingly interested in getting involved in this ambitious project, the district

[1] Articles have appeared in newspapers The Guardian and The Independent, as well as on the website of 'connect4climate' NGO and with articles written by the 'Institute for Ethics and Emerging Technologies'.

council implemented tax breaks for renewable-energy-related enterprises operating in the region. As part of output 2, the WWF has worked with national training authorities to provide traineeships in the installation, operation and maintenance of solar and hydro power technologies. These trainees are part of an initiative attempting to alleviate poverty and provide local jobs, at the same time as advancing the necessary energy transition. By working with regional businesses, including Barefoot Power Uganda, financing has been provided to mountain villages in the west of Kasese to implement small-scale solar projects and bring power to areas barely accessible by road and with no prospect of grid connection before 2050 (Baluku Kime, 2015).

Originally designed to complement central government initiatives and programmes in addressing poverty, Kasese's 100% renewable energy project has already far exceeded results elsewhere in the country. Indeed, as a response to the United Nations 'Sustainable Energy for All by 2030' initiative, the project has made an impressive first step. However, whilst access to electricity and modern cook stoves is now well above the national average, especially for rural areas, the positive effects on health and poverty are yet to be fully realised. Statistics on the reduction of air pollution related illnesses will take years to compile, whilst corruption in the agricultural sector is causing food prices to rise whilst agricultural profits fall. Despite energy prices falling for those who have switched from kerosene to solar lighting, wider issues in the economy are hampering the predicted benefits. Whilst ideally money would be freed up for education, clothing and food, any savings are currently being swallowed up by rising prices in other sectors (Mwesigwa, 2016). Despite a strong start to the project, which is still only four years old, there is currently the very real potential that benefits may be lost as the original impetus is lost. The WWF's role is scheduled to be reduced, handing over more responsibility to local government officials at a time when recent elections have shaken-up the political order in the region (Basiime, 2016; Mwesigwa, 2016). This case study, as well as the paper overall, will not only serve as a reminder of the potential that a successful completion of this ambitious project would unlock, but more importantly it will offer recommendations to breathe new life and direction into the project now that the 'low-hanging fruit' has been picked.

The geography, politics, and economy of Kasese District

In much the same way as any reputable renewable pathway for Uganda should take into account its geographical, political and economic attributes, so is an overview of the specific circumstances in Kasese necessary before introducing potential renewable energy pathways.

Geography

Sandwiched in between the Queen Elizabeth National Park, Rwenzori mountain range and national park and lakes George and Edward, Kasese district consists to a great extent of nature and wildlife conservation zones and open water. Of the 3,400km^2 that make up Kasese district, only 1,076km2 are available for farming and settlement (Kasese District Government, 2016a). With a population density of some 450 people per square kilometre of habitable land, Kasese district is a relatively densely populated region; compared to a national average of 136 people per square kilometre.

Kasese district is blessed with plentiful natural resources, including large Cobalt deposits. Whilst solar radiation is high across Uganda[2], which lies on the Equator, geothermal resources and hydroelectric power have equally been identified as potential sources for energy production in Kasese district. Issues of deforestation are, however, prevalent. Many families rely heavily on selling firewood; thereby crossing into the protected areas of the nature and wildlife reserves bordering Kasese in order to chop down trees (Mwesigwa, 2016; Ritchie, 2012). As far as hydropower in the district is concerned, 24 MW of existing small-hydropower plant will be complimented in 2017 by the addition of another 13 MW run-of-the-river plant in the south of the district. Plans for a 140-200 MW power plant just outside Katwe village, to take advantage of geothermal resources with subsurface temperatures in the range of 200°C, have been in circulation since 2009 (Nyakabwe-Atwoki, 2013). These projects are intended to be connected to the national grid, with transmission cables running directly to Kasese to be distributed throughout the country. As such, despite being located in a rural area, the energy generated in the new plant would not be available to utilise locally.

[2] Kasese District's mean solar radiation of 5.1 kWh/m^2 per day means that solar panels are extremely effective, with little seasonal variation.

Politics

As with many seemingly-simple endeavours in Uganda, however, political instability and corruption have slowed progress. Large projects, such as the potential geothermal plant in Katwe, are especially vulnerable to corruption. Despite an initial agreement in 2009 with American firm AAE Systems, and a successful tender bid awarding AAE systems a licence to construct up to 200 MW of geothermal plant in 2012, construction is yet to begin due to disputes between local contractors and local officials over a $60 million 'enabling fee' (Nyakabwe-Atwoki, 2013).

Whilst there is no proof that this specific issue is linked to corruption, the misuse of public office for private gain is rife across East Africa, and Uganda is no different. The political will for the "Energy Champion" project has come mainly from Kasese's mayor, Godfrey Baluku Kime of the National Resistance Movement (NRM), the party of Uganda's president Yoweri Museveni. In 2012, the regional and district governments were also run by the NRM, providing the necessary funding and approval to kick-start the project. This included converting all street lighting in the region to energy-efficiency LED bulbs, thereby saving up to $200,000 per year (Baluku Kime, 2015). However, as of February 2016, the opposition Forum for Democratic Change (FDC) has been elected to both the regional and district authorities in response to widespread dissatisfaction with the government, amid accusations of corruption against the NRM regime. This has left the mayor of Kasese without many of the resources he had previously enjoyed to help fulfil the promise of 100% renewable energy by 2020. Consequently, the emphasis shifted away from top-down solutions and towards an apolitical, market-led approach. Whilst corruption has been seen as a bureaucratic facilitator in the past (Hayford, 2007), the overwhelming consensus is now that corruption has serious negative effects on the economy; negative effects which are influencing everything from food prices to tax revenues in Kasese district (Hayford, 2007; Uneke, 2010).

Economy

As highlighted previously, Kasese's economy is predominantly focused on agriculture, with contributions from Cobalt mining as well as a cement factory. Economic opportunities are, however, limited. Whilst there is potential for casual labour opportunities with upcoming hydropower and geothermal plant construction, these are temporarily limited, with little capacity for ongoing employment. For those 85% of the population living from subsistence agriculture, food prices and the ability to bypass local officials and market monopolies are the two most significant areas in determining their economic wellbeing (Mwesigwa, 2016). For many, the introduction of mobile money and information services have made it easier to connect with markets further afield. In the case of Kasese district, whose passion fruit, coffee and fish are demanded throughout Uganda, this development is opening up new opportunities to achieve higher prices for their goods. The role of mobile money has become increasingly important to many aspects of the Ugandan economy, allowing people to pay for modern services and be paid in return. This advancement has also enabled the introduction of rudimentary credit scores and records to aid in further expansion of finance and entrepreneurship in the region. Helped by a rapidly expanding[3] and youthful population which is better educated than any generation before, the district has a high potential for developing new skills and engaging with a more modern economy in the future.

100% renewable pathway, tailored for Kasese District

Both academics and practitioners have often fallen into the trap of casting policy options for electricity access as a choice between expanding access to the national grid, or creating a series of mini-grids and relying on local interconnections. The question of how to supply the towns and communities of Kasese that are not currently served is no different. Government in Kampala has emphasised an extension of the national grid. After all, with large-scale hydropower plants coming online and the beginnings of large, grid-connected solar projects, the electricity grid is going to become close to 100% renewable[4]. With more hydropower, geothermal and solar power due to join the grid in

[3] The population in Kasese doubled between 2002-2014, partly due to the return of Internally Displaced Persons who had fled conflict in the region at the turn of the century (Mwesigwa, 2016).
[4] The Ugandan Electricity Grid currently includes 136MW of fossil fuel thermal power plant. Whilst there are no plans to add more fossil fuel plant, existing installations will remain on the grid until at least 2035.

the next decade, the electricity grid will have the theoretical capacity to supply four times the customers it does today with almost wholly renewable energy. However, whilst the Uganda Electricity Transmission Company Ltd (UETCL) is planning to invest $1.2 billion over the next decade, serious concerns remain about the state and stability of the grid and its subsequent ability to serve even its current load. Instead, the Kasese renewable energy project aims to rely on the national grid only for the 3 largest towns in the district, with renewables bringing electricity to other areas in the form of mini-grids (Baluku Kime, 2015).

The legal apparatus outlined in the previous chapter evidently still applies in Kasese, with two specifically relevant additions to the construction of a tailored pathway. Firstly, the Uganda Electricity Act 1999 outlines the legal and regulatory framework for power generation from small renewables, as well as establishing the chronically underfunded but still potentially useful "Rural Electrification Fund". The regulatory framework for the generation of grid-connected renewable power includes the ability for authorities to arrange a Power Purchase Agreement (PPA) with investors. Additionally, a Feed-in-Tariff makes up part of the PPA, with this element regulated as part of the 'GETFiT' campaign to attract renewable energy investment (KDLG, 2012).

LEAP Model results and projections

The following graphs and tables have been created using the LEAP energy modelling software, with the resultant data transferred into Excel for representational purposes. Two scenarios were generated, utilizing a combination of data already used in the WWF 2015 report, statistics available from the Kasese District Local Government (KDLG) and field observations carried out by WWF project members in Kasese and commercial representatives from M-KOPA. The first scenario was designed to represent a 'Business-As-Usual' (BAU) approach, with current national level trends combined with Kasese-level data to project progress through to 2025 without additional effort. The second scenario assumes the implementation of the policies mentioned in this thesis, such as access to cheap finance for pico-power companies and increased support for solar-powered micro-grids amongst others. These scenarios will be, therefore, referred to as 'BAU' and 'potential' scenarios respectively. Both scenarios run until 2025, as running a scenario on 2015 data until 2020 showed a very limited scope for influence.

The goal of 100% renewable energy coverage in Kasese by 2020, whilst technically still feasible, is now extremely unlikely; with those on the ground in Kasese believing that 2025 is now the more realistic target (Mwesigwa, 2016). Any graphs or figures referred to but not included in the text can be found in the Appendix.

Beginning with the demographic data in Kasese, population growth is projected to continue at 3.6% for the next 15 years, allowing for a fairly steady progression as shown in the table below.

Table 2 - Population growth projection - Kasese district

Year	Population
2012	700,000
2013	725,200
2014	751,307
2015	778,354
2016	806,375
2017	835,405
2018	865,479
2019	896,636
2020	928,915
2021	962,356
2022	997,001
2023	1,032,893
2024	1,070,077
2025	1,108,600

Whilst this population growth will continue to put an increasing strain on the sustainable biomass available in the region, the interesting aspect in terms of development between the different scenarios is in the rural-urban divide. As demonstrated in Figures 1 and 2, this divide looks significantly different in the two scenarios. The 'potential' scenario forecasts a much slower rate of urbanization, as the 'pull factor' of grid access and economic opportunity in the large towns and cities is diminished. Whereas the BAU scenario results in a 50-50 split by 2025, the potential scenario suggests only between 34-36% of Kasese district will be urban-dwellers by then. This is in large part due to the rise of off-grid electricity access, both through pico-power systems and micro-grids. Whilst this has traditionally been seen as a negative for healthcare and education, which have historically found it easier to provide in an urban context, the changing nature of rural communities are shifting this paradigm.

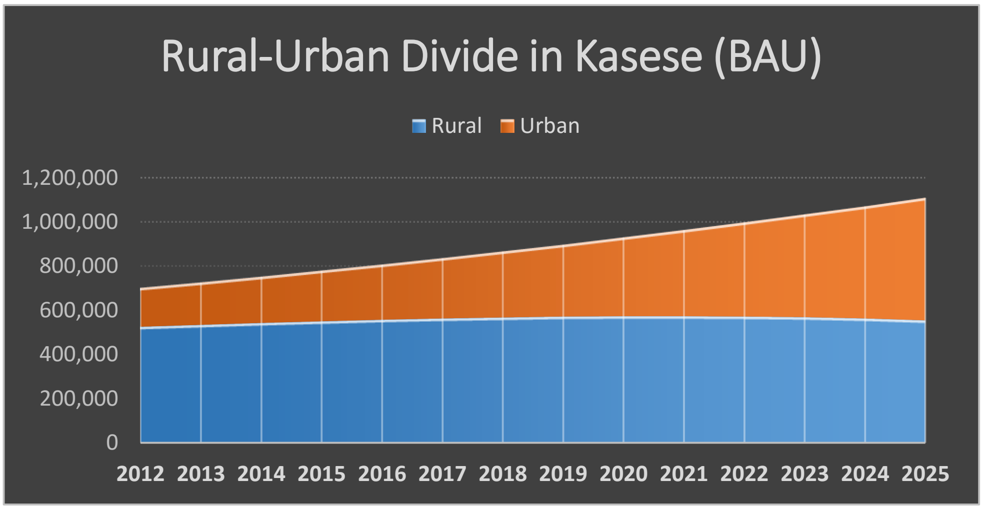


Figure 1

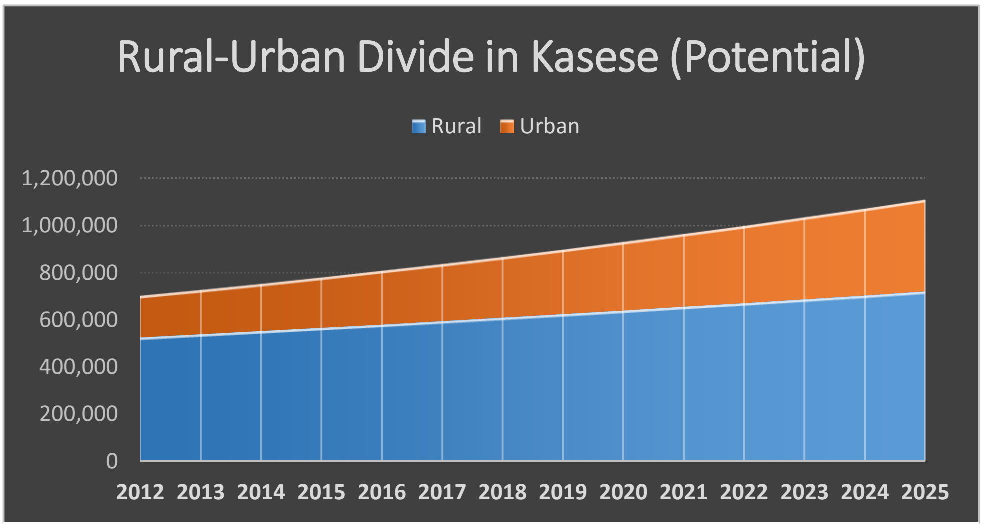


Figure 2

The attractiveness of off-grid electricity access is demonstrated in the differences in uptake of national grid and off-grid electricity across the two scenarios. In the 'potential' scenario, in which pico-power and micro-grid are supported through both subsidies and access to finance, off-grid systems become more popular for new connections in urban areas than the national grid by 2021. The price point for systems like those offered by M-KOPA will have reached a point whereby those who are unable or unwilling to pay for grid connection in urban areas will find a competitive solution from off-grid suppliers (figure 3). In the 'BAU' scenario, by 2025, 48.5% of Kasese's population is served by the national grid, as opposed to 27.8% served by off-grid systems. In contrast, in the 'potential' scenario, these figures are 32.6% and 56.7% respectively. This reflects not only that greatly enhanced share of the population choosing to stay in rural areas, but also the increased share of that rural population able to access modern energy services[5]. The graphs showing these figures can be found in the annex.

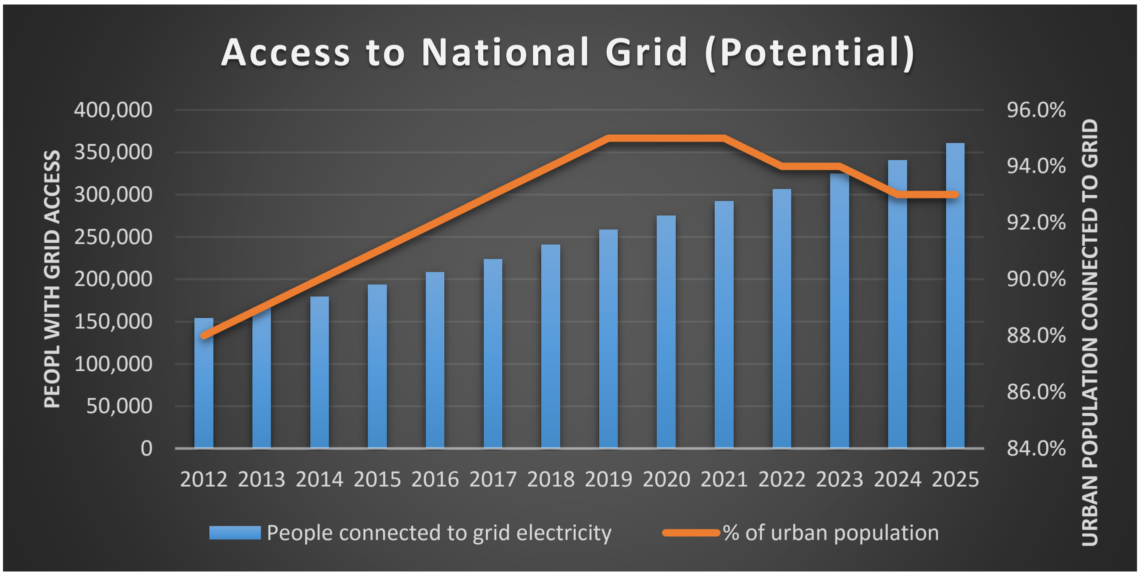


Figure 3

The nature of off-grid systems in comparison to the national grid also means that overall electricity consumption is predicted to be lower. Although national forecasts suggest that kWh per capita consumption will reach 1,117 kWh by 2025 (WWF, 2015), per capita consumption with off-grid systems will be considerably less. With per capita consumption in rural areas set to stay below 200 kWh a year[6], the required installed capacity reduces dramatically. Despite a higher capacity factor in the BAU scenario[7] thanks to hydroelectric and geothermal power in the grid, which serves a higher proportion of the population in this scenario, Kasese district alone would require some

[5] This number rises from 55.6% of the rural population accessing electrical services under the 'BAU' scenario to 87.2% in the 'potential' scenario, despite almost twice the number of people living in rural areas.
[6] This low, by developed country standards, consumption takes into account the reduced needs for lighting and fact that both cooking and cooling will not be electrified for most by 2025.
[7] BAU scenario has an average capacity factor of 30%. The 'potential' scenario assumes a 20% capacity factor due to a higher proportion of mobile, small solar units.

466MW of installed capacity. To put this in perspective, the entire Ugandan national grid in 2015 had an installed capacity of just under 900MW. This kind of dramatic increase in electricity demand is currently seen as unsustainable without the introduction of more thermal (gas/oil) power plant, which is naturally against the

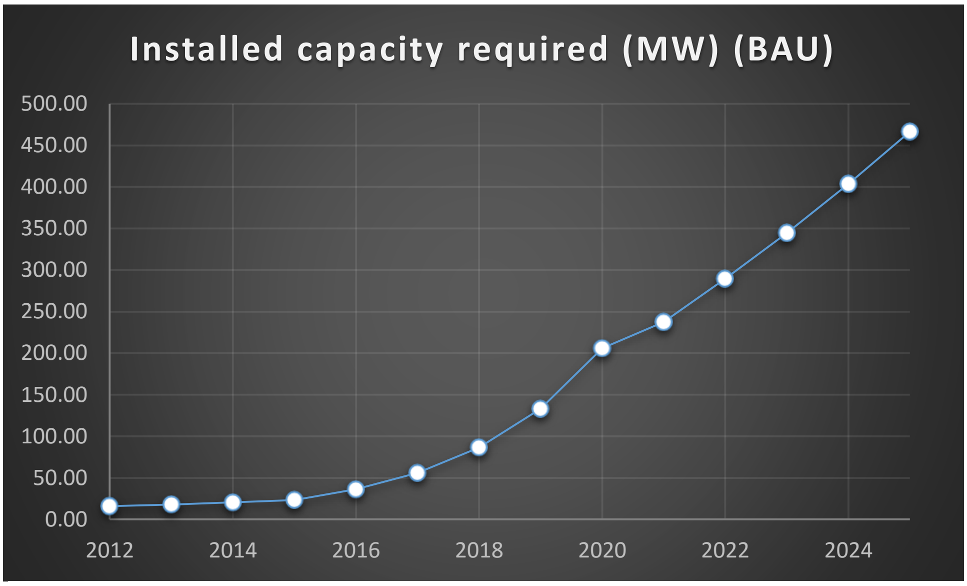


Figure 4

principles of a 100% renewable energy transition. In comparison, the ‘potential’ scenario requires an installed capacity of 339MW, with the vast majority of this coming from solar powered systems. Whilst the difference in average kWh consumption is

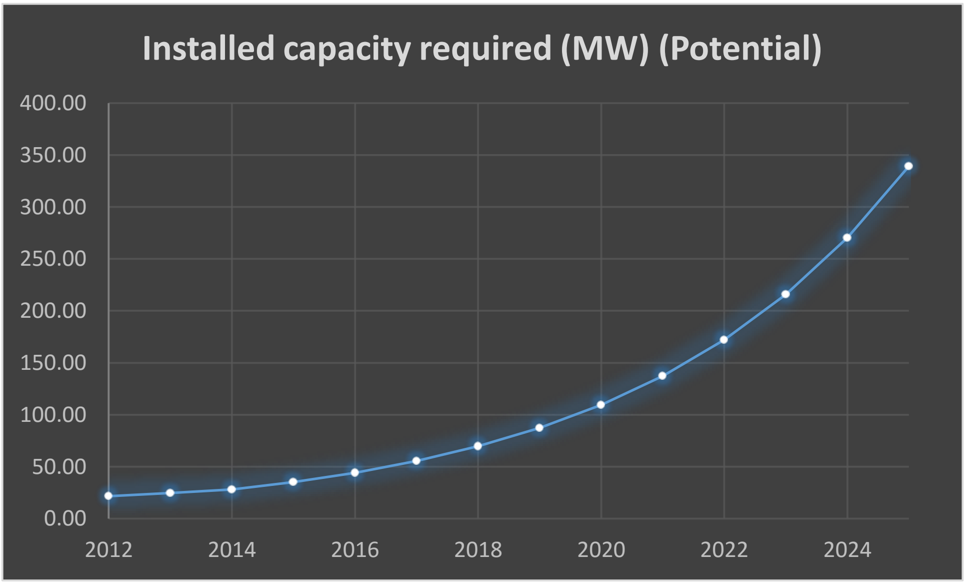


Figure 5

greater, the capacity factor for solar systems is lower than that for a mix with higher hydropower proportions, and as such requires a higher relative installed capacity.

Importantly, these required capacity figures give us an indication as to the costs involved and who will have to bear them.

Separately from the question of electricity provision is the 2nd pillar of a 100% renewable energy mix, the transition to a sustainable use of the biomass resources available in the district. This is one area where the Kasese district champion exercise has so far proven extremely successful, with the local government and the 'Impact Carbon' NGO working together with local industry to provide entire communities with newer, more efficient cooking stoves at little-to-no cost to the consumer. At an average cost of $5 to produce, efficient stove users are reporting ~50% reductions in the amount of biomass required (Mugalu, 2013). Already at the end of 2015, concerted efforts have meant that efficient wood-burning stoves have overtaken the old '3-stone' variety. Whilst the easiest-to-reach sections of society have converted first, mainly in urban areas, the new cook stoves have proven to be a success wherever they have been introduced and progress is expected to continue towards a 91% distribution rate of the new cook stoves by 2021 (Mwesigwa, 2016).

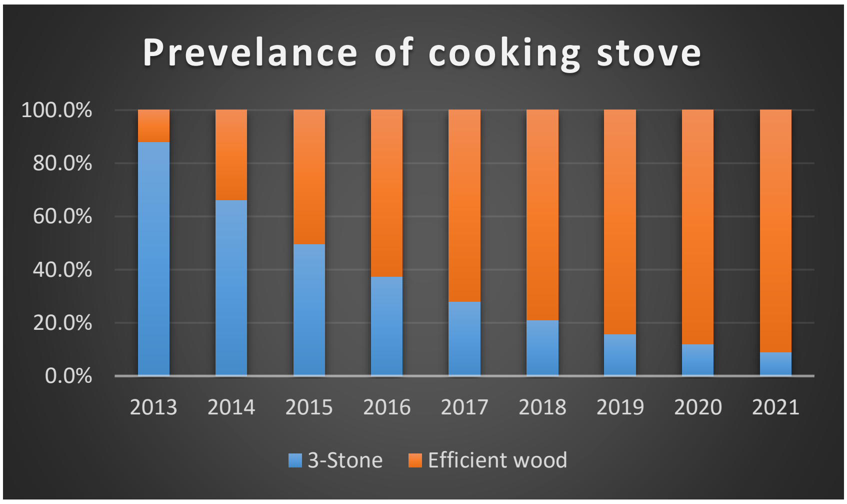


Figure 6

Whilst these, more efficient, cooking stoves are a step in the right direction; Uganda's rapidly expanding population will continue to demand more biomass than is currently sustainable. Whilst per capita biomass consumption is forecast to decrease from 1,100kg/year to ~500-600kg/year, population growth of around 60% by 2025 will continue to put strains on sustainable biomass production. Despite almost 100% utilisation of more efficient cooking stoves by 2025, alongside modern charcoal production methods, biomass demand per capita does not reach sustainable levels in the BAU scenario (Figure 7). As such, new sources of biomass needed to be found to enable the 'potential' scenario to reach sustainable consumption levels. Reduced urbanisation in the 'potential' scenario also meant lower levels of electric cooking and more difficulties in bringing down per capita biomass consumption.

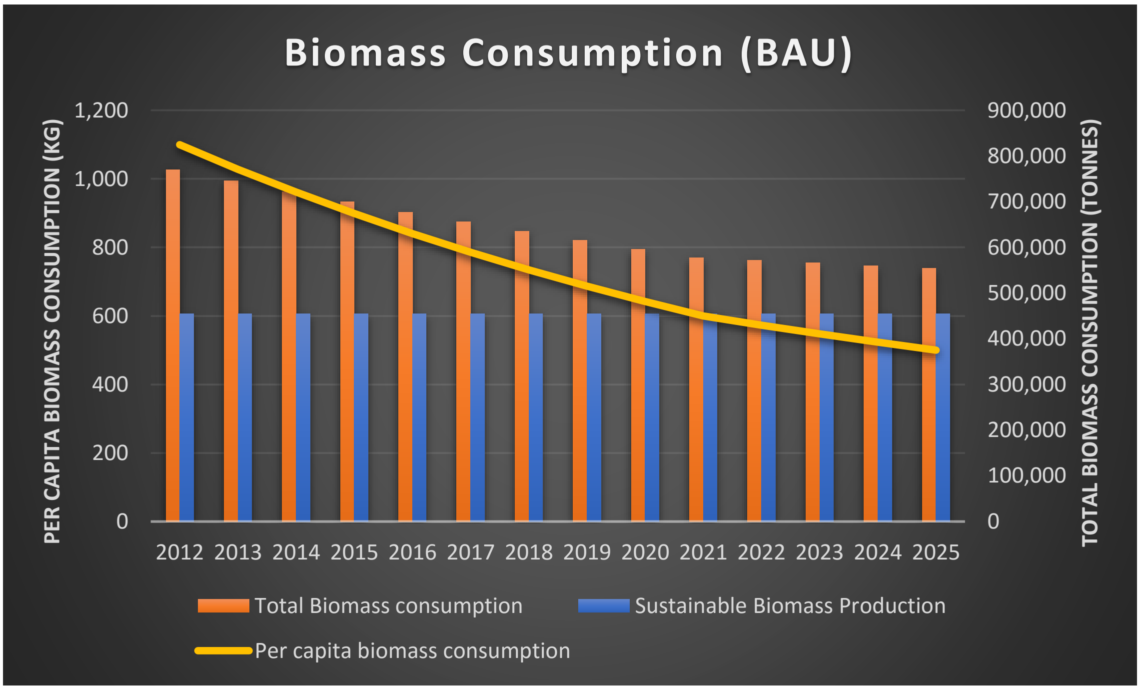


Figure 7

The 'potential' scenario introduces the use of agricultural residues that are currently wasted to the 'sustainable' biomass total. Whilst this would also be possible in the BAU scenario, there are currently no plans to invest in residue preparation for domestic cooking use (KDLG, 2012). Whilst the utilisation of agricultural residues raised the sustainable production figure from 455,000 to 615,000 tonnes per year, the aforementioned issues with high per capita consumption in the 'potential' scenario meant that additional reforestation was necessary. By 2025, under the 'potential' scenario, total biomass consumption stands at 665,000 tonnes per year. At an estimated 5 tonnes sustainable growth per hectare of forest (Okello, Pindozzi, Faugno, & Boccia, 2013), this leaves Kasese district needing to reforest/afforest 10,000 hectares of land to make biomass consumption sustainable in this scenario[8]. The WWF in Uganda puts the cost of reforestation at $200 per hectare, thanks to low labour costs and volunteers. As such, the cost of reaching sustainable biomass in Kasese district is some $2 million;

[8] In context, between 2010-2015, a total of 670 hectares were reforested with the help of the WWF.

with the resulting balance demonstrated in Figure 8 that biomass consumption in Kasese would require significant effort and investment to reach sustainable levels by 2025.

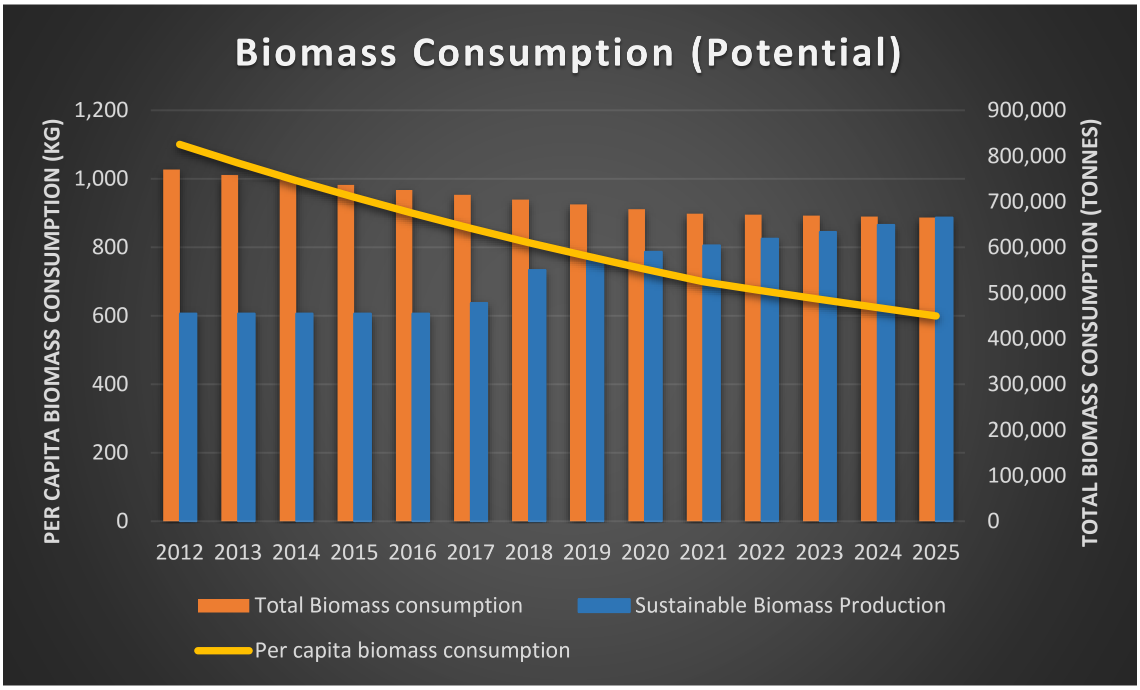


Figure 8

Delivery structures

Grid extension vs. off-grid projects:

Reinforcing and extending the existing electricity grid in Kasese/Uganda is essential due to the rapid urbanization predicted in Kasese, with 50% of the population predicted to be classified as 'Urban' by 2025 (KDLG, 2012). Whilst there are national level issues of energy security, with climate change potentially affecting hydropower capacity as well as issues of high operation and maintenance costs, the benefit of extending grids is the familiarity. International and national expertise is concentrated on a centralised grid system, as nations have been developing these systems for a hundred years. Furthermore, it is a relatively cheap and easy way of expanding the edge of a connected town or city as population grows rapidly. A centralised grid operates best with consistent baseload power; something which engineers have experience in and are comfortable with. Our means of producing this baseload tends to be well-established, using tried-and-tested technologies such as hydropower and gas power plant.

This approach is not without flaws, however. There is the question of how large populations of people of low socioeconomic status in urban and part-urban areas can be provided with safe, reliable electricity, even when their demand and ability to pay are far lower than conventional standards. The typical status of those arriving from rural areas into cities is that they live in 'informal' conditions. The slums, shanty towns and favelas that are produced as a by-product of mass urban migration have been known to experience widespread theft of energy, inadequate regulation of energy use and a lack of safety for population as well as grid engineers. There is also the question of how much urban migration is driven by energy-poverty in rural areas. If rural communities had access to reliable, clean and affordable electricity, would the pull-factor of the city remain as high? If the solution is to extend grids into shanty towns and favelas, is this not just treating a symptom, and in doing so increasing the pull-factor for more rural communities to fracture and lose their (mostly young male) human capital to the cities? Instead, if rural areas can be electrified and the associated economic benefits transferred to rural areas, city infrastructures would suffer less strain and rural communities would be enriched to the benefit of all who live there, not just those willing and able to move away.

Off-Grid projects:

The Off-Grid projects necessary to enable this are seen as crucial in either scenario, as the cost of grid extension and power transmission become prohibitively high, ruling out both private and public enterprises in the most part. The IEA predicts that 55% of the energy required to provide universal energy access by 2030 will come from decentralised (off-grid) systems. The flexibility of off-grid, and its scalability, makes a huge difference in being able to cater to specific resources in an area and the specific demands of the local population. Off-grid systems are split into **Pico** and **micro** grids. Pico-power, like those marketed by M-KOPA and other PAYG providers (M-KOPA, 2015), are used to power either a single household or small business. They tend to seek to replace kerosene lamps, biomass cookstoves and having to pay a central vendor in the next town/village to charge your mobile phone. These systems have the potential to be durable, can be easily installed, require little maintenance or ongoing operational costs and can provide enough electricity to run a fan, TV, small fridge and a few lights. They also end up being highly cost-effective, when the alternative is buying kerosene for dirty lamps or travelling to pay someone to charge your mobile phone. Despite pico-power being aimed at the lowest socioeconomic groups, with the least demand and buying power, the business models appear to be working. By 2025, however, current predictions show only 55.6% of the rural population with access to off-grid electricity. This is in large part due to the extreme poverty amongst some rural communities, for whom kerosene lamps are currently too expensive and solar power units are also out of reach. Whilst prices are forecast to continue falling, it may be that the economies of scale and greater scope for institutional assistance mean that micro-grids are a more plausible option for this group.

Micro-grids

Micro-grids, the connection of multiple households (a village or small town for example), therefore hold the key to unlocking modern energy services for even the least able to pay. These are more closely linked to the concept of the traditional grid, but the smaller scale allows for greater scalability and a more tailored approach to the needs of the community. Whilst they do not have to be powered by renewables, the size of the grids often makes them ideal for small-hydro, biomass, solar or wind installations; or a combination of these. By combining electricity sources, alongside some form of energy storage (battery) capacity, a more consistent power input to the grid can be achieved, along with the benefits associated with an economy of scale over pico-power systems. Many privately-funded micro-grids are ‘anchored’ to one central, larger power user, to ensure a more reliable payment stream and to have a reliable partner when it comes to convincing others to partake and pay their share (Mwesigwa, 2016; WGSI, 2015).

Energy Sources

As the projections have shown, the focus for the next decade in Kasese must be on the needs of rural communities. Whilst large hydropower, geothermal and grid-connected solar projects are all projected to come online to maintain a renewables-powered national grid, the rate of urbanisation is such that increasing demand from urban centres will at least match new supply. As such, for rural areas with little hope of grid-access, it makes sense to focus on those energy resources most likely to fill their need; namely solar, small-hydro, Biomass/Biogas and wind.

Wind

Starting with potentially the least viable for Kasese District, wind power average output can be highly accurately predicted; with wind speed data for Kasese suggesting that only a small capacity is available. Wind power projects have high capital costs, even on land. However, wind power projects have been commissioned in both Uganda and neighboring Kenya, with Kenya's Lake Turkana Wind Power Project, for example, expected to generate about 20% of the country's power when it becomes fully operational in 2017 (LTWP, 2016). Whilst grid-connected wind power only feeds those with access to the national grid, there is a growing demand for 'small wind power' to feed smaller micro-grid systems. As such, whilst Kasese on average achieves only low wind speeds, certain areas may still be viable for small micro-grids to be powered by wind power. Wind power was not, however, included in the Kasese-specific renewable scenario.

Hydropower

Hydropower is another scalable technology, with the benefit of providing a consistent source of energy that can be used as a baseload. Climate change has brought this view into question recently, with erratic rainfall and melting snow-caps failing to provide a consistent water level (Jacobsen & Delucchi, 2011). Despite this, a well-placed hydropower plant can be expected to produce relatively consistent electrical energy all year round. There remains a large untapped potential in Kasese for smaller 5-10 MW 'run-of-the-river' installations. As many communities far from the national grid are settled around rivers, the potential for creating micro-grids from smaller hydropower installations is obvious. Unfortunately, the initial capital requirements for such projects are a significant barrier; whilst the costs are too great for rural communities to bear, they also tend to be too small to attract finance from international donors or through CDM's (Mwesigwa, 2016).

Solar power

Solar power however, in the form of PV panels, provides, the best chances for truly scalable and accessible energy for Pico-power systems as well as mini-grids. The installed capacity of solar power has jumped from 1.8GW in 2000 to 187GW by the end of 2014. “The average price for a utility-scale PV project has dropped from $0.21/kWh in 2011 to $0.11/kWh in 2014” (WGSI, 2015). Unlike wind and hydro, solar can be installed almost anywhere, without site-specific costs and challenges that might put investors off. The fact is that many of the areas facing the most extreme energy poverty are also areas of high solar radiation, making them ideal for solar power. It is highly modular, meaning that is it extremely scalable. As demand may change unexpectedly and quickly in rural areas being provided electricity for the first time through a micro-grid, the ability to scale installations up or down with relatively little cost impediment is crucial. Furthermore, Solar has also been shown to provide the highest ratio of jobs per kWh (Barkham, 2015). When locally fabricated, the construction, operations and maintenance of PV systems can help boost local economic development in one of the most important ways – through sustainable local employment. Kasese already has some ‘heavy industry’, in the form of a cement factory and Cobalt mine, and the chance to bring solar panel manufacturing to the district is being actively pursued (Mwesigwa, 2016).

The financial benefits of solar powered micro-grids are also clear. In the pilot program for coordinated solar deployment in the 4th largest town in Kasese district, it was reported that after 12 months, 240 solar units had been installed in the town and that residents were only required to pay monthly instalments of 50,000 Ugandan shillings (almost $15) for each unit (Overgaard & Nielsen, 2014). Solar has proven itself more cost effective and cleaner than kerosene, to the extent that replacing kerosene with solar in Kasese could save over 6,490,484 litres of kerosene every year, worth between 7 and 8 million dollars (KDLG, 2012).

Biomass/Biogas

There is good reason that biomass constitutes the major source of energy in most developing countries. Widely accessible, free or cheap, and requiring little-to-no technology or infrastructure to utilise, biomass is an extremely flexible fuel. However, concerns exist over the sustainability of supplies and the environmental degradation resulting from its over-use. In Uganda, 44 million tonnes of woody biomass are harvested every year; whilst domestic forests only produce 26 million tonnes sustainably (WWF, 2015). Estimating at 19GJ/tonne of woody biomass and 30% moisture content, Uganda has the potential to sustainably produce around 90 TWh of biomass annually. Current demand, however, is closer to 155 TWh. There are areas in which biomass use could be improved, including the extended use of residues and the distribution and utilisation of more efficient cook stove technologies. In Kasese district 'Action for Development', a Ugandan NGO, has reportedly built tens of thousands of high efficiency stoves and is waiting on permissions to conduct mass distribution. By dramatically improving cooking-fuel efficiency, the strain on biomass resources in the area should lessen, moving the district closer to its 100% renewable aspirations. Furthermore, in September 2013, Kasese district signed a Memorandum of Understanding with the government of Denmark, enabling private investors, academics and NGOs to operate in Kasese in order to transform it into an example of sustainable biomass use (Overgaard & Nielsen, 2014).

Currently, the vast majority of biomass energy in Kasese comes from unmanaged natural forests. The natural forests in Kasese, as well as Uganda as a whole, are dominated by slow-growing species. As such, high rates of harvesting have led to rapid deforestation and environmental degradation. The result is that, "… between the year 2000 and 2005, the annual deforestation rate in Uganda was 2.2%; one of the highest in the world" (Okello, Pindozzi, Faugno, & Boccia, 2013). Whilst it is clear that sustainable use of biomass in Kasese district will require a substantial reduction in end-use, estimates show that the introduction and use of high-efficiency cook stoves alone will not be enough (WWF, 2012). Instead, if utilised sustainably, biomass residues could provide enough biomass to meet the remaining demand and still result in a situation of reforestation. By using the residue-to-product (RPR) ratio method, annual production of forest and crop residues can be estimated for Kasese district. By assigning each residue an energy potential based on its respective lower heating value, the energy potential from residues amounts to between 10-12 Petajoules (PJ) per year; the equivalent of between 2.7-3.3 TWh. Against a 2012 benchmark in which biomass demand in the region was estimated at 4-4.5 TWh per year, it is clear that there is a huge potential here (Okello, Pindozzi, Faugno, & Boccia, 2013). If well managed, the utilisation of residues from crop production and legal-logging can go a long way to meeting the cooking-energy demands of Kasese district in a way that is *"not* *competitive with land and water resources required for food production"* (Okello, Pindozzi, Faugno, & Boccia, 2013).

Geothermal

Kasese district has high potential to generate electricity from geothermal sources, although the utilisation of this potential comes with serious limitations. There are four main geothermal areas in Kasese, with the most advanced project just outside Katwe village on the southern edge of the district. With subsurface temperatures of up to 200˚C, a Katwe geothermal would be suitable for electricity production as well as having potential applications in agriculture and industry; with a potential power output of up to 140MW (Bahati, 2012). However, technical, financial and institutional barriers stand between this renewable resource and its utilisation by the surrounding communities. Firstly, a 140MW plant is clearly too large to be utilised solely by the surrounding communities and would therefore require an expensive grid-connection over some 40km of difficult terrain. Whilst such a grid connection would be feasible as part of central government efforts to add capacity to the grid, it would fail to deliver benefits to the rural communities of Kasese district. The investment required to develop the resource is also out of reach for any local agriculture or other industries that may stand to benefit (KDLG, 2012).

Energy Management Technologies

The remarkable spread of mobile phone technologies and coverage is going hand-in-hand with the ability to monitor and regulate new energy projects further and further away from big cities. The use of mobile banking functions also helps rural communities to access the necessary financing to bring energy to their community. The spread of mobile phone subscriptions suggests that there is an appetite and willingness to pay for high-value technology-driven services, even in otherwise deprived areas. Mobile banking services are particularly significant as it helps to overcome one of the largest risks facing financiers and service providers – the reliability of rural communities' payments.

By allowing customers to prepay for their energy at the beginning of consumption cycles, service providers can obtain a guarantee of payment for services delivered. Remote management technologies (including shut-down) of equipment and services by providers in the case of missed payments provide a further level of security for providers and encourage the timely payment of services. Whilst this may appear burdensome on customers living below the poverty line, the micro-payments made possible by the technology are in fact easier to manage than the traditional system, in which a month or more worth of Kerosene would need to be purchased up front from the nearest town (Oketcho, 2016). Finally, with the introduction of real time monitoring of “demand, payment histories, and other information, credit records and a greater understanding of consumption dynamics can be established” (WGSI, 2015).

4. Recommendations

Given the data, projections and specific technology attributes as relevant to Kasese, it is abundantly clear both that the district has considerable renewable energy potential, and that reaching its goal of 100% renewable energy by 2020 is looking increasingly unlikely. Without an immediate and concerted re-doubling of efforts and investment, extending the project to 2025 appears to be the most realistic pathway to take. This is in large part due to the huge logistical effort required to cut biomass demand and replace kerosene lamps with solar panel systems. Whilst possible, the required financial investment and political infrastructure have not yet been forthcoming. The huge renewable energy potential of the district continues to be unexploited due to perceived financial, technical and political barriers. Utilising what has been shown above, this section will lay out recommendations to circumvent these barriers and outline what is required to achieve 100% renewable energy in the district by either 2020 or 2025.

Grid-extension

Whilst correctly chastised for receiving an unfair share of central government attention, the national-grid does have an important role to play in Kasese district. As with other areas in Uganda and across the developing world, rates of urbanisation are high and set to increase. Whilst Kasese district currently has three towns connected to the national grid, these towns are expected to at least double in size by 2025, bringing with it the challenge of providing grid access to double or even triple 2012 levels[9]. As such, reducing losses in the distribution and payment systems, as well as preparing the system to include distributed power generation will be required. Progress has been made since the national grid was privatised. However, losses are still unacceptably high, pushing prices up above affordable levels (UBoS, 2015). Modern metering and billing systems will be required to encourage better management of power by the consumer; utilising abundant solar energy throughout the day when energy should be cheapest. Indeed, whilst much has been made of off-grid solar solutions and micro-grids, grid-connected solar projects in the region should be actively pursued. President Obama's 'Power Africa' and the British 'Lighting up Africa' initiatives are actively looking for projects to finance (Howard, 2016; USAID, 2016), and Kasese district's track-record, high poverty incidence and high solar irradiance make it a perfect candidate for large-scale, grid-connected solar.

Pico-power and Micro-grids

Companies like M-KOPA and others have been extremely successful across sub-Saharan Africa over the last 5 years, and this growth shows little sign of slowing down. Driven by micro-payment plans which allow even the poorest consumer to obtain high-quality solar technologies, both urban and rural populations are increasingly looking to pico-power for their energy needs. With rural population figures projected to remain steady through to 2025, each new system will result in a measurable and lasting impact on access to electricity. Pilot programs have demonstrated that technically and logistically it is possible to quickly eradicate kerosene use for lighting and provide high quality electricity services (lighting, appliance charging/powering) in rural communities (WGSI, 2015). Indeed, with daily prices lower than what customers typically pay for Kerosene, the key barriers are capital (to provide stock) and awareness amongst the rural population. The business models of companies like M-KOPA and others have so far proven extremely successful, with huge growth over the last 3-4 years. With the addition of targeted tax relief, especially to encourage manufacturing capability with Uganda or even Kasese district itself, stocks of SHS can be increased and the costs for consumers further reduced. Indeed, thanks to specific interventions by the Kasese

[9] Estimated Urban population Kasese district 2012: 175,000; 2020: 355,000; 2025: 554,000

district authorities, access to off-grid electricity rose dramatically between 2014-15 (Figure 9).

Whilst projections for future growth are more moderate, these are based on national trends and it could well be that with extended governmental support, these systems can bring electricity to rural populations on a scale unimagined before 2015 (Figure 9).

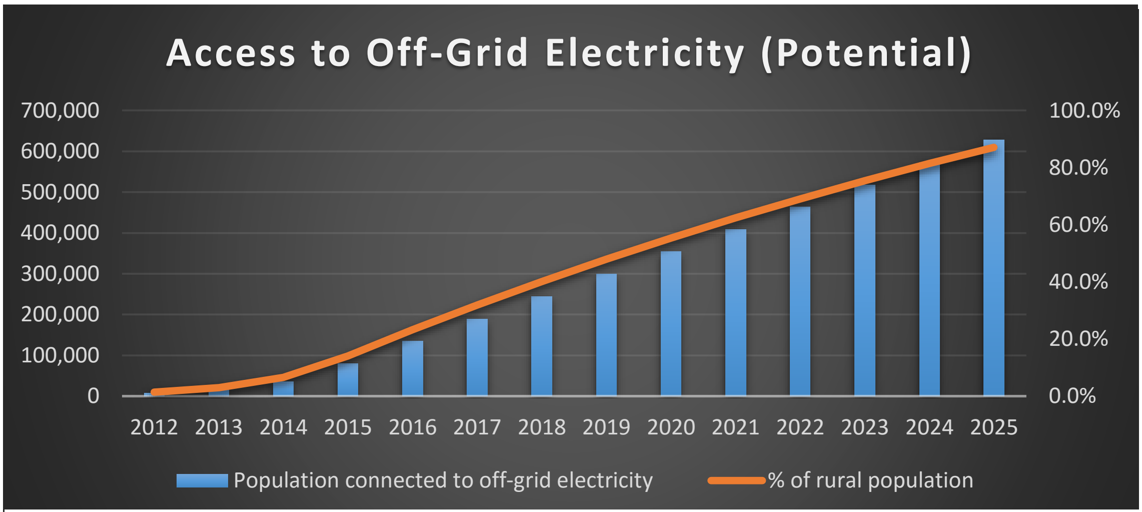


Figure 9

Whilst Pico-power looks set to revolutionise access to modern energy services for the rural population, it does have its limitations. Despite access to light in the hours of darkness and the ability to charge a mobile phone and listen to the radio being extremely important, there is a limit to the economic growth and social benefits it can facilitate in rural communities. The introduction of larger-scale businesses, medical or water treatment facilities, requires far more power than a few 10 watt panels could provide. Instead, where these facilities or businesses are foreseen, the introduction of a micro-grid could be of more use. With much higher capacities and the presence of a central large user to ensure financial viability, micro-grids are currently much easier to finance (Mwesigwa, 2016). Generally supplied by solar, small-hydro or co-generation generators, micro-grids tend to work closely with private industry or local governments in high-potential off-grid locations. The power generated from a solar farm or Bagasse plant, for example, could be utilised by a small agricultural cooperative to add post-harvest processing to their yield and increase profits, or by a hotel chain to power luxury suites for tourists visiting the national parks in Kasese district. These undertakings have the potential to bring in substantial growth to the region, supplying jobs and growth beyond those currently projected.

Challenges to be overcome

The above recommendations and projections come with the caveat that the following challenges are both acknowledged and addressed systematically.

1. High initial investment Costs; applies equally to pico-power systems and large hydroelectric projects. The role of central government and international financing remains the key to unlocking renewable energy development, both in the form of solar panel subsidies as discussed above and power purchase agreements for larger projects.
2. Inadequate awareness; much of the projections for renewable energy access as outlined above have been predicated on technology uptake at the moment of financial viability and societal acceptance. If a lack of awareness, or a negative public reaction to the technologies develops, then these targets will not be met.
3. Lack of Standards and Quality Assurance; one of the key challenges to ensure continued positive public reaction is the implementation and enforcement of quality standards in the industry. Current enforcement levels of existing standards are weak, and this will need to be targeted for action at both central government and local levels.
4. Limited Financing options; an issue related to the high investment costs mentioned above, limited financing options are especially an issue for SHS providers who struggle to provide the stock and financing demanded by rural communities. Greater awareness of the potential of this sector, especially in the developed world, is necessary to open up access to the finance channels to realise the potential of this industry (KDLG, 2012).
5. Lack of stakeholder involvement in planning and implementation; to-date, large renewable energy projects have tended to involve the central government and international finance with little-to-no consultation of local populations. Similarly, rural energy development projects have been run by government and international aid agencies, with little awareness for the specific needs of the people. The last five years have shown that the market is far better able to cater for rural populations, and government/aid agencies would be well-minded to support these endeavours in place of top-down projects flown in onto communities either unable or unwilling to cope.

5. Conclusion

Ideally, independent renewable energy will power tourist facilities, local government institutions and households throughout much of rural Kasese. Issues of standards, regulations, lack of finance and a shortage of skilled installers have been mentioned above and will need to be addressed in order to realise this potential. Once systems are in place, however small, the ability to upgrade and progress up the energy ladder becomes much easier. As consumer demand increases and economic development calls for greater access to electricity, the distinction between the capabilities of 'on-grid' and 'off-grid' will begin to blur as off-grid systems are upgraded and become competitive with the national grid. Indeed, were grid-extension to continue post-2025 and attempt to connect more towns and villages in Kasese district, it would be likely that these communities would only use the national grid as a back-up for their adequate existing solar-powered micro-grids (WWF, 2015).

Whilst the LEAP analysis has shown that, for Kasese, a 100% renewable energy scenario is possible by 2025, questions of feasibility rely on political will and access to finance. Are the challenges Kasese District faces surmountable with today's political and technological establishment, or are new thinking and solutions required away from the state-of-the-art? By combining access to finance for pico-power suppliers, subsidies on solar panels, distribution of efficient cook stoves and the development of agricultural residue harvesting and afforestation efforts, the energy transition is possible. As Kasese's mayor has recently stated;

> *In order to achieve the vision of 100% renewable by 2020, we need sustainable funding of renewable energy technologies. Sustainable financial support for the programme and finance mechanisms for individual households – especially those living on less than $1 a day – need to be ensured over the years in order for the 100% renewable vision to be realised* (Baluku Kime, 2015).

Although the model has shown that 2025 is a more realistic target, the basic principles remain the same. The findings above, and the data behind it, will be shared with the WWF in Uganda and the Kasese Local District Government to help inform their plans for the next nine years.

Touched upon briefly above, the potential of Kasese District lends itself perfectly to a role as an international role model for other regions and districts wanting to make a similar transition. Additionally, the positive image of Kasese will be useful for attracting tourism and further investment, with new technologies and investment welcome in the district. The UK Government's "Energy Africa" campaign has been looking for authorities to work with to expand its off-grid solar operations, as have other governmental and non-governmental organizations, and the findings of this report will be shared also with the Department for foreign investment and Development as well as the Department of Energy and Climate Change in London.

One of the major conclusions of this paper is that decisions on sources of lighting and cooking energy are based on a mixture of affordability, accessibility, convenience and interest. As such, strategies for expanding access to and use of alternative energy sources is often best thought of in a market context. By making the technologies accessible, convenient and affordable, market forces will work quickly to bring through an energy-use transition. By playing a typical governmental role in an emerging industry; namely by providing subsidies for purchase and regulation to ensure the quality of product sold, the Ugandan and Kasese authorities can allow burgeoning businesses to take over much of the effort of bringing modern energy services to the masses.

Ultimately, despite recent oil discoveries, Uganda is a fossil-fuel poor country. This has presented Uganda with a perfect opportunity to transition its electricity sector to a low-carbon industry. With solar, hydro and geothermal resources reaching and surpassing LCOE from fossil fuels, expanded access to electricity which increases its share of renewables at the same time as bringing down prices is perfectly possible. In doing so, Uganda can bypass the *"middle rungs of the electricity ladder (comprising of high-carbon fossil fuels)"*, and create a new image for itself as an example of sustainable growth (Lee, 2013). The decoupling of economic growth and carbon emissions has been an international target for decades, the benefits of which for Uganda go well beyond climate change.

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List of Figures

Appendix 1: Graphs and Tables not included in the text

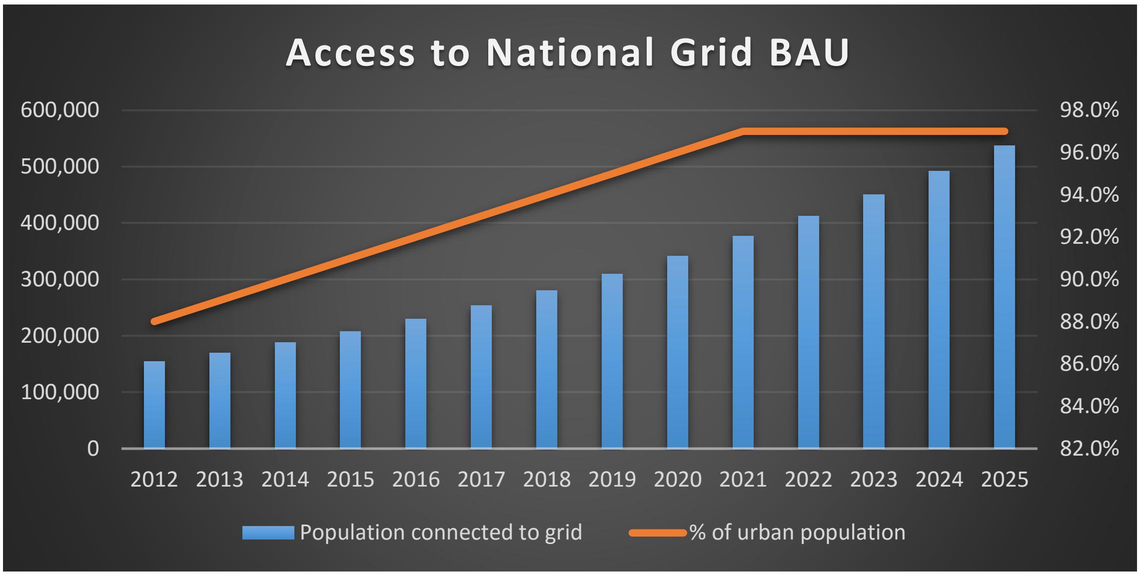

Figure 10

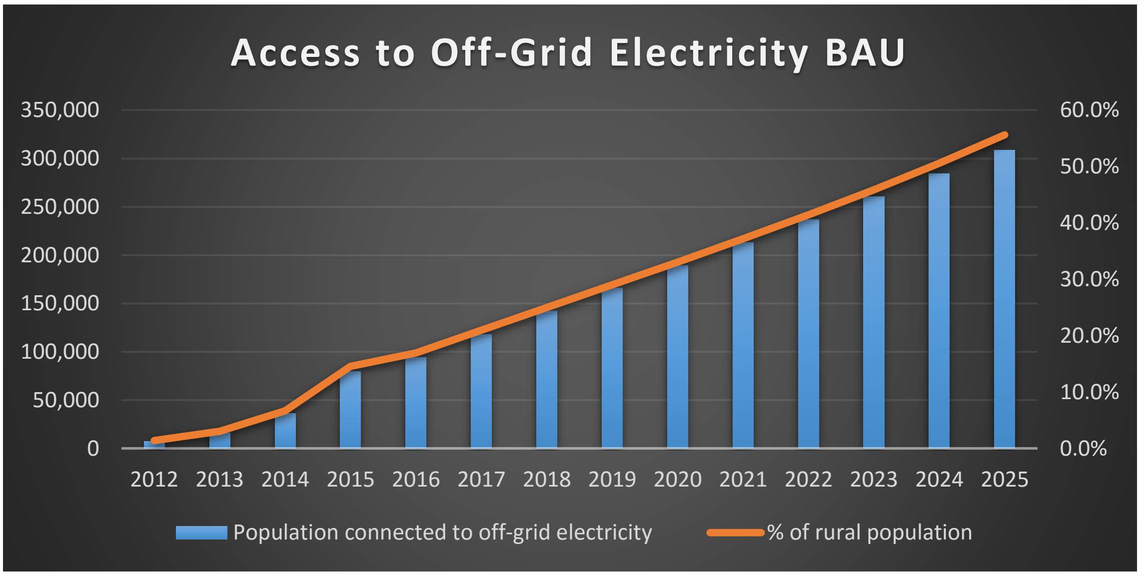

Figure 11

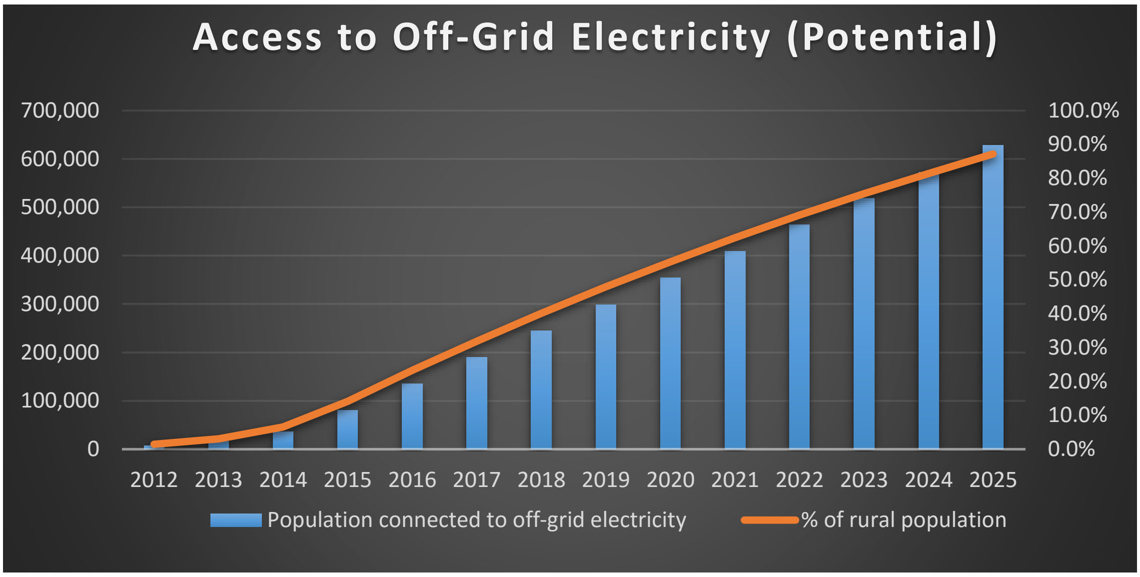
Access to Off-Grid Electricity (Potential)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Population connected to off-grid electricity
% of rural population

Figure 12