State of Energy Management in Greater Kampala Metropolitan Area of Uganda

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Abstract

A secure and accessible supply of energy, demand side efficiency and prudent management of energy is crucial for the sustainability of developing societies. The purpose of this study was to assess the current energy management situation of GKMA in relation with the existing Uganda Policy framework with a view to develop an appropriate research framework for developing and optimizing an EMP for a low carbon GKMA. Empirical literature review method was used in assessing the economy, energy situation and energy policy framework for Uganda in order to understand the state of energy management in GKMA. The study findings indicate that GKMA does not have a comprehensive energy policy framework. Future studies should therefore be conducted focusing on developing and optimizing the EMP for a low carbon GKMA. The EMP will provide a strong legal framework and policy required as a foundation for future energy management reforms of GKMA

1. Introduction

The spatial configuration of cities and its relationship to energy demand, global warming, anthropogenic climate change due to energy activities and the urban environment is a subject of empirical, theoretical and policy research. This, coupled with a quest for a sustainable primary mix and a desire for a low carbon footprint model, is motivating engineers to develop sustainable energy policies through a multi-faceted approach. (Markovska, et al, 2009; Rae & Bradley, 2012). Cities occupy less than 1% of the global land space with 50% of world population living in them and contributing 75% of GHG emissions (Liu, et al., 2012). Nevertheless, integrated local energy planning initiatives have gained greater expression only in the last decade or so (Neves & Vitor, 2010; Neves, et al., 2015). The new energy paradigm calls for a need to focus on the energy services for which energy is actually demanded and to critically assess the levels of demand and identify the appropriate energy carriers and technologies to satisfy those services (Dutta, 2003; Shackley & Green, 2007; Hammond, et al., 2008; Reddy B. S., 2015). Thus, a holistic perspective to local energy systems is deemed necessary (Neves, et al. 2015). More specifically, regional energy plans play a significant role in the sustainable development of cities and countries (Zhang et al., 2014; Madlener & Sunak,

2011; Dincer, 2000; Berke & Conroy, 2000; Naess, 2001; Omer, 2008). Energy planning is vital in achieving a sustainable energy management system (Mavrotas et al. 2008; Omer, 2006; Dovi, et al., 2009; Cai, et al., 2009; Wang, et al., 2009; Dincer, 1999; Banos, et al., 2011).

In the past decades, economic & population growth, urban expansion, concerns over increasing and fluctuating energy prices and demand, exacerbating power shortage, and climate change have been recurring within Energy Management Systems (EMSs) (Lin & Huang, 2009; Lotfalipour, et al., 2010; Smil, 2000; Dai, et al., 2016). These factors have forced decision makers to contemplate on more comprehensive, holistic and ambitious management plans (Hu et al., 2013; Tiba, et al., 2010; Geng & Doberstein, 2010).

Energy management is the planning and operation of energy production and demand in a given target area (Carbon Trust, 2011; Hiremath, at el., 2007; Bunse, et al., 2011; Kannan & Boie, 2003). It is carried out with an objective to conserve the energy resource, protect the environment and optimize the energy system cost, while meeting end-use demands (Turner & Doty, 2006; Kern & Smith, 2008; Baliga, et al., 2011). Energy planning is a way to manage and develop energy systems that can help improve environmental performance and reduce costs (VNRC, 2011; Watson, et al., 2010). It is a complex process that includes cultural, organizational, technical, legal, financial aspects and it consists of determining the optimal mix of energy sources to satisfy a given energy demand (Geem & Kim, 2016; Banos, et al., 2011; Fishbone & Abilock, 1981; Mehleri, et al., 2013; Muela et al., 2007; Loken, 2007; Pohekar & Ramachandran, 2004).). Energy policy is the manner in which a given government decides to address issues of energy development, management, production, distribution and consumption (Saidur, et al., 2010; Abdelaziz, et al., 2011; Zhou, et al., 2010). A good energy policy includes legislation, incentives to investment, guidelines for energy conservation, taxation and associated public policy techniques (Saidur., et al., 2010; Jaffe & Stavins, 1995; Solangi, et al., 2011; Carley, 2009). The main objective of an energy policy is thus meeting energy demand in a sustainable manner (WNA, 2013; Kaygusuz, 2012; Jaafar, et al., 2003; Demirbas, 2001).

For sustainability, a country should have an efficient energy management plan for its commercial, social and industrial hub (Rees, 1992; NJ, 2011; Fang & Zeng, 2007; Nasser, 2003). Greater Kampala Metropolitan Area (GKMA) is Uganda's commercial and industrial hub. It contributes approximately 60% of Uganda's GDP and accounts for 80% of the country's industrial sector (KCCA 2014a). GKMA, is an area covering Kampala District, part of

Mukono District along the Kampala-Jinja road corridor and Part of Wakiso District (Kira, Bweyogere, Kasangati, Nansana, Kyengera, Nsanji, Buloba and Kampala-Entebbe road corridor) (KCCA, 2012). This area consists of the following urban centers: (i) Kampala Capital City with a population of 1,516,210, (ii) Kira Town Council with a population of 313,761, (iii) Mukono Town Council with a population of 161,996, (iv) Nansana Town Council 144,441 and (v) Entebbe Municipality 69,958 (UBOS, 2014). GKMA currently serves as the capital city and seat of the government of Uganda; a tourism hub; center of the Buganda Kingdom; engine of growth for Uganda; and home and living environment for its estimated 3.15 million inhabitants (KCCA, 2016). While GKMA's economy is fairly competitive and has made significant efforts towards improving the livelihoods of its communities, the City is still faced with a number of challenges that needs to be addressed through long-term and comprehensive planning initiatives. These include among others: A concentrated and skewed economy; Energy security and conservation of the environment; Dominance of the informal sector; High poverty levels especially among slum dwellers; High levels of unemployment especially amongst the youth; and the need to define and promote new emerging sectors for growth (KCCA, 2014). The energy sector continues to play a vital role in tackling the above challenges facing GKMA. As such the Government of Uganda prioritizes the energy sector as being vital in the growth of the economy and social transformation of the country. Allocations to the energy sector were 2.4 Trillion Uganda Shillings for fiscal year 2018/2019.

Climate change mitigation and transformation to a global low-carbon economy is a pressing issue in policy discussions and international negotiations. The political debate is supported by the scientific community through a wide range of projections, pathway simulations, and scenario analyses of the global energy system and its development over the next decades. The challenge facing policy makers today is achieving a balance between economic competitiveness, provision of an optimized supply mix and the need to respond to climate change threats so as to ensure sustainability. This situation calls for a rigorous effort that entails a bottom-up approach (engineering modeling) coupled with a top-down approach (economic modeling) on the energy system that will ensure a sustainable energy future through development of low carbon policies (Steenblik & Wigley, 1990; Ebrahim, et al, 2014). A multi-faceted approach addressing the primary mix, conversion & demand technologies and final demand is the way to go in addressing issues pertaining a sustainable supply mix and mitigation of CO_2 emissions. The energy costs are rising, fossil fuels & coal reserves are depleting steadily and the issue of climate change due to the anthropogenic interference are some of the major

concerns for energy policy makers. Thus long-term investment in the oil and coal industries together with sustainable alternative solutions such as energy savings and new & renewables face a socio-economic uncertainty. Available literature indicates that there is no immediate sudden impact but energy, economic and social impacts remain critical as the cost of energy form large balances on government budgets for developing economies. Going forward, the world population is increasing steadily with a promising prosperous economy indicating a steady increase in energy demand and associated CO_2 emissions with nothing in the trends to indicate change in the situation in a short term. This calls for a comprehensive action to cause change to this unstainable situation by developing and evaluating low carbon energy policies to ensure sustainability. Environmentally benign energy management systems need to be developed for cities/metropolitans based on a low carbon city model that will ensure sustainability.

Specifically, in Uganda and in particular GKMA, changes need to be adopted that entail a stronger focus on the optimization of the primary energy mix and balancing the metropolitan's need for energy security with its economic development. GKMA has a Kampala Physical Development Plan KPDP (KCCA, 2014) and the KCCA strategic Plan 2014-2019 but they do not address explicitly the energy requirement of GKMA. Therefore, GKMA does not have an energy policy framework. Other energy policies available in Uganda like Electricity Act of 1999, Energy policy for Uganda of 2002, Renewable Energy Policy for Uganda of 2007, and the Atomic Energy Act of 2008 do not address the energy challenges of GKMA. Thus the existing energy policy framework in Uganda does not provide a satisfactory redress of the energy challenges of GKMA. Therefore, there is a need to develop and optimize the EMP for a low carbon GKMA to provide a strong legal framework and policy required as a foundation for future energy management reforms. A multi-faceted approach addressing the primary mix, conversion & demand technologies and final demand through a comprehensive and appropriate energy planning and energy policy development processes that could cause change to this unstainable situation is necessary and thus proposed. The development of such a framework therefore requires a careful long term planning process by developing socio-economic energy scenarios based on a low carbon footprint and then after, examine such scenarios for their energy and economy wide impacts on the energy management system of GKMA using VEDA-TIMES and CGE modelling framework.

The objective of this study is to establish the current energy management situation of GKMA, available primary energy mix, GDP, population and population growth rate for GKMA, assess the adequacy of the existing Uganda energy policy framework on GKMA energy management system with a view of developing an appropriate research framework for developing and optimizing and energy management plan for a low carbon Greater Kampala Metropolitan Area.

2. State of Energy in Uganda

Biomass at 90% is the dominant source of energy in Uganda. Biomass is separated as follows; firewood (78.6%), charcoal (5.6%) and crop residues (4.7%). Electricity contributes only 1.4% to the national energy balance and oil products contributes the remaining 8.7% (MEMD, 2014). The installed electricity capacity is 850MW with an effective generation of 710MW. HEP contributes 645 MW and 101.5 MW is thermal generating capacity. Thus Uganda is largely dependent on HEP for electricity. Two large hydropower facilities at Karuma for 600MW and at Isimba for183 MW have been built the latter was commissioned in Jan 2019. Uganda has 1500 kilometers of transmission lines over 33kV and the government aims to double this length in the medium term. The Uganda government plans to upgrade existing transmission lines and develop a 220kV “ring” around Lake Victoria in conjunction with Kenya and Tanzania. In 1999, the power sector underwent extensive sector reforms that led to the un-bundling of generation, transmission and distribution from UEB. The new legal and regulatory framework unbundled Uganda Electricity Board (UEB) leading to public private partnerships. This established an environment for private sector investments in generation and distribution of electricity while transmission above 33kV remains a public function managed by UETCL a government parastatal. Under the Electricity Act of 1999, the Electricity Regulatory Authority (ERA) was established as an independent sector regulator. Today, distribution is regulated and with 54% of power generation coming from independent power producers (IPPs). Electricity Regulatory Authority role is to license and regulate operations of all electricity operators. The Uganda government under its poverty eradication program in rural areas established the Rural Electrification Agency (REA) to help extend the grid to non-profitable rural area of the country. Uganda`s per capita electricity demand is 215 kWh per capita per year. Comparing to Sub-Saharan Africa’s average: 552 kWh per capita and World average: 2,975 per capita, it is still very low. The energy sector contributes to the Ugandan economy through fuel taxes, VAT on electricity, levy on transmission bulk purchases of electricity, license fees and royalties and foreign exchange earnings from power exports. The power sub-sector is attracting a sizeable number of investors in the country (MEMD, 2015b).

2.2.1 Energy Demand in Uganda

The total energy demand for Uganda in 2013 was 136TWh with 95% of its population without access to the national grid. The electricity demand is growing at an average of 10% per annum. This is due to the steady GDP growth averaging at 5.8% over the last twenty years(MEMD, 2014). The residential sector is taking up the lion's share of energy demand in form of woody biomass. The industrial sector uses a lion's share of the electricity supply although, electricity makes up less than 2% of Uganda's energy balance. The electricity demand in the energy balance of 2013 was 2.9TWH including 0.86TWH losses in the transmission and distribution lines (MEMD, 2014). Table1 shows the energy and electricity demand for Uganda in 2014.

Demand in the Residential sector of Uganda

The demand in the residential sector was 82 TWH in 2010 (MEMD, 2012d). Firewood (86%), charcoal (5.8%) and agricultural residues (7%) used for cooking constitute the bulk of the residential demand. There is a low access to modern energy sources such as Propane (LPG) at 0.06% and electricity at 0.45% make up a relatively small portion of overall household energy demand. The per capita demand for firewood in rural and urban areas is 680 kg/ year and 240 kg/year respectively. Per capita charcoal demand is 4 kg and 120 kg in rural and urban areas respectively (MEMD, 2012b). Use of biomass is highest in rural areas where, in addition to wood, "lower" forms of energy such as agricultural wastes and dung are commonly used as cooking fuel when wood is not available. The Ekyo'Oto (three stone stove) for burning firewood is used in rural Ugandan households and it has a low efficiency. Efficiency rates for such stoves vary widely; in lab tests thermal efficiency ranges between 20 to 30%, while in actual practice efficiency of as low as 5% can be experienced. The Ekyo'Oto is associated with both environmental and health hazards. Households in urban areas mainly cook with charcoal and it contributes 56% of the household energy demand in GKMA. Charcoal is a preferred urban fuel because it has a high energy density and it can be conveniently transported and stored (MEMD, 2015a). The charcoal is produced in a Tanulu, a low-efficiency earth kiln in rural areas. LPG and electricity are used in affluent urban areas like GKMA but actual demand is yet to be quantified.

Demand in the Industrial Sector of GKMA

Industry is largely made up of Small and Medium Enterprises (SMEs), agro-processing factories (i.e., maize, coffee, sugar, tea) and other businesses associated with the agricultural

sector. Industry is heavily reliant on firewood, which contributes about 60% of the sector's total energy need. At 9% and 7% respectively, diesel and electricity are second and third largest energy contributors in the sector. Demand for LPG in the industrial sector is 3.4% (Gustavsson, et al., 2015). Uganda has a relatively low level of industrialization and so do GKMA. Wood fuel is the major source for heating, brick making, tea drying and lime production. Brick making is wide spread with commercial production in GKMA. The use of firewood in the industrial sector has contributed to extensive deforestation country-wide. Bagasse is a prime source of energy in the sugar industry and also contributes to the national grid through cogeneration (MEMD, 2015a).

Demand in the Commercial Sector of GKMA

The commercial sector is an active part of the informal urban and rural economy, made up of restaurants, bakeries, service enterprises, shops and institutions. Institutions includes schools, prisons etc. In terms of overall energy use, it takes up a larger portion of demand than industry because of the large number of small players.

- Firewood and charcoal, which make up 90% of energy use in the sector, are used mainly for food preparation and heating water.
- Cooking appliances are inefficient. There is a need to adapt to energy saving stoves as well as introduction of solar water heaters in the sector.
- Electricity and kerosene are used for lighting and powering appliances (MEMD, 2015a).

Demand in the Transport Sector of GKMA

The number of motor vehicles on the roads of Uganda has increased dramatically causing traffic jams on roads most especially in GKMA. The traffic jam has become a nuisance and has reduced productivity. The Uganda government has set up initiatives to reduce the traffic jams on GKMA roads (URA, 2008).

The following can be noted about the transport sector in GKMA

- Use of private vehicles in GKMA is increasing and it is a major contributor to traffic jams and congestion during morning and evening peak hours.
- Urbanization of GKMA has increased the number of mini-buses on the roads.
- Walking and cycling are still dominant and critical transportation modes for people living in GKMA, most especially along Katwe-Queensway-Makindye-Nsambya

corridor, Wandegeya-Makerere-Kikoni corridor and Mengo-Lugala- Masanafu corridor. This is usually ignored in academic statistics.

- Boda-boda use is increasing rapidly in urban and peri-urban areas of GKMA.

Though the number of vehicles in Uganda can be tracked from registration of vehicles, a full understanding of the transportation sector is yet to be developed (i.e. how far vehicles travel, how many passengers travel in each vehicle, specific vehicle loads). Transport demand is indicated as million person kilometers (mpkm) for person transport and million ton kilometers (mtkm) for goods as illustrated in Table 2 and Table3 below.

The national transport master plan assessed the annual growth rate of transportation at 8% between 2003 and 2013. The demand for transport in Uganda in 2010 was estimated to be:

- Goods transport demand: 6,554 ton-km
- Passenger movement demand: 26,045 person-km

The management of GKMA is carrying out a feasibility study on how to improve its transportation system in GKMA (NPA, 2015).

2.2.2 Energy Supply Mix for GKMA

The total supply mix for Uganda in 2013 was 178 TWh (MEMD 2014). Although all sectors demand highly renewable woody biomass, the transport sector relies entirely on fossil fuels. The share of renewable energy sources is more than 90% in the supply mix (MEMD 2014). The following observations can be made on the GKMA energy supply mix;

- Electricity is primarily HEP. It accounts for a small portion of overall energy supply mix (<2%) but is extremely important to the industry, commercial and residential sectors. The electrification rate was 15.2% in 2014 and the generation mix by end of 2014 stood at 873.34MW, of which 695MW was HEP and 118.84MW from fossil fuel-based thermal and 59.5MW from Biomass co-generation sources (MEMD, 2014).
- Petroleum fuels imported through Kenya and are used in the transport sector and, to a lesser extent, for electricity generation. Though insignificant in overall quantity, kerosene meets a significant share of household lighting demand in the GKMA rural areas (MEMD 2012a).

- Biomass is highly demanded for cooking and heating in household, institutional and the private sector. The level of demand exceeds the sustainable biomass production levels and is causing deforestation in the country.
- Solar and battery-based electricity in off-grid sites is quite small in absolute energy terms.

3. Sources of Energy for GKMA

Uganda has the following energy resources: hydropower, biomass, solar, geothermal, peat and fossil fuels. The energy resource potential of the country includes an estimated 2,000 MW of hydro power along the White Nile, 450 MW of geothermal, 1,650 MW of biomass cogeneration, 460 million tons of biomass standing stock with a sustainable annual yield of 50 million tons, an average of 5.1 kWh/m^2 of solar energy, and about 250 Mtoe of peat (800 MW). In addition, petroleum has an estimated amount of 6.5 billion barrels in the Albertine region, of which 1.4 billion barrels are recoverable. The overall renewable energy power generation potential is estimated to be 5,300 MW (NPA, 2010)

3.1 Biomass

The energy supply mix in Uganda is predominantly Biomass contributing 90% to the energy demand and 6% to the GDP (MWE, 2013). The bulk of biomass is locally-sourced. Though biomass is considered a renewable resource, its harnessing is still unsustainable and there is considerable deforestation occurring in the country. Currently the demand for woody biomass is estimated at 44 million tons/year. Available forests can sustainably supply about 26 million tons/year, indicating a supply shortage of 18 million tons/year (MEMD, 2015a). Thus there is a need to balance woody biomass production and demand in a sustainable manner.

Charcoal is a high intensive energy resource, easy to transport and a main source of energy for Heating in GKMA, Agro-residues and wood wastes are widely used in the rural areas. Charcoal is mainly used on a metallic stove traditionally known as a ‘sigiri’ though the use of the clay sigiri is picking up. GKMA’s charcoal demand is estimated at 1.01 million tons per annum, from 16 million tons of wood (MEMD, 2015a). The demand for charcoal is growing at 6% per annum (Basu, et al., 2013). Agricultural bio-residues, forest residues and bio-wastes could add another 10 million tons to the biomass supply (MEMD, 2015a). Non-Woody biomass comprising mainly of biomass residues has an estimated potential of 71 TWh (Okello, et al.,

2013). Bio-residues are high intensive modern solid fuels. Transforming this resource into high valve marketable forms such as briquettes or roasted pellets is a sustainable option. Pellets require new demand technologies. Roasted pellets are based on a combinations of coffee residue, saw dust and rice husk (Chen, Lu, & Tsai, 2012), but this technology is yet to be scaled up in Africa and most importantly in GKMA.

Biogas is mostly used in the residential sector for heating and cooking. There are about 5,000 installations of family sized biogas units in Uganda (SNV, 2014). If harnessed well, biogas should meet demand in the residential, commercial and industrial sector of GKMA (Pandey, et al., 2007; REA, 2007). The biggest challenge for biogas is the initial investment costs most especially at the household level.

Uganda does not have a large scale bio-ethanol or biodiesel production at the moment. However, a biofuel program was launched in 2011 and this includes biogas, methanol but tangible results are yet to be realized (Tumwesigye, et al. 2011). Potential sources for the bio-fuel production include sugar plantations and cassava feedstocks. Ethanol from sugar cane is a natural replacement for petroleum. Potential bio-ethanol from sugar canes is about 3.7 million m^3 per annum with 20 TWh/year for Uganda. Bio-diesel can be obtained from a variety of feedstock including oil palm fruits, soy bean and Jatropha. Meeting current demands would require about 30 TWh of bio-diesel production (about 2.8 million tons) per annum. This production level can be met with first generation technologies (Herman, et al.,2014).

There is no mechanism and clear policy on how to harness biomass. Lack of such regulation has profound implications. The awareness of sustainable options available is low. The lack of a clear law/ policy on firewood and charcoal has highly affected the interest of potential investors in the sector. There is a chance to sustainably harness biomass by adopting better forestry management practices. The development and optimization of an EMP for a low carbon GKMA will provide a legal framework to formalize a sustainable charcoal and fire wood harnessing and trading situation within GKMA.

3.2 Hydropower

Uganda had her first electricity supply in 1960s after construction of the Owen Falls Hydropower Dam. It was later renamed Nalubaale Power Station with 10 generators of capacity of 150 MW and after sometime, refurbished and upgraded to 180 MW. Another dam

Kiira, a new hydropower station, was constructed adjacent to Nalubaale with a capacity of 200 MW. With the liberalization of the economy and the unbundling of the electricity utility, both Nalubaale and Kiira hydro power stations were leased to Eskom (U) Ltd under a 20-year concession agreement. The two-hydropower stations form the backbone of the electricity supply network in the country. Kilembe Mines Ltd, Kasese Cobalt Co. Ltd and Tronder Power, have their own smaller hydropower plants Mubuku I with 5.4 MW, Mobuku II with 14 MW and Mobuku III with 10.5 MW. These stations were initially established to supply power to their respective industries, but due to the interruption in the copper and cobalt production, the companies entered into a contract with the UETCL in 2003 to sell power to the grid. Other power stations are the Kanungu Power Station of Eco Power with 6.4 MW, and Mpanga Power Station of Africa Energy Management Systems with 18 MW. Three other small hydro power stations Kuluva (120 kW), Kagando (60 kW) and Kisiizi (300 kW) supply electricity to isolated hospital grids. The German Agency for International Cooperation (GIZ) set up small hydro power plants in Bwindi (64 kW) and Suam (40 kW). However, during droughts like in 2009, only half of the installed capacity could be used as a result of the low water level of Lake Victoria. An HEP dam was constructed at Bujagali and was commissioned in February of 2012 with a capacity of 250 MW. Before Bujagali became operational, 150 MW thermal capacities had been added in order to bridge the gap until the beginning of 2012. All big power generation plants belong to the Uganda Electricity Generation Company Limited (UEGCL) but are operated and managed by Eskom Uganda Ltd, Aggreko and other companies. Karuma and Isimba will be added by end of 2018.

3.2.1 Hydro potential and distribution

A Hydropower Development Master Plan for Uganda is available. Uganda has an estimated HEP of 4500 MW of which 2,000 MW is along the White Nile (NPA, 2007). In the long term, three large hydro power stations will be constructed. Isimba Power station with a capacity of 183.2 MW was commissioned in Jan2019 and Karuma Power Station of capacity 600 MW is due end of 2019. There plans to set up Ayago Power Station with a capacity of 600MW by 2023. The small and mini hydro sites are mainly located in the Eastern and the Western parts of the country, which are hilly and mountainous. A total of 59 mini hydropower sites with a potential of about 210 MW have been identified through different studies. There is an identified 210 MW of small hydropower sites to be developed off the grid (REA, 2007). However, it is not sustainable to exploit 100% of the HEP potential due to environmental and social concerns. A sustainable HEP resource should be set to 3,500 MW to allow for environmental and social

concerns when designing and positioning of hydropower stations. Because of seasonal limitations impacting on hydropower production due to climate change there is need to explore other sources of electricity.

3.3 Solar Energy

The use of Solar energy in Uganda is still very low. Uganda is located astride the equator making solar energy a viable potential source of power. Uganda with a surface area of 236,040 km^2, has 5 kWh/m^2/day of solar energy giving 430,700 TWh of solar energy arriving each year on its surface area. But this energy must be collected and stored using PV technology for it be used. Solar energy is also used directly to heat water, dry crops, drying fabric, sterilize, and cook using technologies such as solar water heaters, solar driers, solar stills and solar cookers.

Solar electricity: Solar energy can be converted to electricity on and off the national grid through photovoltaic or concentrated solar power (CSP) technology. The 236,040 km^2 of Uganda's surface area has a solar radiation in excess of 2,000 kWh/m^2/year (i.e. 5.48 kWh/m^2/day). This is considered a high potential for solar power investment (Hermann, et al., 2014). A relatively small area with installed solar PV or CSP can theoretically power all of Uganda. A solar PV array of four square kilometers could produce over 1,000 MW which is more than the current output of the Uganda grid. With irradiance of 1,000W/m^2 and solar panels of 10% overall efficiency covering 4km^2, a PV array could easily supply 1,000 MW. Given the above resource data, it can be argued that virtually any available land, or any rooftop space within GKMA, is a potential site for solar PV electricity supply for the metropolitan.

The demand for solar electricity is growing with an increasing number of private businesses dealing in Pico systems. Pico solar systems are widely available over the counter in GKMA. There is a wider usage of solar lanterns in the residential sector (Alstone, et al., 2015). The solar electricity industry is growing at 20% per annum with many small off-grid installations in place. (MEMD, 2012b). Most solar home systems are modules of 20-100W that significantly provide more power than Pico-solar systems. PV home systems were installed in 5,600 households, 420 commercial buildings and 1,700 institutions by REA and donor agencies in 2012 (MEMD, 2012b). Institutional PV systems supplement power in schools, health centers

and police posts. Isolated solar systems are used in areas where there is little or no access to the grid. The primary challenge of the PV technology is the affordability.

3.4 Wind Energy

In Uganda, currently wind is quantified for meteorological purposes. From the department of meteorology, Ministry of Water, Lands and Environment, the wind speeds in most areas of Uganda are moderate with average speed not exceeding 3 m/s. The maximum speed recorded is around Mt. Elgon with an average of about 4 m/s. From these figures, previous researchers concluded that the wind energy resource in Uganda is insufficient for large-scale electricity generation. However, current researches in the Karamoja region and along the shores of Lake Victoria have shown that there could be potential for production of electricity on a medium scale (Alobo & Xsabo, 2013; RECP, 2015; Sanya, 2013).

3.5 Geothermal Energy

Geothermal resources in Uganda are still at the exploration stage. Geothermal energy potential is estimated at 450 MW. Exploration of geothermal energy has been ongoing since 1993. Katwe-Kikorongo, Buranga and Kibiro are potential areas identified for detailed exploration. Previous studies show that the temperature level varies between 150 C° and 200 C° which is sufficient for electricity generation and for direct use in industry and agriculture (SE4ALL, 2014; Bahati, et al., 2010).

3.6 Cogeneration

From bagasse, 29.7MW is output to the national grid as fuel (MEMD, 2014). Previous studies indicate a considerable potential of cogeneration in the sugar processing industry, textile manufacturers, beer industry, cement industries and foods and beverages industry. The potential in the sugar industry alone is currently estimated to be over 100 MW while for other industries it could be over 50 MW (SE4ALL, 2014; MEMD, 2013)

3.7 Fossil Fuels

The demand rate is about 7% (MEMD, 2014). Petroleum products are all imported from overseas because there is no local production yet. About 95% of Uganda's petroleum imports are routed through Kenya and only 5% come through Tanzania (MEMD, 2014). Oil was discovered in Uganda in the Albertine region. The Oil reserves stands at 6.5 billion barrels of which 1.4 billion barrels are recoverable. The Uganda government has plans to set up a refinery

with an input capacity of 60,000 barrels per day and starting with a capacity of 30,000 barrels per day (MEMD, 2014). A production sharing agreement between the Government and the consortium of Tullow Oil (UK), Total (France) and CNOOC (China) was concluded in February 2012(SE4ALL, 2014).

Petroleum fuels in GKMA are used for:

- Diesel and premium for transportation.
- Diesel for on- and off-grid power generation. Uganda Electricity Generation Company Limited (UEGCL) uses generators for peak generation and for remote rural mini-grids. Industry and commercial groups use generators for back-up power and off-grid base load.
- Kerosene for household lighting. Wick lamps (locally known as Munaku Tadooba) and hurricane lanterns are primary lighting devices in non-electrified GKMA households. Use of kerosene dropped by 13% between 2012 and 2013 (UBOS 2014b).
- LPG for cooking. LPG is used by top-tier households, institutions and industries.

3.8 Electricity Transmission and Distribution

Uganda's power grid is predominately HEP at 85%. The national grid is split up into transmission (> 33 kV) and distribution (<= 30 kV). The grid coverage is only 14% of the population. Rural electrification access rate is 7% (NPA, 2015).

3.8.1 Transmission

Uganda Electricity Transmission Company Limited (UETCL) is a state owned company that manages the high voltage network above 33 kV. It publishes standardized tariffs for renewable energy generation systems and also buys and sells in bulk the national grid power. It purchases all independently generated power in the country and it also imports electricity from neighboring countries. The length of domestic transmission and distribution lines is about 14,312 km (MEMD, 2014).

3.8.2 Distribution

Uganda Electricity Distribution Company Limited (UEDCL) is a state owned parastatal mandated to build a distribution network at 33kV and below. UMEME Uganda Ltd manages

the distribution network on behalf of UEDCL under a 20-year concession agreement. UMEME is fully-privatized and is listed on Uganda's stock exchange. UMEME distributes, trades, supplies and manages all operations of the electrical network at 33KV and below within GKMA with over 450,000 customers (MEMD, 2012b; MEMD,2012a). Recently UMEME introduced a pre-payment system dabbed YAKA- an automated meter reading (MEMD, 2012b). Challenges in the power distribution include illegal connections, bill payment and debt collection.

3.9 Energy Tariffs

The tariff for the domestic consumers is at 520.6 Uganda shillings and is the highest in East Africa. The tariff is based on consumer category. In order to cater for the low income users, the lifeline tariff is set at UGX.100 per unit up to 15 kWh per month.

3.10 GKMA Energy Supply Mix and Some Key Observations from the Energy Situation in Uganda

From the on-going discussion of the energy situation in Uganda, it can be argued that Biomass shall continue to be an important source of energy for GKMA for heating (domestic cooking, brick making & bakery industries). Hydropower remains the dominant source of electricity at present and for planning purposes in the medium term. The pattern for electricity demand is 29% residential, 13% commercial and 58% industrial for Uganda. The low absorption of electricity in the residential area is attributed to the high tariffs. Wind energy is not feasible and therefore will not be considered for the optimized planning energy for a low carbon GKMA. Therefore, Biomass, HEP, Solar, Biogas, Geothermal, Cogeneration and Fossil fuels will constitute the supply mix during the development and optimization of an energy management plan for a low carbon GKMA.

4. Uganda Energy Policy Framework

4.1 Introduction

In April 2010, the Government of Uganda launched the National Development Plan (NDP) that covers a number of energy issues. One of the objectives of this plan is to increase access and demand of electricity for growth, employment and socio-economic transformation. The NDP highlights the following strategies to overcome the barriers of the energy sector towards achieving its goals:

- Increase power generation capacity to reach 780-820 MW, mainly through large and small hydro
- Increase rural electrification from 6% to 10% by, among others, subsidization of mini-grids
- Promotion of energy efficiency, reduction of power losses from 40% to 16%
- Revision of existing policies in the energy sector and promotion of renewable energies, esp. biomass and solar

To create a favorable investment climate and boost economic development, there is need for policy reform to ensure sustainability. There is a need to increase electricity supply to drive the economy as compared to middle-income countries like Vietnam, Malaysia and Korea (NDP, 2010). Table8 matches the capacity requirements against the demand per capita for the planning period 2010 to 2040.

The Uganda energy sector is constrained by the following;

- Weak policy and enforcement instruments
- Little funds are available for investment in sector
- Power losses in the distribution lines
- High energy tariffs for commercial and domestic users
- Un-coordinated planning and policy development
- Limited transmission and distribution network
- Limited generation capacity

Observations from the National Development Plan 2010:

The NDP talks of strengthening the policy, legal and institutional framework in order to regulate and monitor energy policies and plans. It suggests policies on atomic energy, thermal power; reviewing the existing policies and acts and formulating a PPP framework to allow private investment in the energy sector. The NDP also identifies UBOS as the sole provider of statistical data for all sectors but does not discuss the energy and economic-wide impacts of suggested measures. The optimized planning of the energy sector for a low carbon GKMA is not addressed. Therefore there is a need to develop and optimize an EMP for a low carbon GKMA as a foundation for future management reforms.

4.2 Public Institutions

There are three main governmental institutions dealing with the energy policy framework:

- The Ministry of Energy and Mineral Development (MEMD) is the lead institution in the energy sector. The Ministry is responsible for policy formulation, promotion, coordination, monitoring and evaluation. MEMD is also responsible for initiating legislation in the energy sector.
- Rural Electrification Agency (REA) is a semi-autonomous body established by an Act of parliament to operationalize government's rural electrification function. REA functions as the secretariat to the Rural Electrification Board, which realizes MEMD`s rural electrification plans as stipulated in the Indicative Rural Electrification Master Plan and the Electricity Act of 1999. REA controls public funds for the subsidization of rural electrification projects.
- Electricity Regulatory Authority (ERA) established by the Electricity Act of 1999 issues licenses for the generation, transmission, distribution or sales of electricity and establishes the tariff structure (MEMD, 2015b).

4.3 Development Partners

Uganda has a large community of international development partners in the energy sector who support energy access activities that have better value for money. Activities are coordinated through the Energy and Mineral Development Partners Group (EMDPG) with Germany having the lead since November 2010. The group includes the following: GIZ, USAID, DFID, EIB, EU-Commission, France, Ireland, IWF, JICA, Norway, World Bank, NORAD, IAEA, USTDA, IDB, UNDP, UNIDO, NDF and SIDA (UBOS, 2012).

5. Energy Policy Frameworks of Uganda

5.1 The Electricity Act, 1999

The salient features of the Act are:

- Liberalizing the electricity industry;
- Disbanding of the Uganda Electricity Board-UEB, historically a vertically integrated monopoly into three entities namely generation, transmission and distribution;
- Establishment of Electricity Regulatory Authority (ERA) to regulate the sector;
- Establishment of the Rural Electrification Fund (REF), with the main objective of enhancing rural access to electricity; and

- Establishment of the Electricity Dispute Tribunal (EDT) that has jurisdiction to hear and determine electricity sector disputes which are referred to it.

2.3.3.1 Key observations on the electricity Act

The general methodological framework for splitting UEB into UEGCL, UETCL and UEDCL as well as establishing ERA and REA is good. However, there are some underlying issues that were not properly addressed for example the Electricity Act does not:

- Provide electrical power demand projections optimized planning
- Provide a 50-year period power supply plan
- Provide an optimized fuel mix for the electricity generation for a long-term planning horizon.
- Link the electricity sector with other sectors of the economy
- Provide a mechanism to assess the economy-wide impacts of the electricity options suggested on the various economic sectors.
- Identify GMKA as the social, commercial, industrial and political capital of Uganda and thus doesn't plan for the GKMA electricity.

From the ongoing discussion on the Electricity Act, 1999 we can argue that since the Electricity Act, 1999 does not address the energy management of GKMA, it is paramount to develop and optimize an energy management plan for a low carbon GKMA that will provide a strong legal framework and policy as a foundation for future management reforms.

5.2 The Energy Policy for Uganda, 2002

The main policy goal is "to meet the energy needs of the Ugandan population for social and economic development, in an environmentally sustainable manner". The broad policy objectives are:

- To establish the availability, potential and demand of the various energy resources in the country. And to achieve this objective the government shall prepare a database on all the available energy resources and energy demand patterns. This will help in (i) matching the various demand/supply options, (ii) availing information on potential projects in energy investment, and the Government shall build the necessary local capacity in order to acquire the data required in assessing and evaluating the resources
- To increase access to modern affordable and reliable energy services as a contribution to poverty eradication. And to achieve this objective the government shall (i) Attract

private investors in the sector (ii) create a conducive and competitive environment within key players (iii) Manage tariffs of energy consumption (iv) help consumers to acquire new appliances (v) promote and develop new energy technologies and services

- To improve energy governance and administration. And to achieve this objective the government shall create a transparent legal and regulatory framework for the sector and as well as build capacity at the national and local levels for a better formulation and implementation of energy policies and programs
- To stimulate economic development. And to achieve this objective government shall (i) encourage competition within the energy sector (ii) promote energy trade in the region and (iii) ensure security and reliability of energy supply
- To manage energy-related environmental impacts. And to achieve this objective government shall (i) promote environmentally friendly technologies for the various alternatives of energy sources (ii) work towards ensuring acceptable GHG emissions levels during energy production
- To increase the role of private sector in the power sector operations and future development (GoU, 2002; Walekhwa, et al., 2009; Karekezi & Kithyoma, 2002).

The following were the characteristics that the government considered in formulating the energy policy:

- Uganda has abundant energy resources for example hydrological and Biomass, yet there is widespread energy poverty all over the country. There is an urgent need to develop the resources and improve energy supply.
- Planning for modern energy supply, especially electricity has been limited mainly to urban and semi-urban areas. A paradigm shift in energy planning is required to achieve equitable modern energy distribution.
- There is an inadequate and inefficient power supply system, a poor transmission and distribution infrastructure as whereas poor utility commercial practices. The sub-sector badly needs large investments and prudent utility practices.
- Government has to expand access to affordable, reliable and adequate energy supplies to address the economic poverty prevalent in the country.
- There is a need of a policy to mitigate energy development and environmental damage.
- The country needs a policy framework that will provide a harmonization of the energy sector with the policies of the other sectors of the economy.

- The country needs a policy that will provide a conducive environment to attract private finance and encourage energy trade and other aspects of partnerships.
- Institutional and legal weaknesses exist in the downstream petroleum industry, renewable energy, energy conservation/efficiency and atomic energy applications. Therefore, a continued sector reform to incorporate the regulation of the above sub-sectors is required (GoU, 2002).

The following are the key issues in the energy policy:

- Inadequacies within Government institutions to plan for and monitor the sector and carry out appropriate research and development (R & D) due to:
  - Understaffing in key areas;
  - Budgetary constraints; and
  - Lack of appropriate curricula in energy studies at institutions of higher learning.
- Inefficient supply and use of energy resources due to the neglect of the sector during the country's years of economic and political turmoil
- Inadequate co-ordination and information sharing among the various projects, government institutions and the private sector.
- Inadequate information on energy supply and demand as well as the country's resource potential.
- Lack of appropriate mechanisms to enable modern and efficient energy services to be accessed by the rural population (GoU, 2002).

A review of the energy policy suggests that the objectives of the energy sector are very comprehensive. However, the policy lacks on a clear discussion on how it will implement the objectives on the national and local level. For example, the policy talks of Energy security and conserving the environment but it does not discuss how to achieve a low carbon font print. The policy doesn't not provide mechanisms of optimization of the supply mix to achieve sustainability.

Another observation can be made on the willingness of government to allow competition for private suppliers of energy in exchange for low prices. The policy lacks an explanation on whether a thorough examination was made on the social impacts and how the people will be

affected after liberalizing the energy sector when the energy tariffs are solely dependent on the liberal market mechanism.

Another observation is that the energy policy does not highlight GKMA, the economic, residential and industrial hub of the country. Therefore, no energy planning specifically for GKMA is addressed in the energy policy of Uganda and thus there is a need to develop and optimize the EMP for a low carbon GKMA to provide a strong legal framework and policy required as a foundation for energy management reforms.

5.3 Renewable Energy Policy for Uganda, 2007 (GoU, 2007)

The overall goal of the Renewable Energy Policy (REP) is to increase the use of modern renewable energy. The key policy objectives include:

- To maintain and improve the responsiveness of the legal and institutional framework to promote renewable energy investments;
- To establish an appropriate financing and fiscal policy framework for investments in renewable energy technologies;
- To promote research and development, international cooperation, technology transfer and adoption of standards in renewable energy technologies;
- To utilize biomass energy efficiently so as to contribute to the management of the resource in a sustainable manner;
- To promote the sustainable production and utilization of bio-fuels; and
- To promote the conversion of municipal and industrial waste to energy. Under the power generation program, REP promotes power generation from mini-hydro power schemes, biomass, cogeneration, wind, solar, geothermal and peat. There are plans to consider nuclear power generation in the power mix in the long term

The objectives of the policy are well founded but the policy is shot of methodology of achieving the targets and the effectiveness of the proposed strategies, for example the policy talks of converting municipal waste to power generation but the economic-social and environmental-wide impacts are not well discussed in achieving this objective. GKMA renewable energy supply mix is not discussed in the renewable energy policy of Uganda and therefore, there is a need to develop and optimize the EMP for GKMA to provide a strong legal framework and policy required as a foundation for energy management reforms.

5.4 The Atomic Act, 2008 (GoU, 2008)

The Act provides for:

- Regulation of the peaceful applications of ionizing radiation;
- Establishment the Atomic Energy Council (AEC);
- Protection and safety of individuals, society and the environment from the dangers resulting from ionizing radiation;
- Production and use of radiation sources and the management of radioactive waste;
- A framework for the promotion and development of nuclear energy for use in power generation and other peaceful purposes;
- Compliance with international safety requirements for the use of ionizing radiation, radiation protection and security of radioactive sources;
- Repeal of the Atomic Energy Act, Cap. 143; and other related matters.

The enrichment of Uranium for power generation is associated with global politics and the use of atomic energy in the supply mix of GKMA is not feasible and thus shall not be considered for this study.

6. KCCA Strategic Plan 2014 -2019

The KCCA Strategic plan was formed to align both the National Vision 2040 and the Greater Kampala Metropolitan Area (GKMA) Development framework 2040 that was approved in April 2013 by cabinet. The GKMA development framework 2040 presents Kampala City and its environs as an economic and administrative hub and a major investment destination. KCCA strategic plan addresses the need to transform Kampala, rebuild key institutional, infrastructural and social structures that drive the delivery of goods and services, and respond to the challenges of increasing urbanization influenced by a younger population and influx of rural-urban migration. The plan covers the following themes:

- Planned and Green Environment
- Economic Growth
- Integrated City Transport Infrastructure
- Social Development, Health and Education
- Urban Governance and Operational Excellence

Kampala City has grown to become the largest urban center of Uganda, the only city in the country. Kampala is the political capital of Uganda contributing 80% of the country's

commercial and industrial activities. Kampala generates 65% of the national GDP. Kampala has 23% of its area fully urbanized, 60% semi-urbanized and the rest considered rural settlements.

Kampala serves multiple roles and functions of critical importance to Uganda as a whole, to the City itself and to its inhabitants. These roles and functions have directly influenced the City's development, indeed dictated its direction as detailed in the KPDP SR (KCCA, 2014; Gore & Muwanga, 2014).

Key Observations on KCCA Strategic Plan 2014-2019 indicate that:

- Although the plan talks of improving the city`s adaptability to climate change, and cites physical planning, engineering and public health as possible areas of intervention, the plan doesn`t show how critically engineering will intervene in providing the city`s adaptability to climate change. This calls for further analysis and examination of the city`s policy on energy supply and generation among others.
- The plan talks of economic growth by enhancing the growth of local economy, promoting the city`s heritage and attractiveness, improving public transport services and improving the quality of city human resource capital. But the plan is silent on the linkage between the economic development and the energy sector. The plan does not mention energy as a key requirement in this economic growth.
- The plan talks of revamping and expansion of street lighting network by introducing solar and modern LED street light systems. KCCA strategic plan does not show how the introduction of; the new technology, supply energy mix and the economic impacts shall be merged to achieve this objective.
- Generally, KCCA strategic plan does not plan for energy of GKMA. Therefore, there is a need to develop and optimize an EMP for a low carbon GKMA to provide a strong legal framework and policy required as a foundation for energy management reforms.

7. The Kampala Physical Development Plan, KPDP

In 2010, Uganda government created the Kampala Capital City Authority (KCCA) as a central government agency with overall responsibility to streamline operations and improve service delivery in the city. Over time, it became apparent that the development challenges of Kampala couldn't be resolved by KCCA alone. Thus in 2013, Cabinet approved the Greater Kampala Metropolitan Area (GKMA) Development Framework 2040 that provided the new boundaries

and its associated maps. GKMA spreads over an area of up to 839 square kilometers. The framework also includes various physical, spatial, environmental, ecological, socio-economic and other plans designed under a Capital Investments Planning (CIP) modular that define intended micro and macro projects for the development of the GKMA (KCCA, 2014).

The desired long term future roles and functions of Kampala are defined with due consideration for the current developmental conjuncture, primary development trends, Vision and interests. These are:

- Hub of an integrated, balanced urban system in Uganda;
- Engine of growth for Uganda, enabling and driving prosperity;
- The "Garden City of Africa" - the Gateway to and Showcase of Uganda;
- Capital City and Seat of Government;
- Leading Cultural and Educational Centre of East and Central Africa;
- Centre of the Buganda Kingdom;
- Quality Home and Living Environment for its residents;
- Tourism Destination and Hub.

The GKMA, currently with a population in excess of 3 million is projected to grow to about 5 million in the coming decade and to exceed, at the very minimum, 10 million within a generation. (Jos, et al., 2012). And if in-migration is to accelerate over the coming generation the city's population may well significantly exceed 15 million by 2040. The city is already overwhelmed by its current population, failing to adequately provide housing, employment, services, utilities and amenity for the bulk of its population and battles to absorb the current rate of in-migration.

A planning team from Israel was given the task of developing a Vision for the development of Kampala and its Metropolitan Area, and providing a Physical Plan for development in aims of achieving this Vision. The planning team includes Tzamir Architects and Planners Ltd., Shapira & Hellerman Planners, ROM Transportation Engineering Ltd., and Larry Aberman Associates. The planning team performed a thorough analysis of the Greater Kampala Metropolitan Area (GKMA) and developed the Kampala Physical Development Framework (KPDF) aimed at carrying out the Vision of Kampala to create a well-organized and modern urban metropolitan system. The boundaries of GKMA where later expanded to include also the following areas: (KCCA, 2012)

- Nakisunga: Kyetume, Namuyenje, Namaiba, Kyabalogo

- Ntenjeru: Mpatta, Ssaayi, Bugoye, Kabanga
- Nsangi: Katereke, Maya, Nanziga
- Goma: Bukerere, Misindye, Nyenje
- Busukuma: Magigye

The plan draws the physical boundaries of GKMA and KCCA and also presents a well-detailed physical plan of the GKMA. The plan does not address the energy requirements of GKMA and therefore, there is a need to develop and optimize an EMP for a low carbon GKMA to provide a strong legal framework and policy required as a foundation for energy management reforms.

8. Challenges Facing the GKMA Energy Sector

From the preceding discussion, it can be observed that the energy sector in the GKMA has a number of challenges. These challenges can be categorized into structural, political, economic and social challenges.

8.1 Structural Challenges

- Lack of an optimized energy supply mix
- Lack of adequate and efficient power supply system with the main issues arising from stunted generation capacity growth, a poor transmission and distribution infrastructure and poor utility commercial practices.
- The challenge of ensuring efficient and safe use of petroleum products especially in the transport sector.
- Woody biomass energy source remains dominant for heating with unsustainable usage
- Lack of mechanisms to mitigate and also quantify CO_2 emissions.

8.2 Political Challenges

- The government institutions do not plan adequately for the energy sector and do not have efficient mechanisms for monitoring performance.
- The appropriate research and development (R&D) is still low and this is attributed to: understaffing in key areas, lack of appropriate curricula in energy studies at higher institutions of learning and budgetary constraints.
- Lack of an Energy management plan (EMP) to act as a legal policy framework to guide KCCA management on the energy issues of GKMA

8.3 Economic Challenges

- The city depends on grants for funding the development of the energy sector.
- The high costs of mobilization of the imported petroleum products.
- The uncertainty of the international oil industry
- The initial costs of renewable energy technologies for Solar, Geothermal and hydropower are high and this makes the energy quite expensive.
- The demand for power is continuously increasing hence the need of massive investment to meet the demand.

8.4 Social Challenges

- There is an urgent need of adequate local expertise to management the energy sector
- There is a need to develop a low carbon sustainable energy management system to mitigate the intensities of CO_2 emissions.

9. Recommendations and Way Forward

GKMA lacks an adequate energy policy that will provide a strong legal framework required as a foundation for energy management reforms. The required policy would focus on the following issues,

- Security of the energy supply mix
- Energy efficiency and conservation
- Realistic energy sector reforms and environmental protection
- Optimization of the supply energy mix
- Improvement of the demand side energy efficiency
- Promotion of modern technologies for both the energy supply mix and end-use demand
- Protection of the GKMA environment from GHGs emissions
- Long term optimized energy planning
- Formulating a coordinating system with the existing national energy policies
- A central government legislation, incentives to investment, guidelines for energy conservation, taxation and associated public policy techniques

10 Policy implications and conclusions in light of GKMA' Energy Policy

Uganda has diverse natural energy resources. However, many of these resources are not properly exploited. The low economic growth and lack of effective energy policy framework are the barriers for optimal utilization of the available energy resources. Effective energy policies are key in ensuring that the environmental and social impacts of the energy sector don't

cripple attempts to move toward a sustainable economic development. (Mohamed & Lee, 2006). Recent studies indicate that developed economies like USA, Great Britain, Sweden and Finland continue to review their energy policies with a goal of moving towards a sustainable energy economy (Ericsson et al., 2004; Tsai & Chou, 2004; Wang, 2004; Winkler, 2005). Likewise, developing economies like Vietnam, Malaysia, Thailand and Philipines that have efficient energy policies are also continuously reassessing their policies with a simlar goal of moving towards a sustainable energy economy (Abdullah, 2005; Karki et al., 2005, Lebel, et al., 2002). For GKMA to realize a sustainable energy economy, it should develop an energy management plan and also adopt approaches from developing countries like Vietnam that have efficient energy systems & policies with mechanisms of continuous improvement. Such approaches would include developing a research framework on energy policy development and use such framework to set up a sustainable EMP for a low carbon GKMA. The EMP for low carbon GKMA will then assist in; improving the enforcement of environmental and energy conservations policies, integrate energy demand issues and data as part of the annual management agenda, link environmental and energy policies to maximize impact of conservation programs, tackle ambitious targets for reducing CO_2 emissions. A research framework based on an hybrid approach and using scenarios analysis needs to be developed. A multi-faceted approach addressing the primary mix, conversion and demand technologies and final demand through a comprehensive and appropriate energy planning and energy policy development process is proposed to cause change to the unsustainable situation of GKMA. The process involves developing energy scenarios and examining them for their energy and economy-wide impacts using VEDA-TIMES and CGE modelling framework. This hybrid research framework combines an engineering model, VEDA-TIMES and an economic model, CGE to assess the energy and economy-wide impacts of scenarios on the energy and economic sectors of GKMA. VEDA-TIMES considers the energy supply mix, process & demand technologies as well as CO_2 emissions while CGE methodological approach provides a higher level of representation of transactions within individual economic sectors that could be useful in examining the wider impacts of the low carbon scenarios.

A lack of a comprehensive energy policy framework for GKMA, given a modest availability of various energy sources within Uganda, and a need to tackle CO_2 emissions within GKMA calls for the development and optimization of an EMP for a low carbon GMA that will provide a strong legal framework and policy required as a foundation for energy management reforms.

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