Chapter

The Energy and Climate Change Nexus in Uganda: Policy Challenges and Opportunities for Climate Compatible Development

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Abstract

Although Uganda has abundant energy resources including hydropower, oil and gas, biomass, geothermal, and solar energy, energy poverty is still very high and constrains socio-economic transformation. Biomass energy accounts for approx. 88% of the energy mix and only up to 28% of the country population have access to electricity, and the two energy sources are climate sensitive. The reliance on biomass energy is a driver to deforestation and forest degradation that also reduces the country's resilience to climate hazards such as flooding, drought and landslides. Besides, deforestation is driver to greenhouse gas (GHG) emissions and adversely affects the delivery of ecosystem services. Uganda is also warming very first and rainfall patterns are becoming more variable. Coupled with increasing occurrence and severity of drought, intense rainfall, flooding and landslides, energy supply systems are becoming more vulnerable. While Uganda is currently not a major emitter of GHG, emissions will rise significantly in the future given the country's rapidly growing population and urbanization that are increasing demand for energy and exacerbated by ongoing oil and gas development. Therefore, as Uganda strives to attain a middle-income status country, building climate resilient and transiting to decarbonized energy systems is not only a necessity but transformational to reducing energy poverty, increasing access to clean and affordable energy services, spurring investment and economic growth, job creation, improved health and poverty reduction. In this chapter, we examine the nexus between energy and climate change in Uganda, focusing on energy as both a driver and victim of climate change while at the same time exploring opportunities for achieving enhanced access to affordable, reliable and clean energy as a contribution to sustainable, green and resilient development.

Keywords: energy, climate change, vulnerability, sustainable development, Uganda

1. Introduction

Energy and climate change are important topics in the sustainable development discourse globally and in Uganda. Indeed, the two touch on almost all sectors and

achievement socio-economic and environmental sustainability. Excitingly, the two topics are closely linked to the extent that one cannot be exhaustively discussed without reference to the other. Energy is driver of climate change because it is the main source of greenhouse gases (GHG) that are responsible for global warming and climate change. But still energy is a victim of climate change because energy supply systems are sensitive to the impacts of climate change that affect the accessibility, reliability and affordability of energy services. Therefore, while increased investment in sustainable and clean energy systems can be a solution to the global climate change challenge, addressing climate risk can increase the reliability and resilience of energy supply systems.

While Uganda's contribution to global GHG emissions is still very low (given that fossil fuel consumption is low) the country is highly vulnerable to climate change, ranking 166th out of 181 countries in the 2019 ND-GAIN index[1] which makes it the 12th most vulnerable and 36th least ready country [1] to adapt to climate change. Energy poverty is high and the main energy related GHG emissions in the country are caused by overreliance on biomass energy which is also a driver to deforestation land degradation and in-door air pollution. However, the rising population, rapid urbanization and ongoing oil and gas development point to a significant increase GHG emissions in the future.

Uganda's long-term development agenda aims at socio-economic transformation and attainment of an upper middle-income country status by 2040 [2] and to achieve this the country needs increased access to clean, affordable, and reliable energy. But Uganda also seeks to 'pursue a green growth and resilient development path' in line with its national development agenda and international development commitments, and particular the implementation of the Paris Agreement on Climate Change but this will not be achieved unless increased investments are made in green and resilient energy systems. In this chapter, we explore the nexus between energy and climate change in Uganda and its implications to achieving green, resilient and sustainable development.

2. Uganda country profile

Uganda is a landlocked country in East Africa across the equator, located between longitudes 29° 34′ and 35° 0′ East, and latitudes 4° 12′ North and 1° 29′ South. It covers an area of 241,550 km^2 of which 41,743 km^2 (17.2%) is open water and swamps, and the land area is 199,807 km^2 [3]. The terrain is mostly plateau raging between 1000 and 2, 500 meters above sea level (a.s.l.) averaging about 1,200 meters a.s.l. The lowest point is 620 metres (in the Albert Nile) and the highest point is at 5100 meters (the peak of Mt. Rwenzori) [4]. The main mountain areas are Mt. Rwenzori, permanently snow-capped mountain located in Western Uganda marking the border with the Democratic Republic of Congo (DRC); Mt. Elgon (4,321 m a.s.l), an extinct volcano in the eastern part of the country at the border with Kenya, and Mt. Muhavura (4,127 m a.s.l.) in the south-west bordering Rwanda and D.R.C.

Uganda is generally fertile, and well-watered country with many lakes and rivers. The most important water bodies include the Nile River, one of the world's longest, and whose source is Lake Victoria, the largest lake in Africa. Other major lakes are Kyoga, Albert, Edward and George. Uganda has a pleasant tropical climate, with moderate temperatures and the rainfall is more regular with a bimodal

[1] ND-GAIN index summarizes a country's vulnerability to climate change and other global challenges in combination with readiness to improve resilience. https://gain.nd.edu/our-work/country-index/

rainfall distribution. The main rainy seasons are from March to May and October to December, although though the northern part has a single rainy season from March to mid-October. Mean daily temperatures are 28°C and the long-term mean near-surface temperature is 21°C. The highest temperatures are observed in the north, especially the north-east, while lower temperatures occur in the south, and these mild conditions make climate one of Uganda's most valuable natural resources [4, 5]. However, the climate is becoming more variable and changing i.e. temperatures are rising, rainfall is becoming more erratic and unreliable, and extreme weather events are on the rise. It is widely expected that the impacts of climate change will be felt in varying degrees across all the country's sectors and regions [6].

Uganda's population is still small, estimated to be 41 million (Uganda Bureau of Statistics - [7]) of which 51% are female and 49% are male, and the life expectancy at birth at 63.1 years having increased from 50.4 years in 2002 [8]. The highest proportion of the country's population (54%) is young, under 18 years, and 73% of population living in rural areas while only 27% is urban [7]. The challenge is that the population is growing very rapidly at 3% per annum, making it one of the world's fastest growing populations and [9], and the political leadership (government) seems to be happy with this population growth trend. At this growth rate, it is projected that Uganda's population will reach 57 million and 72 million by 2030 and 2049 respectively [10]. While the proportion of the urban population is still small, the country is also urbanizing very fast with one of the world's' highest annual urban population growth rates at more 5% [11]. Kampala, the capital is also largest city in the country, with the Greater Kampala Metropolitan Area accounting for more than 60% of the country's GDP.

Uganda is a Least Developed Country (LDC), and indeed a highly indebted poor country (HIPC), with per capita GDP of USD 794.3 [12], and annual growth

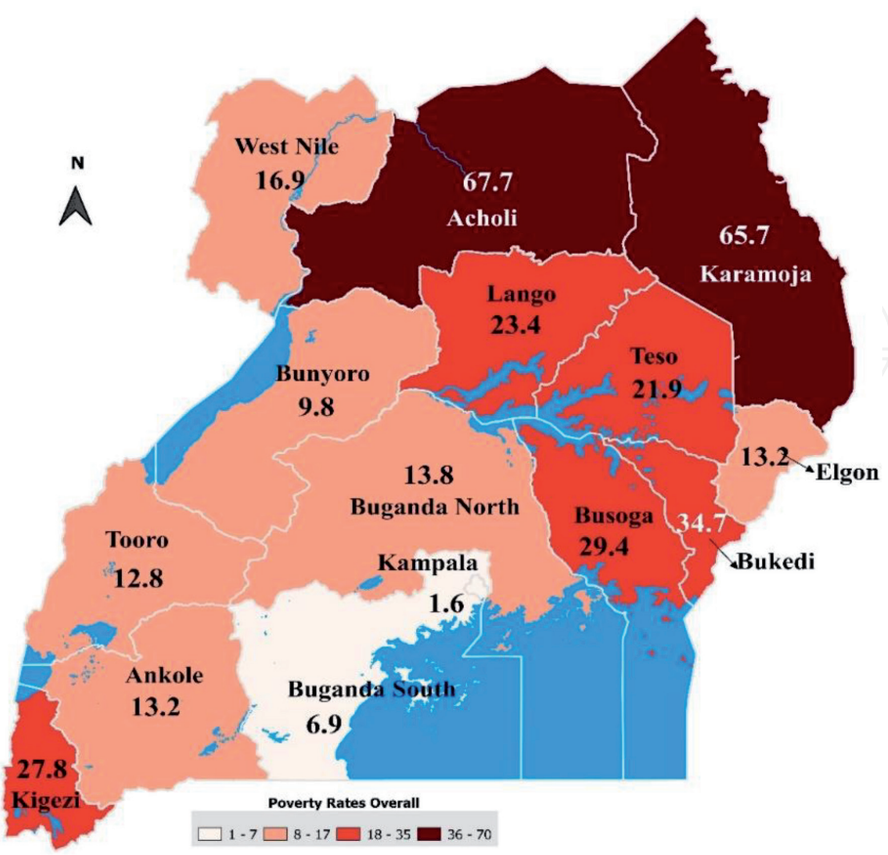

Figure 1.
Proportion of poor people in Uganda – Percentage (source: Uganda Bureau of Statistics - [7]).

was 2.9% in 2020, less than half the 6.8% recorded in 2019, due to the effects of the COVID-19 pandemic on the economy [13] and the debt to GDP ratio is very high 50.09% at in mid 2021. As at 2019, the population living below the poverty line was still high at 20.3%, with approx. 1.3 people living in absolute poverty [7]. The highest poverty rates are in northern Uganda in Acholi sub-region (67.7%) and Karamoja sub-region (65.7%), and the lowest is in the central region i.e. Kampala (1.6%) and Buganda (6.9%), (see **Figure 1**).

The country's long-term goal, articulated in the Uganda Vision 2040 [2], is 'transforming Ugandan society from a peasant to a modern and prosperous country within 30 years' and attainment of a middle-income country (MIC) status in which per capita income was envisaged to increase from USD 506 in 2010 to USD 908 in 2020, when the country would supposedly achieve a lower MIC status and then striving to achieve an upper MIC status by 2040 with a per capita income of USD 9,500. However as of 2021, the country had not yet achieved the MIC status. Agriculture is the Uganda's main economic activity employing around 64.3% of the country's population (47% employed in susbsistence farming), and acconted for 21.9% to the GDP in 2018/2019. Approx. 28% of the children are in child labour. However, the services and industrial sectors are also expanding and their contribution to GDP is increasing now standing at 51.1% and 18.7% respectively [7, 14, 15].

3. Energy profile and transitions

SDG 7 obligates member states to ensure access to affordable, reliable, sustainable, and modern energy for all. The Government of Uganda recognizes that energy is catalytic to economic and social development and that there is a direct relationship between per capita consumption of electricity to GDP and overall prosperity [16]. Recognizing, the link between energy and development, the Uganda Vision 2040 and NDP III (2020/21–2014/15) recognizes the critical role of electricity in the attainment of their key development priorities of economic growth, job creation and inclusive development. However, although Uganda is rich in energy resources, access to affordable, reliable electricity remains a major constraint to the country's socio-economic transformation and achievement of sustainable development. The energy resources potentials include renewables such as hydropower, biomass, solar, wind and geothermal, but also fossil fuels such as peat, and oil and gas, and these resources and are fairly distributed throughout the country.

Uganda has one of Sub-Saharan Africa's largest hydroelectric potential estimated to be well over 4,500 MW [2, 17] with a big portion of this potential lying along the Nile River, which increases dependency on the Nile. Renewable energy resource potential, estimated to be well over 7,500 MW, includes hydro, geothermal (450 MW), biomass cogeneration (1,650 MW), wind and peat (300 MW), as well as 460 million tons of biomass standing stock with a sustainable annual yield of 50 million tons, and an average of 5.1 kWh/m2 of solar energy [2, 17, 18]. As at 2019, the country's energy mix was dominated by biomass energy (88%) consumed mainly through firewood and charcoal, electricity (2%) and oil or fossil fuels at 10% [19], and energy consumption has been on rise over the years (see **Figure 2**).

The dominance of biomass energy in the country's energy mix remains socio-economic and environment challenge; hindering socio-economic transformation, a source of indoor air population with the associated health challenges, a driver to increased deforestation and forest degradation and a source of GHG emissions. However, limited availability of alternative affordable clean energy sources for cooking means that biomass will remain Uganda's most important source of cooking energy in the foreseeable future. Currently, Uganda depends on imported

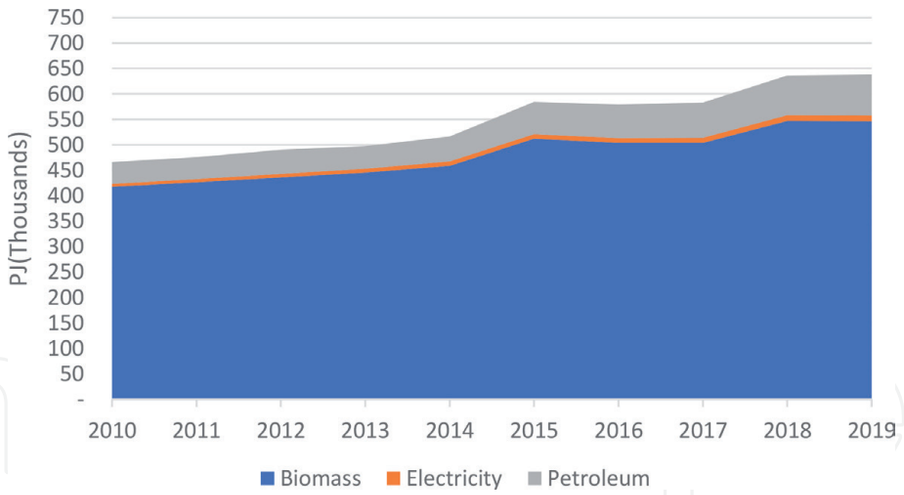

Figure 2.
The trends of contribution main energy by type (data sourced from MEMD and ERA 2010–2019).

oil/petroleum with the annual imports of petroleum products having increasing over the years e.g. from 1.4 billion liters in 2014 to 2.1 billion in 2018 [10]. Transport consumes 90% of the imported petroleum products, while 6% is consumed as kerosene in households consumes mainly for lighting [19].

Uganda depends on hydropower for its electricity accounting for more 80% of the country's electricity supply, the other sources being thermal (8%), co-generation (8%) and solar (4%). The grid installed electricity generation capacity has been increasing over the years from 183 MW in 1997 to 1,246 MW in 2019, while the energy losses in the distribution segment have reduced from 34% in 2008 to 16.4 in 2019% [16, 20]. Construction of Uganda's largest power plant (the Karuma hydropower plant) with 600 MW installed capacity is ongoing and could be commissioned by the end of 2021 or early 2022, and together with other small hydroelectricity plants that are under construction will increase the country's grid electricity generation to approx. 2,000 MW by 2025. However, the country's sustainable energy transition is still being hindered by the government's emphasis on large-scale hydroelectricity over other renewables [11], even when it is known that hydro-electricity is highly climate sensitive. Some interest in decentralized renewables exists, including solar and bioenergy, but they have not attracted the required state attention, and of late government attention is rather shifting to tap into oil and gas development for domestic power generation in the near future.

Nearly all the electricity generated in Uganda is consumed domestically, with households consuming the largest amount (61%), followed by commercial (14%), transport (13%), industry (8%), and others including export consuming only 4%. But then even at household level, the use of electricity is limited to lighting due to the high tariffs and for most households, charcoal and firewood remain the most accessible and affordable sources of energy for cooking. While there has been general increase in energy consumption in all the main sectors of economy over the last decade (see **Figure 3**), consumption of electricity in the industrial and commercial sectors remains low due to the low levels of industrialization, urbanization and overall economic development in the country.

Energy poverty is as electricity access remain low in Uganda with connectivity at only 28%, [21], which far lower than Sub-Saharan Africa average of 45% in 2017 [22]. In addition, electricity consumption per capita is approx. 100kWh [19], which is one of the lowest in the world. Besides the high costs of electricity, coupled with unreliable supply contribute to overdependence on biomass energy for cooking and the high cost of doing business which reduces the country's competitiveness [23].

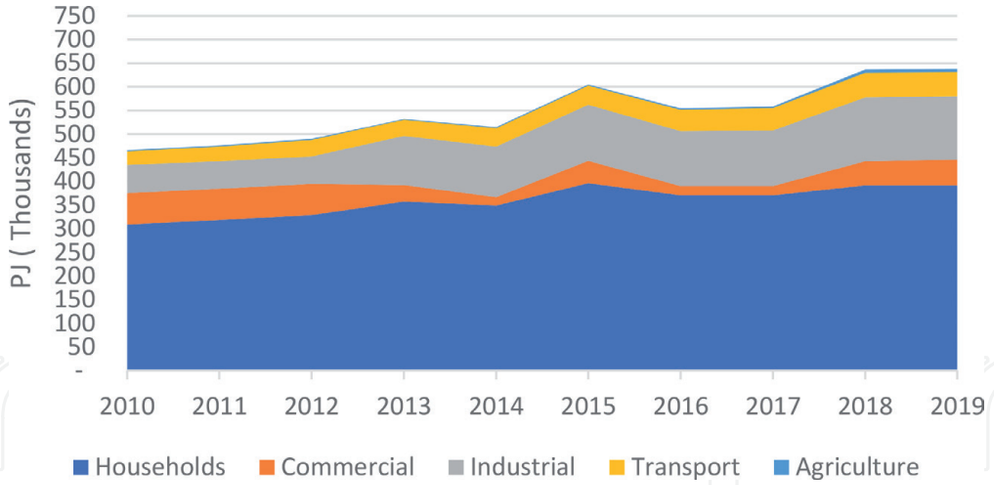

Figure 3.
Trends in energy consumption by sector (data sourced from UBOS 2010–2019; and MEMD, 2015–2020).

This makes it more than urgent for the country to increase access to modern energy in rural and urban so as to reduce deforestation, stimulate the growth of economies, and promote green and resilient development.

The government's target is to increase electricity connections to 60% by 2025 and 80% access to modern energy by 2040 [2]. An estimated US$1.6bn capital investment will required to meet the present plan of 60% electrification [16]. With the Uganda Vision 2040 foreseeing a country developing at a high to achieving an upper MIC status by 2040, Uganda will need much more modern energy with the energy demand is likely to outstrip the supply by 2030. By 2040, energy demand (including energy to propel industrial and commercial sectors) could reach 41,738 MW and capita electricity consumption could increase from the current 100 KWh to 3,668 kWh, indicating that therefore there is still a lot to be done in the energy sector.

4. Climate vulnerabilities of energy systems and adaptation

Uganda's climate is changing: temperatures are rising, rainfall is becoming more variable, and extreme weather events are increasing in frequency and severity. Between 1900 and 2010 temperatures in Uganda increased by 0.8°C - 1.5°C and are projected to increase by between 2-5^{O} by 2100 and rainfall received in 2000–2010 was on average about 8% lower than rainfall received between 1920 and 1969rainfall was observed to be variable [24, 25]. Melting of the ice caps on Mt. Rwenzori, increased occurrence of droughts, rainstorms and flooding and landslides have been observed in the last three decades.

Drought and rising temperatures affect biomass availability, causing gradual drying up of biomass which will increasing hardship for the majority of Ugandan's who are dependent on wood fuel for their domestic energy needs. During extreme wet seasons, access to firewood is limited because of the reduction in the amount of available dry firewood, and the dangers associated with fetching firewood in such conditions. The scarcity and increasing prices of firewood greatly affects poor rural households that largely depend on biomass energy as they move long distances to collect firewood, a process that disproportionately affects women and girls exposing them to gender based sexual violence (GBSV), including sexual assault, rape and defilement. The projected change in climate means that droughts will occur which will increase scarcity of biomass. Even without climate change, the unmet demand for biomass energy will become extreme by 2050, estimated

at 1,710 million tonnes over the period 2010–2050, and climate change will add a plausible loss of 5 to 10% of domestic wood between 2020 and 2050, which could increase the costs of inaction from US$123.6 bn to between US$130 bn and 136 bn [6]. Therefore, the current growth in demand for biomass is not sustainable and a sustainable solution is needed to address the predicted deficit [5]. Besides, the reliance on biomass energy is a major driver to widespread deforestation and land degradation across the country. Uganda's forest cover reduced from 24% percent in the 1990s to a mere to 12.4% currently, a two percent annual loss of forest cover, which is among the world's highest forest cover losses, driven by among others by increased demand for fire wood and charcoal, but also by expansion of farming and urban centres into forest land. But deforestation and forest degradation also results catchment degradation that indirectly affects hydro-electricity generation. i.e. it is a driver to soil erosion, run-off and flooding in the catchments which lead to siltation and sedimentation of lakes and rivers that in turn reduces water availability for hydro-power generation.

The impacts of climate change also significantly affect electricity supply. The Stern Report posits that that a 3-6°C increase in temperature in the next few years could result in a 30–50% water reduction [26] and this could disrupt hydro energy supply, alter energy demand patterns but also damage energy infrastructure [27]. With Uganda's temperature projected to increase by 2-5OC by 2100, the effect on energy will be significant, and indeed the functioning of electricity supply systems is already being adversely affected by the rising temperatures, increased rainfall variability, drought and flooding [28]. Hydro electricity generation, on which Uganda highly depends, is the most affected as droughts and higher temperatures often reduce water in lakes and rivers causing a reduction in electricity generation. For example, persistent droughts have in the past reduced water levels in Lake Victoria affecting hydropower generation at the Nalubale electric power generation dam in Jinja [29]. Electricity generation at hydro-power plant on Mpanga river in Western Uganda significantly declines during prolonged dry seasons or droughts [6]. A study conducted by MWE with support from the Climate and Development Knowledge Network (CDKN) predicts a reduction in rainfall that could reduce Uganda hydropower potential by about 26% by 2050 [5].

In **Figure 4**, the possible the impact of climate change on electricity generation is illustrated further. The loss in hydro electricity production is due to reduced runoff, a scenario where a drop in available capacity is between 0% in 2025 and 26% in 2050 [5]. The loss would be met by increasing generation through nuclear and renewables (geothermal and solar) where nuclear accounts for 95% of the difference of the reduced yield (35.4 TWh). However, global opposition to nuclear power generation is very high due to its environmental and political sensitivity, and besides nuclear power plants are very expensive to put up.

Besides, that is only part of the story as significant increase in rainfall amounts and intensity, and flooding as predicted could also seasonally increase water levels in lakes and rivers and also become barriers to energy generation. Between 2019 and 2020, the Lake Victoria basin received increased rainfall and run-off which increased the water level of Lake Vitoria to unprecedented levels, by 13.42 metres at Entebbe, which exceeded the 13.41 metres level recorded in 1964 [30][2]. This rise in water level created some challenges to electricity generation, with moving islands/floating vegetation blocking water flow to the hydro power stations on the Nile in Jinja. According to Eskom, Uganda's major power generation company, on April 14, 2020 a floating island docked at the Nalubale power dam blocking water for power

[2] https://storymaps.arcgis.com/stories/bd820937c06845faa86f7f8944d56f47

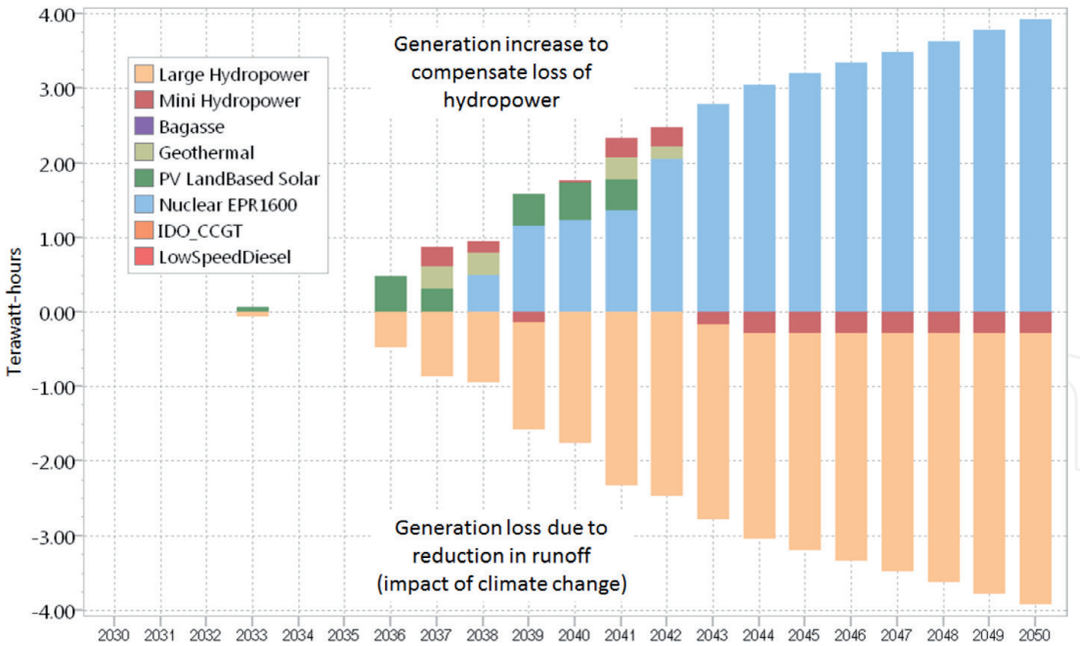

Figure 4.
Impact of climate change on electricity generation in TWh/yr. under the scenario of reduced runoff assuming high electricity demand with low supply capacity (DHSLWBC) vs. no impact of climate change (source [5]).

generation causing a nationwide power blackout.[3] However, Uganda's National Environment Management Authority (NEMA) also attributes the floating islands on the lake to environmental degradation in the lake basin. The old Maziba hydro-electric power station, in south western Uganda, was closed due persistent siltation that affected electricity generation and all these point to need to "climate-proof" the country's energy infrastructure.

Another major source of energy vulnerability is that the impacts of climate change disrupt the energy supply chain. The increased intensity and frequency of extreme weather events such as heavy rainfall storms and floods affect energy infrastructure - power plants, transmission lines and power lines - that disrupt energy supply resulting in power cuts and higher energy prices [31, 32]. Moreover, the heavy rains and flooding make road and rail transportation inaccessible. The disruption of rail and road transport indirectly affects energy supply, as fuel is typically imported into the country by train from the coast and distributed by trucks [23].

Adaptation to climate change for energy sector should that focus significantly reducing dependence on traditional biomass. A biomass supply deficit is already being experienced, with prices of charcoal rising each passing day, and indeed supply will not meet demand in the future even without climate change. It is also important to ensure the efficiency gains in biomass use (e.g. efficient cook stoves) are increased, and diversifying energy sources and promoting renewable energy that transition into more households switch to LPG, biogas, and electricity. It is critical to increase electricity connectivity, affordability, and reliability and de-risking the use of LPGs through tax incentives and supply in rural areas. The adaptation cost for replacing lost biomass is estimated at between $5 and $11 bn over the period 2020–2050 at a 10 percent discount rate [5].

The best use of hydropower needs careful management of the water resources and thus catchment management is also important. Afforestation and reforestation measures to protect watersheds that supply major hydroelectricity generating sources should be a key part of such protection, and Uganda is promoting

[3] Eskom Uganda Limited. Press Release. April 16, 2020.

catchment-based water resource management, and the country is divided into 17 catchments, for which catchment management plans are prepared to address the issues affecting water and other related resources (forests, biodiversity, wetlands, soils etc.) that could among others ensure sustained water availability for electricity generation.

Above all, coping with extreme events requires strengthening the structures of small dams to withstand increase in rainfall intensity or reduced water levels.

But still, Uganda government's preference for large hydro-power projects in areas of rich ecosystems and biodiversity, and eco-tourism sites is an environmental controversy, given the dependence on hydropower on natural systems (climate and water availability). The ongoing construction of Karuma hydro-electricity dam/station and the proposal to construction another hydro-electricity dam on Murchison Falls (and adjacent Uhuru Falls), all projects in Murchison Falls National Park, a protected area with rich biodiversity and eco-tourism potential is are cases in point. These energy projects remain controversial given that Uganda is not lacking alternative renewable energy resources – solar and geothermal potential is very high and there are many other alternative sites for hydro-electricity development. The larger questions are the levels of Uganda government's assessment of the 'economic benefits' versus 'environmental costs' of its energy development model. Besides, the dams on the Nile remain insecure to current and future climate risk i.e. fluctuating water levels and extreme weather events. But also, the Nile is a transboundary resource and water governance and security concerns are hot topic of debate and a potential source conflict in the Nile basin countries, especially with downstream neighbors (Sudan and Egypt), putting Uganda's dams at future risk of reduced flow.

5. Energy and GHG emissions in Uganda

Globally, energy is the main source of GHG emissions, with 70% of the global emissions emanating from fossil fuels combustion processes to generate electricity, in industry, buildings and transport, [27]. However, as an LDC, Uganda's energy consumption (especially fossil fuel consumption) is very low and electricity generation in Uganda is dominated by hydro-power which is a renewable energy source and thus the country'contribution to global GHG emissions and climate change is negligible. For example, Uganda accounts for only 0.01% of total world emissions its per capita CO_2 emissions is also low at only 0.13 t (2017)[4]. However, Uganda's GHG emissions have been on the rise, having slowly increased from 53 442 Gg CO2e in 2005 to 90 230 Gg CO2e in 2015 (see **Figure 5**).

The energy sector ranks third as a major source of GHG emissions in Uganda accounting for 10.7% of the country's total emissions, with dominant source being the Land Use and Land Use Change and Forestry (LULUCF) sector accounting for 59.5% (53 670 Gg CO2e) of the total emissions.

It needs to be recognized that energy is an indirect driver of the LULUCF emissions because the country's high dependency on biomass energy (charcoal and firewood) is a major driver to deforestation. Indeed, Zutari [37] observes that emissions from fuelwood and charcoal are the largest contributors to the CO2 emissions in Uganda but these emissions are not accounted for under energy emissions but rather the LULUCF sector as wood removal losses. The other major sources of GHG emission are agriculture (26.9%) and waste (2.3%).

Uganda has the basic infrastructure to manage GHG inventory system which includes software, a database to hold data from all the sectors and officers to

[4] https://ourworldindata.org/co2/country/uganda?country=~UGA)

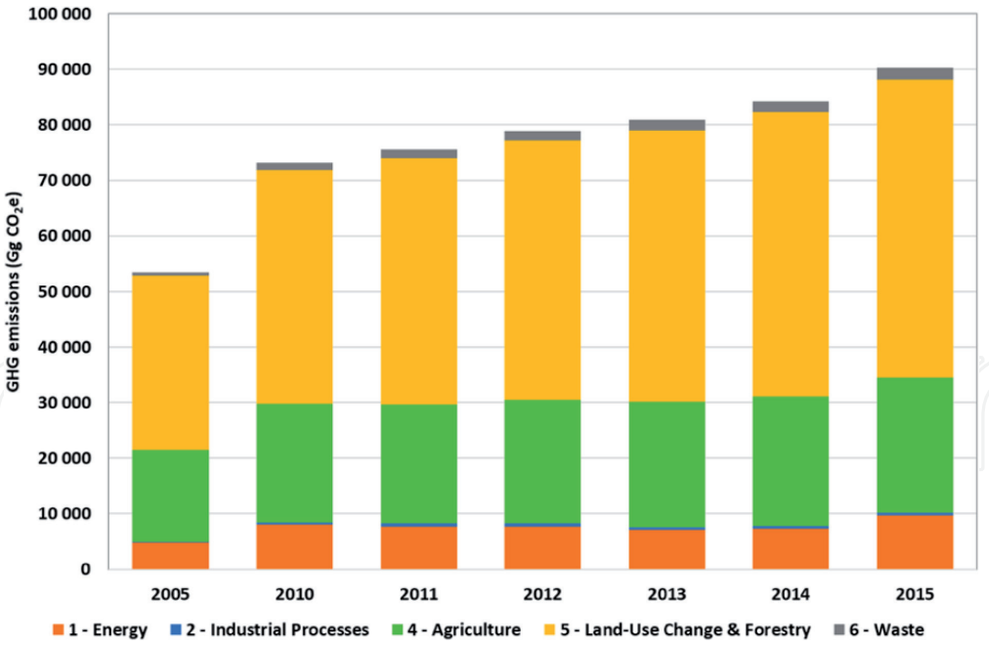

Figure 5.
Sectoral trends in GHG emissions for Uganda (source: [15, 33–36]).

manage the system, and the MEMD is one of the data provider sectors [14, 15]. In addition, Uganda has made efforts to mitigate climate change by deploying decarbonized development pathways as required by the UNFCCC. Uganda's first Nationally Determined Contribution (NDC) reveals that under the business-as-usual (BAU) scenario GHG emissions will increase to 77.3 Million tons of carbon dioxide equivalent per year (MtCO2eq/yr) by 2030 but the NDC commits to 22% emission reduction of national GHG emissions in 2030 compared to business-as-usual, through implementation of mitigation policies and measures, including those in energy. Various Nationally Appropriate Mitigation Actions (NAMAs) actions have been development and are implemented, with those that are energy relevant revolving around improved institutional cook stoves in Ugandan schools, integrated waste management and biogas production, vehicle fuel efficiency and bus rapid Transit (BRT).

6. Oil and gas: challenge for decarbonizing energy systems and the environment

Although Uganda is targeting a low carbon development path in line with its climate change policy and Nationally Determined Contribution to UNFCC, at the same time, there is ongoing development in oil and gas sector. There have been great expectations that oil and gas development will socioeconomically transform Uganda to MIC status through increased investments, revenue generation, infrastructure development and job creation along the value chains. For example, the oil and gas resources once fully developed could fetch up to US$2bn per annum for 20 to 30 years, and to contribute between 20% and 30% to the country's Gross Domestic Product [19]. However, the sub-sector has enormous challenges it poses to the environment, biodiversity and ecosystems and particularly for upstream and mid-stream activities, but besides oil development and use is a challenge for decarbonization efforts the country and achievement of carbon neutrality because it will greatly increase the country's GHG emissions. In this section, we provide an overview of Uganda's oil and gas sector and

its likely impact on environment and naturals resources and Uganda's efforts to contribute to the achievement of the Paris Agreement on climate change.

6.1 Overview of the oil and gas sector in Uganda

Uganda has abundant oil resources, estimated at approx. 6.5 billion barrels of oil reserves of which 1.4 billion are said to be economically recoverable and the country's oil production potential is estimated at 200,000 barrels per day once the resources are fully developed [19]. The country's gas resources are estimated to be 700 billion cubic feet (bcf), with associated and non-gas gas estimated at 173 bcf and 500 bcf respectively.

Oil resources were first discovered in the 1890s MacKeinze *et al.* [38], but it was not until the 1920s that the country's oil and gas potential was evaluated [39]. Attempts on oil and gas exploration were first undertaken between 1936 and 1956; where the first deep well (Waki B1) was drilled in 1938 at Butiaba in Buliisa district, after which about 20 wells were also drilled in Kibiro and Kibuku, and several geological surveys were also undertaken the 1940s to 50s. These exploration efforts were halted due to the political conflicts and turmoil that ensued in the 1970s till the 1990s.

The economic viability of Uganda's oil and gas reserves was not ascertained till around 2006 [40, 41] and since then significant achievements have been made in the exploration and moving towards full development of the oil and gas resources in which various international companies have been licensed for oil exploration and development including Total E&P Uganda B.V, China National Offshore Oil Corporation Uganda Limited (CNOOC Uganda Ltd) and Tullow Uganda Operations Pty Limited together with Armor Energy Limited and Oranto Petroleum Limited [19]. By 2016, 21 oil and gas sites had been drilled, which is an 88% success rate of viable oil and gas resources. These oil and gas estimates are expected to increase as additional discoveries are made since only 40% of the total area with the potential for oil and gas reserves has been explored by 2021 [19].

Recognizing the socio-economic importance of the oil and gas sector, the GoU developed the National Oil and Gas Policy (2016) to operationalize and regulate the sub-sector. A number of laws have also been enacted including the Petroleum Exploration, Development and Production (PEDP) Act 2013 and the Petroleum (Refining, Conversion, Transmission and Midstream Storage) Act 2013 to replace the Petroleum Exploration and Production Act of 1985. The oil and gas policy and regulatory frameworks give MEMD an oversight role to guide and monitor work in the oil and gas sector and activities of the Directorate of Petroleum, Uganda Petroleum Authority [42], and the Uganda National Oil Corporation (UNOC) [43]. The Directorate of Petroleum is responsible for policymaking, licensing, and coordinating all developments in the sector. The Uganda Petroleum Authority [42] regulates and monitors actors by enforcing compliance of the operations of oil companies. The Uganda National Oil Corporation is mandated to handle business interests across the oil and gas value chain.

6.2 Effect of oil and gas exploration and development on vegetation and wildlife

Most of Uganda's oil and gas resources (and thus their exploration and development), are in the Albertine Graben region in the western part of the country, situated within the western arm of the East African Rift Valley at the border between Uganda and the Democratic Republic of Congo (DRC). The graben stretches for about 500 km with an average width of 45 km covering a total area of approx. 23,000 sq. km [41].

Unfortunately, the Albertine Graben region is not only one of Uganda's richest biodiversity hotspots [41, 44] but the eco-region is the most important forest system in Africa for biodiversity [24]. The eco-region ranks first out of the 119 distinct terrestrial eco-regions of continental Africa in terms of endemic species of birds, mammals, reptiles and amphibians, and second in terms of globally threatened species; there are around 567 endemic plant species" [45, 46]. Indeed, the graben reportedly has seven designated conservation (protect areas) and various eco-tourism attractions among which include the 45 m waterfall along the Victoria Nile River, 556 bird species, 144 different mammals that include endangered and rare species such as Rothschild's giraffe and tree climbing lions, 51 reptile species, 51 (28 and 23 known and unknown respectively) amphibian species.

The biodiversity in the area, and more especially wildlife, are very sensitive to oil and gas exploration and development. As observed by MacKeinze et al. [38], whereas oil exploration and development could take place within conservation areas (according to the Uganda Wildlife Statute 1996: Section 19(5)), the activities pose serious impacts on vegetation cover and wildlife in the Albertine Graben eco-region. Indeed, the Uganda Wildlife Authority (UWA), an agency mandated with management of conservation areas, the National Environment Management Authority, the agency mandated for environment management; and the communities in the region are cognizant of the negative impacts that up-steam and midstream oil and gas development activities have on wildlife [44, 47, 48].

One of the oil and gas exploration activities that affect biodiversity is the seismic surveying, that involves holes in the grounds into which dynamite or special vibrators that pump air or water into the ground. The associated seismic vibrations are reported to have caused migration of large mammals and fish, and impacted the breeding of wildlife [38, 40, 47, 49]. The most affected mammals are the elephants, giraffes, buffaloes and oribi [44] that have moved further (about 0.75–1 km) away from oil exploration (seismic drilling) sites (Wildlife Conservation Society of Uganda (WCS), [50]) showed that many big mammals have moved away to distances of about 750 to 1000 metres from seismic drilling, and seismic waves affect breeding and migratory patterns of fish. The migration of wildlife has impacts on tourism and fishing, which are prime socioeconomic activities for the communities in the Albertine Graben region.

The drilling and/or establishment of drilling pads is also a driver to wildlife migration (WCS, [50]) and is also linked to deforestation and the degradation of pristine vegetation cover and habitats [48, 50]. Habitat degradation is another driver to wildlife migration which has culminated into human-wildlife conflicts. Drilling pads cause habitat fragmentation which is another major factor leading to loss of biodiversity [48]. Besides, oil explorations is associated with increase noise resulting from drilling and road construction to the exploration sites that scares wildlife and forces it to migrate [40, 51–53], Indeed UNRA [53] recognizes the environmental impact of noise emanating from the construction of oil roads that negatively disrupted mammals and birds in the area.

The exploration and development processes require many workers that need to be accommodated which gives rise to settlements and other service provisioning. Therefore, oil companies have construction of workstations and more will come in future. These works stations have been constructed in remote and high vegetative areas which has caused deforestation and degradation, and Nnakayima [52] observes a decrease in tropical high and low forest, woodlands and grasslands in the areas caused up-stream oil and gas activities.

Oil spills from oil collection pits have been reported and more are expected as the oil development progresses [50]. These spills cause soil and water pollution there by affecting biodiversity and the livelihoods of many people in the region [40, 52].

Gas flaring is another activity that is linked to air pollution [54], with gases associated with gas flaring comprising carbon dioxide, methane, sulfur dioxide, nitrogen dioxides, dioxin (CJP/ERA 2005), some of which are GHG that cause global warming and climate change. Besides the increased dissolution of these gases could form acid rainfall, which could scotch vegetation. During gas flaring, hazardous compounds that ensue from unburned fuel components such as benzene, toluene, xylene, and hydrogen sulphide, and the seepage of these compounds into the environment results in soil pollution, destruction of vegetation and water contamination which could causing death of wildlife that drink the water.

6.3 Construction and infrastructure (pipeline, roads and airport)

In April 2021, Uganda and Tanzania signed an agreement to jointly construct a 1,440 km crude oil pipeline to connect Uganda's oil fields in the Albertine region to Tanzania's seaport of Tanga on the Indian ocean [42]. The US$ 3.55 bn East Africa Crude Oil Pipeline (EACOP) is needed to transport crude-oil from the Albertine for export. Once completed, the pipeline will be able to transport 216,000 barrels of oil per day, and will be the world's longest electrically heated crude oil pipeline. The construction of the pipeline will necessitate acquisition of large expanses of land for construction camps (172 acres); pipeline Right of Way (RoW) and orphan land (2,745 acres); and feeder roads covering 182 acres. The pipeline runs through forests, dense vegetation covers, and protected areas and will therefore cause deforestation and land degradation. Indeed, the EACOP environmental and social impact assessment (ESIA) shows that the pipeline construction would result in deforestation and forest degradation resulting in habitat fragmentation and wildlife disturbance and migration, and have significant impacts on wetlands that are vital sources of water for wildlife. For example, the proposed pipeline's right of way cuts through Bugungu Wildlife Reserve which is an important bird and key biodiversity area) in the Albertine Graben, [51, 55]. The deforestation and degradation of the vegetation cover which will result in loss of carbon sequestration potential, and thus will thus increase GHG emissions.

Although the new "oil roads" constructed in the Albertine region have improved access, jobs and incomes of communities [56], there have also been noticeable negative impacts. Road developments have increased access to pristine and remote high biodiversity hotspots, and caused land fragmentation that causes habitat fragmentation [57] and wildlife disturbance [40, 48]. Similarly, the increased accessibility has exacerbated illegal activities such as felling of trees, poaching and wildlife trafficking in the Albertine eco-region [52]. For example, the construction of the Kaiso-Tonya road has increased poachers' access to Kabwoya Wildlife Reserve as well as disturbance of wildlife, death of wildlife (knocked) along the road, as well as noise and air pollution [52].

7. Policy: challenges and gaps

Uganda is a signatory to the Paris Agreement on Climate Change that requires parties to develop climate change policies, strategies and plans that promote adaptation and mitigation. The Uganda Vision 2040 and the NDP III call for appropriate adaptation and mitigation strategies to ensure that Uganda is sufficiently cushioned from any adverse impact of climate change, while at the same time promoting low carbon intensive pathways. In 2015, Uganda unveiled both the National Climate Change Policy (NCCP) and Nationally Determined Contribution (NDC) that reference both adaptation and mitigation, but state that adaptation is the primary

priority and mitigation is a secondary priority [15]. Both the NCCP and NDC prioritize climate sensitive energy services. The NCCP prioritizes sustainable energy access and utilization for increased climate change resilience, increased investment in renewable energy and clean energy technologies to reduce GHG. Similarly, the NDC priorities efficient biomass energy production and use, increased electricity access and energy efficiency, expansion of off grid solar systems and overall climate proofing of the energy sector.

Besides both the NCCP and NDC prioritize mainstreaming climate change in national, sectoral and local development plans, plans and budgets. In 2018, Uganda became the first country in Africa to sign the Partnership Plan for NDCs to achieve national climate goals as part of its obligations to the Paris Agreement. Under the NDCs, the country committed itself to reduce national emissions and adapt to the impacts of climate change. Currently Uganda is developing its Long-term Strategy for climate change and updating its NDC.

The Paris Agreement (Articles 2 and 4) also asks Parties to formulate and communicate a Long-term Low Emission Development Strategies (LT-LEDS) to strengthening global response to the threat of climate change i.e. "holding the increase in the global average temperature to well below.

2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" [58]. Uganda is on track to develop its Long-Term Strategy for Climate change, ahead of COP 26 in in UK in December 2021. Only 29 parties have so far submitted their LTS for climate change, only two of which are from African i.e. Benin and South Africa[5], implying that Uganda will be one of the first leading countries worldwide to develop an LTS. The focus of the LTS is to identify one or more low-emission pathways in line with the country's development objectives and strives to identify emission pathways compatible with the temperature goal set by the Paris Agreement. Uganda's LTS will cover both mitigation and adaptation aspects, and will include all of the main outcomes from the major plans, policies and strategies that have been previously developed, including among others, the Vision 2020, NDPs, NCCP, Second National Communication to UNFCC, NDC of 2015, Uganda Green Growth Development Strategy, First Biennial Update Report (BUR) submitted in 2019, and the NDC submitted to UNFCCC 2015 and is currently being updated in the run-up to COP 26. A National Climate Change Act was passed by the Uganda parliament on 27th April 2021[6] and is now awaiting presidential assent before it becomes law. The new law provides for national participation in climate change, institutional arrangements for coordinating and implementing climate change response ansd for financing for climate change action, including for climate smart energy systems.

The main energy policies for Uganda are the National Energy Policy 2002 and **the National Renewable Energy Policy.** The aim of energy policy is to meet the energy needs of the Ugandan population for social and economic development in an environmentally sustainable way. The policy is b being revised and revised policy is place [19], aimed at "meet the energy needs of the Ugandan population by providing adequate and reliable energy supply for socio-economic growth and sustainable development". The renewable energy policy aims at increasing the use of modern renewable energy, from 4–61% by 2017. The energy policy framework addresses issues of with renewable energy technologies and energy efficiency devices which can translate into low GHG emissions and promoting low carbon development and provides the necessary framework for private sector investors in renewable energy projects to benefit from the available facilities in emissions trading. One of policy's

[5] https://www.climatewatchdata.org/lts-explore

[6] https://www.parliament.go.ug/news/5093/climate-change-bill-passed

strategies is to integrate biomass energy production and efficient utilization and its impacts on climate and health into the formal education system. The policy also recognizes the need for promoting the conversion of municipal and industrial waste to energy to reduce methane emissions.

The Ministry of Energy and Mineral Development (MEMD) is the main energy actor in Uganda, responsible for energy policy development and guidance. The Ministry has two departments that support climate friendly energy policy and practice i.e. the Renewable Energy Department and an Energy Conservation Department. However, the policy provides for the establishment of a National Energy Committee at the National level and District Energy Committee and District Energy Offices at the local Governments, to date, they are not yet in place. Small-scale renewable energy sources which would have been ideal the rural areas have remained marginal compared to large scale commercial energy and yet 85% of Uganda's population is rural. Taxes on energy saving products, efficient technologies and solar products for lighting, cooking and heating, water pumping (which are also climate change compliant) are still high. If these products continue to be highly priced due to high taxes, their future potential is at risk, given the low-income levels of the majority of Uganda's population. Consequently, renewable energy technologies have remained financially out of the reach of many Ugandans. Moreover, the high electricity tariffs make it unaffordable for cooking purposes and the alternatives remain charcoal and firewood. Besides, energy blackouts and outages remain frequent and many institutions, commercial enterprises and households' resort to use of thermal generators for energy as compared to use renewable energy like solar or biogas.

Following the discovery of commercial oil deposits, the Government of Uganda came up with the National Oil and Gas Policy for Uganda in February 2008 whose main policy goal is to use the country's oil and gas resources to contribute to early achievement of poverty eradication and create lasting value to society. Given that consumption of fossil fuels is the greatest contributor to GHG emission, the policy and utilization could prove a serious challenge to climate change and overall environmental management. Already, the country plans to use the oil reserves for thermal electricity generation to fill the electricity deficit, which will definitely increase GHG emissions. Although one of the policy priorities of the oil and gas policy is to ensure that oil and gas activities are undertaken in a manner that conserves the environment and biodiversity, the policy remains climate change not incorporating climate change issues.

8. Conclusion

Energy poverty remains high in Uganda amidst the high energy potential, but the current main sources energy (biomass and hydro-electricity) are extremely vulnerable to the impacts of climate change. With no viable and affordable alternative sources of energy is sight, dependence on biomass energy remains inevitable in the foreseeable future. This makes managing climate risks to energy systems an urgent necessity to ensure supply systems reliability and resilience, if Uganda is to achieve its development targets.

The main barriers to attaining climate smart and sustainable energy systems in Uganda financial constraints and weak technical ability, most which has to be obtained from external sources. But while the climate change vulnerability of the energy sector and need for increased resilience are highly recognized, international focus has been put on mitigating GHG emissions and greening energy, and much less on building climate resilience. This creates a conflict in policy for

Uganda because Uganda's primary climate change policy priority is adaptation, and mitigation is secondary. Still, the much-anticipated oil and gas development, compounded by rapid population and urbanization will inevitably increase Uganda GHG emissions, and thus what is needed is green energy innovations and solutions that can take the country towards carbon neutrality while deliver co-benefits for adaptation, health, economic growth and environmental sustainability. It will be essential for Uganda develops its oil and gas resources, but it also important that it is done in a way that protects ecosystems and biodiversity. It will be transformational if Uganda would invest a significant portion of its oil and gas revenues in green and renewable energy to enhance equitable and affordable energy services. With its huge renewables, future hydropower development should not cause ecosystem and biodiversity loss.

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