UGANDA 100%
RENEWABLE ENERGY
SCENARIO AND PLAN BY 2050

With support from CISU CIVIL SOCIETY IN DEVELOPMENT

January, 2023

Acknowledgments

Uganda Coalition for Sustainable Development (UCSD) would like to thank its fellow partners to the Project: The East African Civil Society for Sustainable Energy & Climate Action - EASE &CA PROJECT namely: International Network for Sustainable Energy (INFORSE), JEEP, Nordic Folkecenter for Renewable Energy (NFRE), TaTEDO and Sustainable Environmental Development Watch (Suswatch) Kenya for the valuable comments and inputs to the draft report.

We are equally indebted to all the Ministry of Energy and Mineral Development, EASE CA Project participating Civil Society Organizations and individuals for actively participating in providing us with the relevant information that informed this study report.

Finally, we thank the Danish Ministry of Foreign Affairs through CISU's Civil Society Fund that provided support that has enabled this national baseline study to be done as part of the EASE & CA project.

January, 2023, ISBN 978-87-970130-7-6

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EASE-CA Project Partners are: UCSD, JEEP, SusWatch Kenya, TaTEDO, INFORSE & INFORSE-East Africa, and Nordic Folkecenter for Renewable Energy.

The EASE-CA Project is supported by Civil Society in Development - CISU, Denmark.

More on the EASE-CA Project: www.inforse.org/africa/EASE.htm

More on the 100 % Renewable Energy Scenarios in Africa: inforse.org/africa/Vision2050.htm

Acronyms

CDA	Centre for Development Alternatives
EE	Energy Efficiency
GDP	Gross Domestic Product
GHG	Green House Gas
GHGs	Greenhouse Gases
IEA	The International Energy Agency
IRENA	The International Renewable Energy Agency
JICA	Japan International Cooperation Agency
LPG	Liquefied Petroleum Gas
MEMD	Ministry of Energy and Mineral Development
MW	Megawatts
PV	Photovoltaic
RE	Renewable Energy
REA	Rural Electrification Agency
RESP	Rural Electrification Strategy Plan
RETs	Renewable Energy Technologies
SID	The Society for International Development
SDGs	Sustainable Development Goals
SEforALL	Sustainable Energy for All
SHP	Small hydropower
UNSD	The United Nations Statistics Division
WB	World Bank
WHO	World Health Organization
WWF	World Wildlife Fund

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Executive Summary

This Report provides a general overview of the Ugandan situation regarding energy supply and demand, and presents a scenario for how Uganda can move into a 100% renewable energy economy by 2050 and also move from a lower income country into an upper middle income country while sustainably harnessing its biomass resources along with other renewable energy sources.

The Report explains specific proposals that could lead to 100% renewable energy development based on on-going and future policy processes.

Following presentation of the scenario and for comparison to a business as usual scenario, the Report includes suggestions on Uganda's potential to raise its NDC ambition based on its energy sector; as well as the Long-Term Emission Reduction Strategies (LTS)

The Uganda renewable energy scenario presents a viable model in which modern energy services, based on currently available technology, are accessible to all. It explores how Uganda can stimulate a growing economy based on renewable energy instead of venturing down a business-as-usual path with increased dependency on fossil fuels.

The Report recognizes that for Uganda, achieving universal energy access is as important as achieving a 100% renewable energy production target. It also recognizes that to be sustainable, the renewable energy solutions presented must address poverty and other social needs as outlined in Agenda 2030 / Sustainable Development Goals.

The Report gives an overview of costs of different energy supplies that meet the increases in energy demand expected with the growth of the Ugandan economy till 2040.

1.0 Introduction

A growing economy based on Renewable Energy (RE) instead of a business-as-usual path characterised with increasing dependency on fossil fuels is possible for Uganda. The country is endowed with abundant Renewable Energy Sources that include biomass, water, geothermal energy, sun and wind. What is required is to fully utilise this potential to make RE a driver and shaper of the country's economic transformation. Fortunately, the transformation towards a 100% Renewable Energy system is already under way internationally. The last decade has seen the cost of renewable energy decline continuously, making it cost-competitive compared to conventional energy in many parts of the world. Since 2009, the module prices for solar photovoltaic (PV) have fallen by around 80%, while wind turbine prices have declined by 30-40%, making the business case for renewable energy stronger than ever before (IRENA, 2017).

Uganda's Policy direction is poised for a Renewable Energy Future. The Sustainable Energy for All (SE4All) goals for Uganda 2030 are: more than 98% of population with electricity access, more than 99% of population with access to modern cooking solutions, a yearly improvement in energy intensity by 3.5% and renewable share in final energy consumption for power to at least 90%. (Fische 2014). Similarly, ambitions set in "Uganda Vision 2040" (NPA 2007) include increase in access to electricity services, improve natural resource management (e.g. forests, biodiversity, water resources), development of road and transport infra-structure. One of the NDP III's 18 programs is the Energy Development Programme: which aims to increase access to and consumption of clean energy.

Increased use of renewable energy, combined with intensified electrification, could not only prove decisive for the world to meet Agenda 2030 (Sustainable Development Goal 7) and key climate goals by 2050, but also lead to economic transformations of economies like Uganda. All economic activity requires energy, high productivity sectors require more, more reliable and modern forms of energy (CDA, 2019). Ramping up electricity to over half of the global energy mix (up from one-fifth currently) in combination with renewables would reduce the use of fossil fuels, responsible for most greenhouse-gas emissions (IRENA, 2019).

This report provides a general overview of the Ugandan situation regarding energy supply and demand, and presents a first scenario for how the country can move into a 100% renewable energy economy by 2050 and also move from a lower income country into an upper middle income country while sustainably harnessing its renewable energy resources.

Renewables provide a wide range of socio-economic and environmental benefits, in addition to offering an affordable source of energy. The transformation to a 100% renewable energy system in all end-uses would generate millions of new jobs, bring significant welfare gains in the form of health benefits from cleaner air and water, as well as increase energy independence and economic growth as shown in various studies (IRENA, 2018).

East African countries face some of the world's most significant development hurdles —including poverty, high maternal and child death rates, and low rates of literacy and education.

Lack of a grid connection or unreliable power supplies are underlying contributors to these challenges (WRI, 2019). Even those that are able to have access to electricity experience sporadic service provision which is also costly.

Hence, there is a need to exploit all the available energy sources to increase energy access for all Ugandans, since the country has one of the lowest electrification rates in Africa, with a current access rate of 28% (Draft Energy policy, 2019). In addition, there is low access to modern energy sources and services, e.g. solar home systems, LPG, biogas and improved cook stoves, for lighting, heating and clean cooking.

Uganda Government approved the Electricity Connections Policy 2018-2027 with the aim of scaling up clean energy access throughout the country, with a goal to achieve 60% access to electricity in Uganda. Specifically, the Policy seeks to increase annual connections from 70,000 to 300,000 and increase electricity demand on the main grid by 500MW by 2027. There is also a need to exploit the high potential of energy that the country has, for instance, analysis from the World Resources Institute's Energy Access Explorer reveals that 60% of the area where Uganda's schools and hospitals are located has good potential for small-scale hydropower.

On the other hand, the reliance on biomass in the EAC energy sector has a negative impact on both the environment and people's health. The unsustainable harvesting of woody biomass contributes to forest depletion and to the disruption of ecosystems and hydrological catchment areas. In 2012, indoor air pollution caused by the burning of biomass affected the health of an estimated 138 million people in the region, resulting in 60,000 premature deaths. In general, policy makers in East Africa have not placed priority on reducing dependence on biomass in the heating and cooking sector. As a result, woody biomass will remain the central energy source in the sector for the foreseeable future, as the transition to other fuels will take decades to materialise (IRENA, 2016)

As of 2019, biomass contributed 88% of the total primary energy consumed through firewood, charcoal and crop residues; electricity contributes approximately 2%; while fossil fuels (oil products) account for 10% of the national energy mix (Draft Energy Policy, 2019). There is limited productive use of electricity especially in rural areas which negatively affects demand growth, affordability and uptake.

Low demand growth compared to planned generation capacity is likely to exert pressure on consumer tariffs. Affordability is also impacted by other factors including pricing that is in turn affected by foreign exchange rate fluctuations, inflation and the performance of energy service providers. Additionally, there is low access to modern energy sources and services, e.g. solar home systems, LPG, biogas and improved cook stoves, for lighting, heating and clean cooking.

In this report, three tasks have been completed. First, a basic analysis of the current total energy demand and supply patterns for Uganda is completed. Secondly a renewable energy scenario; universal access to modern energy services by 2030 (Sustainable Energy For ALL). Thirdly, a course of action is proposed which outlines how Uganda can contribute to the Paris Agreement's long-term temperature goal of reducing global greenhouse gas emissions by 2050 through its Nationally Determined Contributions (NDC).

The goal for 2050 is to greatly develop supplies of energy in Uganda based on renewable sources that are resilient and that have low impacts on environment and climate.

However despite the progress and the plans ahead, key challenges remain to be addressed: How is the government committed to attainment of a renewable energy future? For instance the Electricity Connections Policy 2018-2027 is currently suspended; the purchasing power of many households remains very low – according to the Centre for Development Alternatives domestic customers of electricity increased by 17% from 2015 to 2016 while electricity sales grew by only 5% during the same time. There are also technological challenges and implementation challenges as discussed in detail under section 6.0.

This report is expected to be a crucial planning tool for Uganda to pursue in a low carbon energy development pathway. In the medium term perspective (up to 2030) it outlines energy demand and supply issues linked to the realisation of Sustainable Energy for All (SE4All) ambitions and Agenda 2030 (Sustainable Development Goals especially SDG7). It will therefore be useful as a contribution to, among others, Uganda's Energy Policy review, the NDC enhancement and development of the Country's Long-Term Emission Reduction Strategies (LTS) that are underway.

1.1 Objective of the Study

The overall objective of this study was to assess the current national renewable energy situation, and energy efficiency potentials, the future demands with a continued economic growth in Uganda, and to combine the information to formulate a 100% renewable energy scenario and plan until 2050, that can inform the ongoing national renewable energy-related policy processes.

1.2 Methodology of the study

The report includes a literature review, information from key informant interviews and present results of Energy Modelling. Literature review involved study of available written national information such as reports, policy, strategies, plans, statistics, and others. Virtual and physical Consultations were conducted with government ministries, agencies, academia, private sectors and CSOs (including INFORSE Uganda Members). The energy modelling included the use of INFORSE's spread sheet model for development of energy balances 2000 – 2050 and the Energy Plan model with analysis of variations hour by hour of energy flows and of costs for the years 2030 and 2040.

Both with the INFORSE model and the Energy Plan model are developed scenarios for a transition to 100% renewable energy in 2050 and a business as usual (BAU) scenario, where fossil fuel in the form of oil continues to fuel the transport sector and increasingly the industry sector. Another larger difference between the 100% renewable energy scenario and the BAU scenario is that in the 100% renewable energy scenario, 25% of cooking is made with highly efficient electric pressure cookers in 2050, which is not the case in the BAU scenario.

2.0 Energy Status in Uganda

Uganda has one of the lowest electrification rates in Africa with an access rate of 28% (Draft Energy policy, 2019). In addition, there is low access to modern energy sources and services, for example solar home systems, LPG, biogas and improved cook stoves, for lighting, heating and clean cooking.

Despite this, Uganda is endowed with abundant renewable energy potential from sources such as water, wind, biomass and the sun. A study commissioned by WWF Uganda Country office has shown that it is possible to meet 100% of Uganda's energy needs from Renewable energy sources by 2050. Uganda is a landlocked nation that has substantial RE resources that are distributed evenly across the country (MEMD 2015). These include wind (that is mainly in north eastern parts of the country), hydroelectric, solar, peat, geothermal, biomass-based cogeneration, biomass, and biogas. However, hydropower remains the nation's dominant source for electric energy production with a potential of over 4100 MW (Norton Rose Fulbright (NRFC), 2015). On the other hand, geothermal possess a potential of 1500MW , biomass cogeneration a potential 1650MW, biomass has an potential annual sustainable yield of around 50 million tons (combining existing wood from existing forests and trees, agricultural residues and proposed new community plantations) , solar energy an average of 5.1 KWh/m2, (Norton Rose Fulbright (NRFC)., 2015). Concerning the total primary energy consumption, biomass is presently the most essential energy source for most of the Ugandan populace, accounting for 90% of energy consumed (firewood: 78.6%, charcoal: 5.6%, crop residues: 4.7%) (Norton Rose Fulbright (NRFC), 2015)

Renewable Energy (RE) resources are some of the most promising and important assets that can have a multiplier effect on the development of any nation (Sadorsky P.; 2009). Therefore, Uganda is among the countries which are implementing the Sustainable Energy for All (SE4All), a global initiative to ensure universal access to modern energy services, doubling the rate of improvement of energy efficiency, and doubling the share of renewable energy in the global energy.

The Country has set national objectives to be achieved by 2030 in order to increase access, efficiency, and sustainability of energy. Specifically, Uganda aims to: increase electricity access to cover 98 percent of the population from 15 percent; increase access to modern cooking solution to over 99 percent of the population; improve energy efficiency of power users by a minimum of 20 percent and to reduce wood fuel consumption by 40 percent; and increase the renewable share in the total final energy consumption for electric power to over 90 percent and increase renewable energy for thermal purposes to 36% (World Bank.; 2017).

Implementation of the SE4All initiative in Uganda will follow three phases involving transition, consolidation, and acceleration of strategies and actions to achieve energy efficiency, access, and renewable energy goals by 2030.

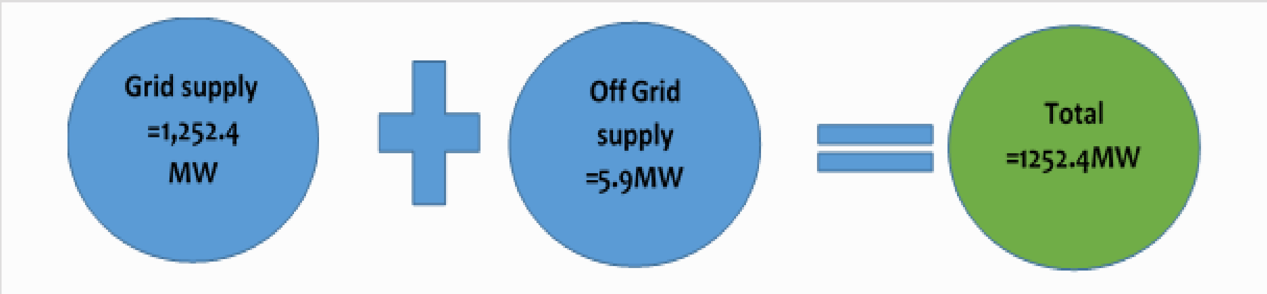
Among the strategies put in place by the Government are: increasing generation capacity and renewable energy for access from four percent in 2007 to 61 percent by 2017; achieve universal rural electrification by 2040; financing renewable energy projects; and doubling the rate of improvement in energy efficiency (World Bank., 2017).

[1]Commissioner Godfrey Bahati quoted in article https://www.thinkgeoenergy.com/three-private-groups-with-geothermal-licenses-in-uganda/

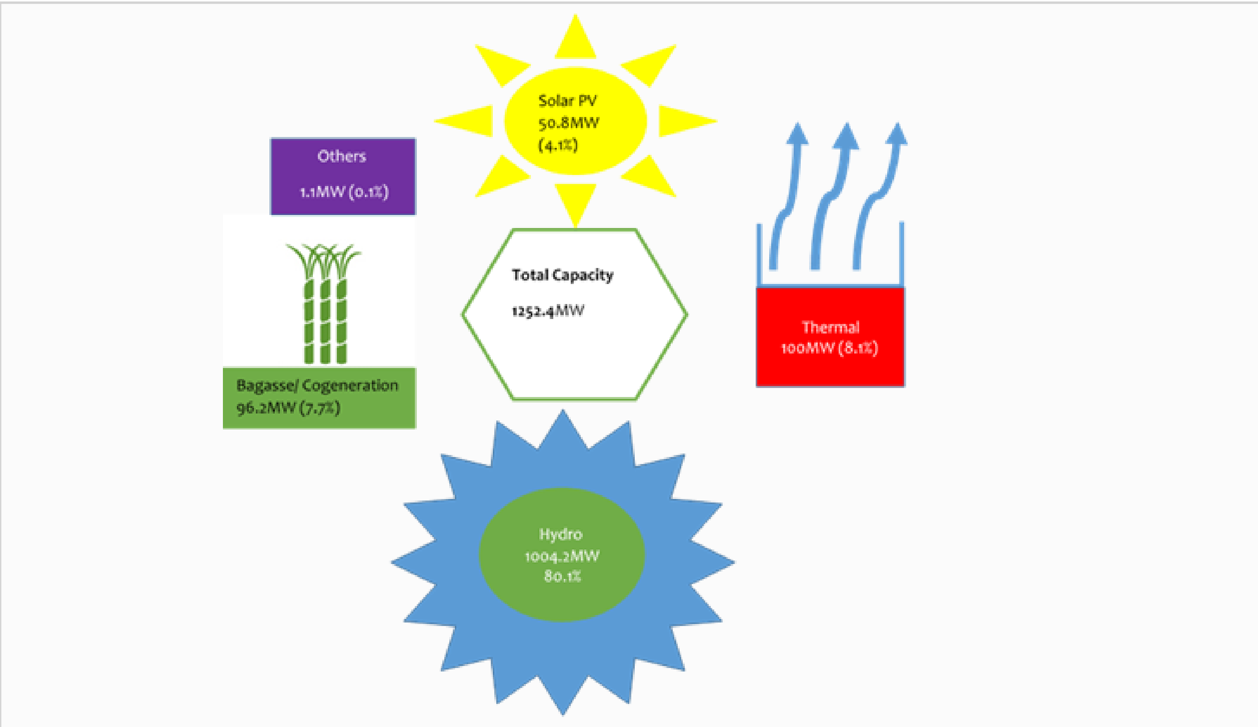
2.1 The current installed capacity of Uganda Electricity

The current (as of Dec 2019) the total installed capacity was 1,252.4MW of which 1,246.5MW supplies the main grid and 5.9MW is off the Main grid having increased from 1,182.2 in May 2019. Off-grid supply accounts for 5.9 MW (ERA, 2019).

Total Installed Capacity



Installed Capacity by Technology



Source: Electricity Regulatory Authority

Poor maintenance during the politically unstable 1980s resulted in a drop in production at the Owen Falls Dam (now Nalubaale Power Station), at the mouth of the White Nile, from 635.5 million kilowatt-hours in 1986 to 609.9 million kilowatt-hours in 1987, with six of ten generators broken by the end of 1988. The 200-megawatt Kiira Hydroelectric Power Station, built adjacent to the Nalubaale Power Station, raised total production capacity to 380 megawatts.

Between 2007 and 2012, the 250-megawatt Station was constructed as a public-private project, at a cost of approximately US$862 million. The consortium that owns the station includes the Aga Khan Fund for Economic Development, Sithe Global Power LLC (a subsidiary of the Blackstone Group), and the government of Uganda. Bujagali Energy Limited is a special-vehicle company created to run the power station on behalf of the shareholders.

In October 2013, construction of the 183-megawatt Isimba Power Station began, approximately 40 kilometres (25 mi) downstream of Bujagali, at a budgeted cost of approximately US$590 million, as a public enterprise with funding from the Export-Import Bank of China. The construction was completed in January 2019, and commercial operations began in March 2019 (ERA 2019).

Also in 2013, work on the 600-megawatt Karuma Power Station commenced at a budgeted cost of about US$2 billion, including US$250 million to build the high-voltage transmission lines to evacuate the generated power. Completion was planned for late 2018. However, a more realistic completion date is in 2023 (ERA 2019).

Uganda has operational mini-hydropower plants connected to the national electricity grid, supplying about 87.1 MW (GET FiT Uganda, 2018). The main objective of the GET FiT Program is to assist East African nations in pursuing a climate resilient low-carbon development path resulting in growth, poverty reduction and climate change mitigation. The GET FiT Uganda Programme made substantial progress in 2018. Four new hydropower projects with a total capacity of 29 MW were commissioned during the year, thus increasing the total installed capacity of the GET FiT portfolio to 87.1 MW (GET FiT Uganda, 2018). More information on Current generation capacity of licensed plants under Operation (As of Dec 2019) is contained under Annex 1.

The NDPIII recognizes that access to affordable, reliable and stable power is critical to the industrialization process and is one of the development strategies. The main aim under this strategy will be to lower the cost of power to 5 U.S. cents per unit, increase generation capacity to at least 3500 MW and increase access to the national grid to a minimum of 60 percent of the population. Emphasis will be on extending electricity supply to business and industrial parks, factories and other production centres. A three-pronged approach of increasing power generation and evacuation, upgrading transmission and distribution networks as well as extending coverage will be utilised.

2.2 Estimated Renewable Electricity Potential

Uganda has ample renewable energy potentials. Even using conservative estimates of commercially-viable biomass, hydro, solar and geothermal resources, with determined efforts, Uganda will not need any fossil fuel or nuclear energy by 2050, in spite of a large, expected growth in energy demands.

A robust enabling environment will need to be created during this period to establish the necessary springboard for achieving the ambitious goals for the years 2030 and 2040 (MEMD, 2013). Uganda electricity access has reached nearly 60% of the population in urban areas, while in rural areas is still limited to 18%, although increasing.

Energy Source	Estimated Renewable Electrical Potential (MW)
Hydro	4100 MW large and 400 MW small
Geothermal	1500 MW (large)
Biomass cogeneration	1650 MW (medium scale)
Solar	No practical limit, all scales
Wind	Above 1000 mw (medium scale)

Data Sources: See text above and 2.2.1 – 2.2.9 below

2.2.1 Hydroelectricity

Hydropower is the major source of electricity generation. The government developed a Hydropower Development Master Plan. Uganda has considerable potential accumulating to over 2,000 MW. Two large-scale projects with a total of 783 MW are currently implemented and planned to be completed in 2018. Other large-scale sites with a potential of more than 1,500 MW have been identified as well as 59 mini hydropower sites with a potential of 210 MW. Recently, the Ministry of Energy and Mineral Development permitted the construction of five small hydropower projects with a total capacity of 33.7 MW. Some of these are developed under the GET FiT program.

With the support of the Japan International Cooperation Agency (JICA), a hydropower development master plan was developed with the potential of hydro resources estimated to be over 4100 MW (CleanTechnol; 2018).

The large-scale hydropower potential is located near the River Nile which originates from Lake Victoria. The flow of the River Nile is controlled by the Owen Falls Dam (now Nalubaale Power Station), a hydropower station constructed in the 1960s (UBOS, 2013). The station initially had 10 generators with a total installed capacity of 150 MW before it was refurbished and upgraded to 180 MW alongside the construction of a new 200 MW power station in Kiira (UBOS 2013).

However, with the economic liberalisation and the unbundling of the electricity utility, both Nalubaale and Kiira hydropower stations were leased to Eskom (U) Limited under a 20-year concession agreement (CleanTechnol; 2018). As a result, the two hydropower stations became the back-bone of the electricity distribution network in the country.

A new 250 MW hydropower facility at Bujagali was completed in 2012 and started operation in the same year. The current total installed capacity of hydropower in Uganda is about 932MW. Another barrier to electricity supply is the increasing growth in demand for electricity which has not been matched with present generation capacity.

To alleviate this problem, the government mandated UMEME to operate, maintain, upgrade and expand the distribution network, trade electricity to its customers and to improve energy efficiency (EE) with the electricity distribution system.

Large-Scale Hydropower

The installed capacity for large-scale hydropower that is operational to date is 932 MW (Clean Technol; 2018). These include the Nalubaale Power Station with a capacity of 180 MW, Kiira Power Station with an installed capacity of 200 MW and the Bujagali Power Station with an installed capacity of 250 MW, Isimba Power station 183.2 MW that became operational in March 2019.

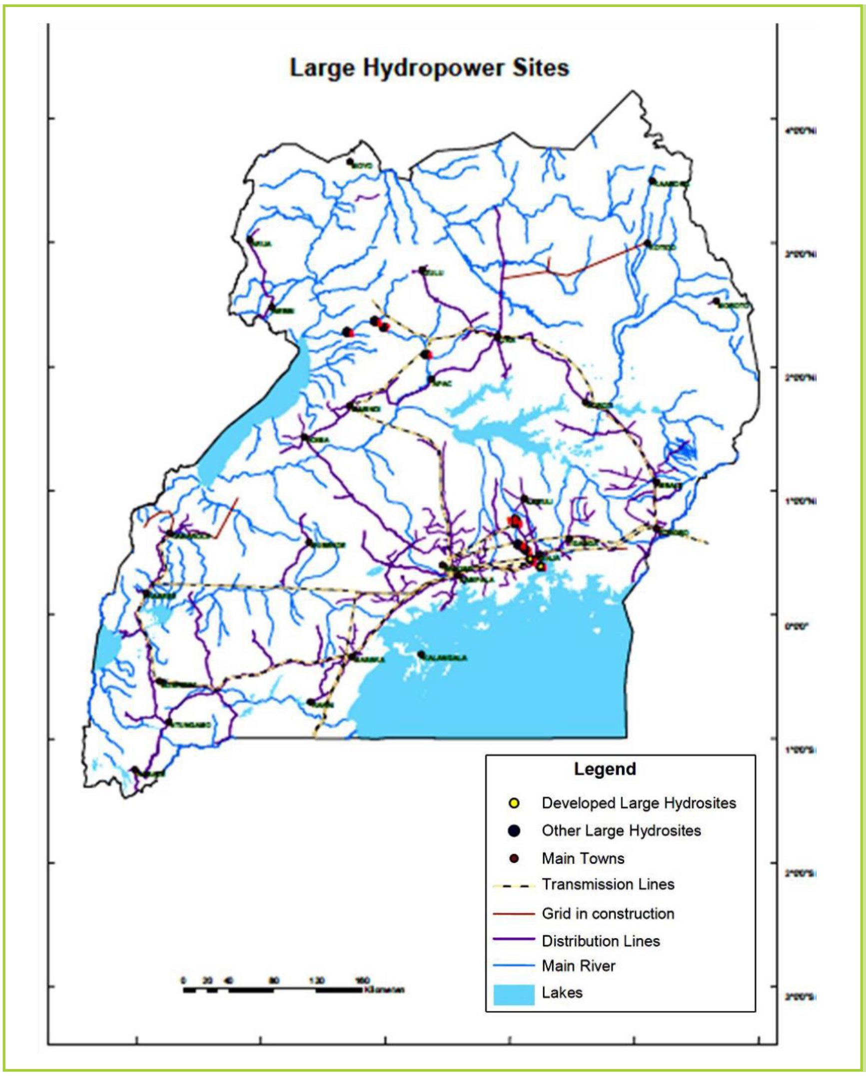
Presently, on a public-private partnership (PPP) basis in order to produce electricity in the medium term, the Karuma Power Station with a capacity of 600 MW is expected to be operational mid-2023 and the Ayago Power Station with a proposed size of 840 MW, which is can be operational before 2030.

Other major potential sites for hydropower that are yet to be developed include Kalangala with a potential capacity of 450 MW, Oriang with a potential capacity of 400 MW, Kiba with a potential capacity of 300 MW and Murchison Falls with a potential capacity of 600 MW (Norton Rose Fulbright (NRFC)., 2015).

This implies that the potential of existing and identified large-scale hydropower in the country is as shown below:

Existing large hydropower	932 MW
Karuma Power Station	600 MW
Ayago Power Station	840 MW
Kalangale Power Station	450 MW
Oriang Power Station	400 MW
Kiba Power Station	300 MW
Murchison Falls	600 MW
TOTAL	**4122 MW**

Figure 2 below shows the large hydropower sites nationwide in Uganda (Norton Rose Fulbright., 2015).



Data Source: MEMD 2007

Small- and Medium-Scale Hydropower
Unlike large-scale hydropower, the small- and medium-hydro sites are not located on the Nile, but they also possess potential resources which are yet to be fully exploited (Twaha, S., et al; 2016). These sites are majorly located in the Western and the Eastern regions of the country which are hilly and mountainous.

Some of these small hydropower stations that are operational include the Kuluva (120 kW), Kagando (60 kW) and Kisiizi (300 kW) which supply electricity to isolated hospital grids.

Furthermore, a total of 59 medium hydropower sites with a total potential of approximately 210 MW electrical capacity have been identified via various studies in the country (Twaha, S., et al; 2016). Some of the sites have the potential to be used for isolated grids, while others can be used for energy supply to the national grid (Twaha, S., et al; 2016).

Some of these sites include the Kanungu Power Station of Eco Power with 6.4 MW capacity of electricity, and Mpanga Power Station of Africa Energy Management Systems which has 18 MW installed capacity of electricity. The combined installed capacity for small-scale and medium-hydropower that is operational to date is 53 MW (Norton Rose Fulbright., 2015).

According the Annual report (GET Fit 2018) further four small hydropower projects (SHP) achieved commercial operation during 2018 – Nyamwamba SHP, Lubilia SHP, Nkusi SHP, and Waki SHP – adding an additional 29.0MW of power capacity to the national electricity grid. Combined with the six projects already operational by the end of 2017, the total installed capacity of operational GET FiT supported projects is now 87.1 MW

In total here has been identified a potential of 374 MW of small- and medium sized hydro power stations, combining the power of 109 potential stations.

In this way, the hydro-power potential can be estimated to be around 4500 MW.
Another estimate, by the Uganda Hydropower Association, is 5300 MW (https://www.hydropower.org/country-profiles/uganda).

In the scenario, we will use the potential of 4500 MW as a maximum.

2.2.2 Biomass

Despite the many alternative energy sources available in Uganda, the population in both rural and urban areas heavily relies on biomass energy, especially for cooking, due to its accessibility and affordability. Biomass is the most important source of energy, providing for 90% of the total primary energy consumption in the form of firewood, charcoal or crop residues. This practice contributes to severe forest degradation, leading to fuel scarcity and high fuel prices. Apart from the heavy dependence on scarce supply, inefficient cook stoves emit harmful fumes and present a health and fire injury hazard to those using them.

Biomass is the main source of energy in Uganda, contributing about 94% of all energy consumed (MEMD 2014). Of the total biomass consumed, wood fuel accounts for about 80%, charcoal 10% and crop residues 4%. (MEMD, 2007) Firewood and crop residues are mainly consumed in rural areas while charcoal is consumed in urban areas. Limited storage space in urban areas, high standards of living, higher calorific value of charcoal than for wood and easier handling by vendors makes charcoal the favoured fuel over firewood in urban areas. (MEMD, 2015). The main sub-sector that utilises biomass residues for electricity production is the sugar industry.

A small amount of coffee and rice husks is also utilised for heat production in cement and tiles manufacturing and the production of briquettes.

Currently, biomass is the leading type of energy used in Uganda, constituting about 94% of the total energy consumed in the country (Okello, C., et al., 2013).

Biomass is the major source of energy for rural industries, and its trade contributes to the rural economy in terms of employment, rural incomes and tax revenue [93–95]. Charcoal is mostly used in urban settings while firewood, agro-residues, crop residues and wood wastes are broadly used in the rural areas (Okello, C., et al., 2013). The consumption of charcoal is increasing at a rate of 6% per annum and this has contributed to the degradation of forests as wood reserves are depleting at a rapid rate in many regions of the country (CleanTechnol; 2018). Apart from fuel wood, wood is similarly used for paper products, plywood, electric poles and sawn-wood. However, the consequence of this is the continuous falling of trees which can lead to an ever-increasing problem of soil erosion and desert infringement if left unchecked (CleanTechnol; 2018).

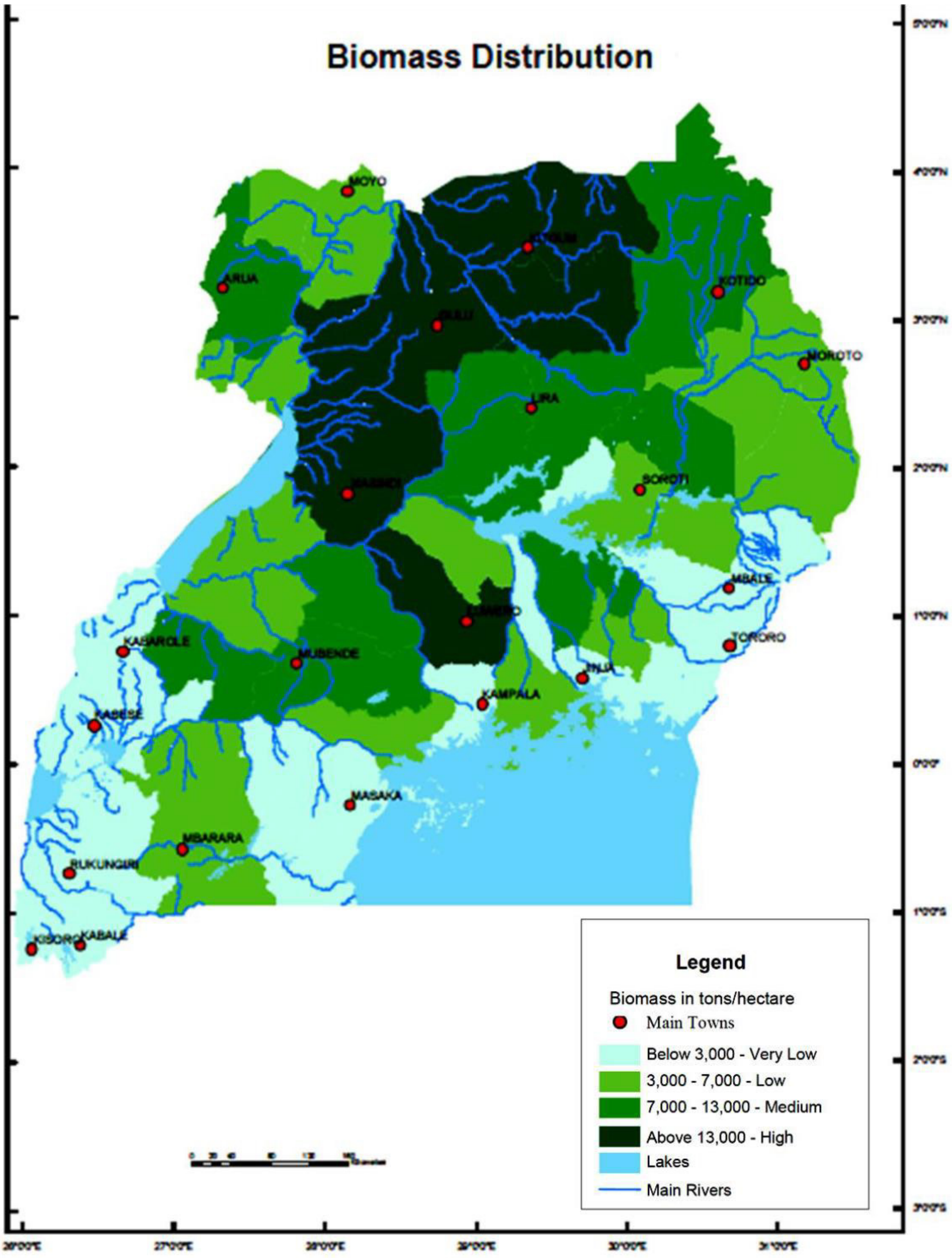
Efforts are being made by the Ministry of Energy and Mineral Development (MEMD) with the support of some foreign partners (such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)) to promote the use of the improved Rocket Lorena Stoves among households and institutions and thus reduce deforestation and the use of wood fuel.

The rocket stoves for households were locally made out of materials that can be acquired cheaply or at no cost in order to produce efficient stoves that fit the socio-economic setting of the poor living in the rural areas (CleanTechnol; 2018). Since 2005, over 500,000 of this product has been successfully distributed in places such as Rakai and Bushenyi districts in Uganda (CleanTechnol; 2018. Although about 10% of all households in Uganda have benefited from the dissemination strategy/program (CleanTechnol; 2018). More awareness about the importance of the affordable and acceptable biomass stoves needs to be promoted among the masses if the consumption of fuel wood must be reduced in the rural/urban areas. Lately NGOs like Joint Energy and Environment Programme (JEEP) have disseminated simpler improved cookstoves that villagers can be trained to make and repair themselves. (http://inforse.org/s_e_news.php3)

In addition to biomass for direct combustion, Uganda has numerous biomass resources that can be used for production of biogas, including municipal waste, oil palm products, manure, sludge from cleaning as soft plants including water hyacinths from Lake Victoria.

Table1 below shows the various biomass resources from agricultural residues and their estimated quantities in Uganda (Norton Rose Fulbright (NRFC), 2015) and figure 3 shows the biomass sites country-wide. On the other hand, the plant biomass can also be used as fuel for small-scale industries and could also be fermented by anaerobic bacteria to produce a multipurpose and cheap biogas which can be used for cooking (Norton Rose Fullbright (NRFC), 2015).

Figure 3: Map showing the biomass sites country-wide in Uganda



Data Source: MEMD 2007

Table 1: Energy production potential from agro-residues

Biomass Type Estimated Annual Production	('000 Tons/Year)
Bagasse	590
Bagasse surplus (available immediately)	50
Rice husks	3 x 25-35
Rice straw	45-55
Sunflower hulls	17
Cotton seed hulls	+50 (being developed)
Tobacco dust	2-4
Maize cobs	234.
Coffee husks	160
Groundnut shells	63

Data Source: Ministry of Energy and Mineral Development, Uganda 2015

Currently, pine trees (33%), eucalyptus (50%) and cypresses (17%) are the main sources of hardwood plantation in the country Okello, C., et al., 2013. The total standing biomass stock is estimated to be 284.1 million tons with a potential sustainable biomass supply of 45 million tons (Okello, C., et al., 2013). Nevertheless, the sustainable wood that is within reach for biomass supply stands at 26 million tons, and this can only meet about 59% of the total demand of 44 million tons per year.

Apart from the sugar companies that utilise their sugarcane residue to generate electricity and heat, the use of other biomass such as coffee husks, rice husks etc. has not been fully explored in Uganda (Norton Rose Fulbright (NRFC), 2015).

Energy potentials of residues from crops has been estimated to 149 PJ/year by researchers from Gulu University (Uganda) and others [Development of bioenergy technologies in Uganda: A review of progress, Okello, Collins, Gulu University, Uganda, et al., 2013]. Most of the potential of crop residues is from maize, around 50%. These are theoretical potentials, and cannot be used 100%, but it probably does not include the full potential.

In the study, annual bagasse production is given as 25% of sugar cane production of 197,000 tons, equal to 49,000 tons, but in a study from Ministry of Energy and Mineral Development, Uganda from 2015, the bagasse potential is estimated to be 590,000 tons. This could add 10 PJ to the potential, reaching 159 PJ.

Another study identified a potential of 10 mill tons including agro-waste at farms and processing as some grass etc. (1 mill. tons) [Biomass Energy Strategy (BEST) Uganda 2014, see https://www.undp.org/content/dam/uganda/docs/UNDPUg2014%20-%20Biomass%20BEST%20Strategy(compressed).pdf], which is equal to around 140 - 175 PJ depending on energy content (varies from 14 to 18 GJ/ton). In addition to that, the study found a potential on energy from bush and papyrus & reeds of 10,5+4,5 mill tons equal to around 240 PJ (with energy value 16 GJ/ton).
According to energy statistics, the use of residues was 136 PJ in 2018, which is equal to 7.5 million tons of dry matter with the energy content of 18 MJ/kg (equal to the energy content of dry bagasse, lower heating value).

Though the potential is probably higher than 149 PJ, as indicated by the study on bagasse and the BEST study, the full potential cannot be used. So, we will include a potential of 160 PJ (which is conservative compared with the BEST study's potential around 300 PJ).

2.2.3 Gaseous biomass / Biogas

Biogas is 55-70% methane (CH4) with varying amounts of carbon dioxide (CO2) as the chief constituents. It also has traces of hydrogen sulphide (H2S), ammonia (NH3), oxygen, hydrogen (H2) and water vapour (H2O), depending upon feed materials and other conditions. The feed materials are usually animal and human waste.

Biogas is a zero-waste technology. The products of biogas digesters, like biogas and digested slurry, can be utilised economically for cooking and as manure for agriculture and horticulture. Biogas is a non-poisonous and non-toxic gas, which when mixed with air burns with a clean blue flame, and can therefore be used as a substitute for kerosene, charcoal and firewood in households and institutions. Syngas is produced by the gasification or pyrolysis of carbonaceous materials. Gasification involves subjecting the materials to high temperatures in the controlled presence of oxygen, with only limited combustion to provide thermal energy to sustain the reaction. In Uganda, according to Uganda Biogas Solution limited, there are close to 10,000 biogas plants that are in use at household level.

One study identified a potential of 2 million m3 biogas per year [OG BIOGAS] equal to 44 PJ. Most of the (theoretical)l biogas potential is from cattle manure while most of the remaining potential is from goats and sheep. These animals are kept on fields or kept by pastoralists, where it is impractical to collect the manure. Thus, we assume a practical potential to only 20% of the theoretical potential. There is also a potential from pigs (4 PJ) and humans (3 PJ). Useful potential is then around 16 PJ from these sources.

Wet organic waste is the major part of waste in Kampala (89-95%) and probably the same in other Ugandan towns. In Kampala, 28,000 tons of waste was collected per month in 12 months (2011-2012), which is about 40% of the waste generated (60% is not collected).

The dry matter content was found with drying to be 28% on average and the energy (calorific) value of the dry matter was found to be 17.3 MJ/kg (Allan John Komakech et. Al., 2014). Using these figures, the total waste generated in 2012 in Kampala was 840,000 tons (wet weight) of which some 760,00 tons was wet organic waste. Since 2012, Kampala has roughly doubled in population. Assuming that the waste has increased with population, the organic waste from Kampala is around 1.5 million tons/year.

Assuming that the potential from other towns is the same (1.5 million tons/year), the total organic wet organic waste that could be collected is 3 million tons/year. With an estimated dry matter content of 28%, the dry matter is around 0.8 million tons/year. In a biogas process, around 40% of the energy of the dry organic matter can be made into biogas energy, around. 6 PJ. We estimate the accessible potential to be half of that, i.e. 3 PJ.

Total accessible biogas potential is then estimated to be 13 plus 3 PJ which is equal to 16 PJ. Also residues can be used in biogas plants, but they are already included above in the potentials for energy from residues, so they are not included in the potential for biogas to avoid double counting. Smaller cost-effective biogas technologies have been introduced to bolster the energy access in poor communities and have spread across five districts across Uganda (Norton Rose Fulbright (NRFC), 2015. They include Iganga, Kabarole, Mbale, Mpigi, and Tororo. Initially, a total of 50 biogas plants were installed.

Biogas is used today in some 10,000 family biogas plants to produce cooking gas. We include in the scenarios that this is gradually expanded to provide 4.5 PJ of cooking energy in the BAU scenario and 10 PJ in the action scenario in 2050.

2.2.4. Waste to Energy

Municipal waste consists of solid waste including organic and inorganic waste from homes, institutions and industries/businesses. Additionally, it comprises waste generated by manufacturing, agriculture, mining, construction and demolition debris, as well as sludge and liquid waste from water and wastewater treatment facilities, septic tanks, sewerage systems and slaughterhouses, among others. With appropriate waste-to-energy technologies, municipal waste can be used to provide energy while helping to clean the environment.

Gasification is a process tol convert organic carbonaceous materials at high temperature into carbon monoxide, hydrogen and carbon dioxide. This technology is more efficient than direct combustion of solid waste.

It can be used to convert municipal waste into renewable energy. If solid waste is sorted in a wet, organic fraction and dry fractions (paper, metal, glass, plastic, etc). The wet organic fraction can also be used to produce biogas in a biogas digester.

In the scenario we include waste as feed-stock for biogas and we include use of agricultural residues for energy, but we do not include high-temperature gasification or incineration of waste for energy.

2.2.5. Biomass cogeneration

Cogeneration is one of the energy production technologies where biomass can be used as a form of clean energy (Okello, C., et al., 2013). Biomass cogeneration systems are systems with a combined heat and power technology that simultaneously generate two or more forms of energy such as electricity, mechanical energy and thermal energy in a single or integrated system (Cleantechnol. 2018). This is comparable with the common practice in Uganda, where electricity is produced from central power plant and on-site heating and cooling equipment that are used to meet non-electric energy needs (Cleantechnol. 2018).

The thermal energy retrieved in a cogeneration system can be used for heating in industry or buildings. Currently, the installed capacity of a cogeneration plant is estimated to be approximately 30 MW, and most of them run with bagasse as fuel in sugar production (Okello, C., et al., 2013).

Some notable factories that utilize cogeneration for electricity production in the country include Kinyara Sugar Works Limited, Kakira Sugar Works Limited and Sugar Corporation of Uganda Limited (Lugazi). This implies that there is a substantial potential of cogeneration in the sugar processing industry.

Furthermore, any system that requires both electrical and thermal energy (e.g., cement and iron production, beer production, and foods and beverages processing among others) has the potential of exploring the modern cogeneration technologies (Okello, C., et al., 2013)]. However, the potential of the sugar industry alone is presently estimated to be more than 100 MW, whereas the combined potential capacity for the other industries is estimated to be around 50 MW (Okello, C., et al., 2013).

We expect that the 100 MW of biomass gasification remains until 2050 and that it will be used to help balancing power production and demand, which is mainly required in the 100% renewable energy scenario after 2030.

2.2.6. Solar Energy

Uganda is endowed with favourable solar irradiation of 1,825 kWh/m² to 2,500 kWh/m² per year (See figure 4 below). In the recent past solar power has received increasing attention by investors as well as a promising potential for exploitation of geothermal energy. Solar energy has been used with appropriate technology for cooking food, water heating, refrigeration, lighting, telecommunications, and many others.

Solar energy is an alternative source of energy in rural and remote communities whose connection to the national grid may not be economical. Small solar applications are often used in rural electrification projects such as Solar Home Systems or solar water heating.

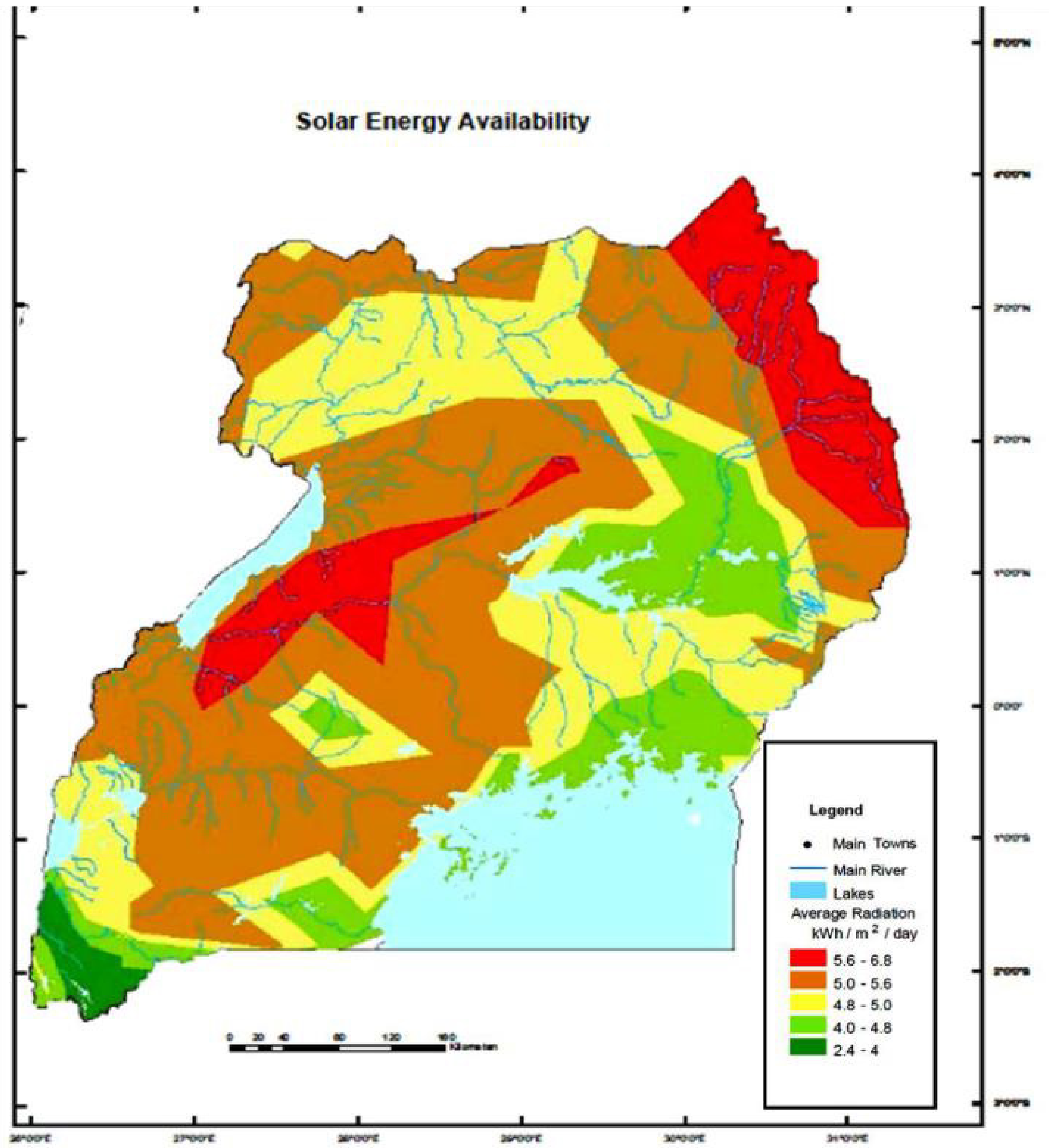
To diversify the national energy pool, in 2016, the Electricity Regulatory Authority commissioned the Soroti Solar Power Station that produces 10 MW and is connected to the national grid. The Tororo Solar Power Station generating 10 MW, was also completed and connected to the national grid 2017.

In January 2019, Kabulasoke Solar Power Station, a 20 megawatt development by a private IPP was commissioned and connected to the national grid in 2019 and Bufulubi Power Plant in Mayuge District in June 2019. This gives a solar contribution of 50MW power to the national grid (ERA, 2019). Solar is becoming an important source of electricity, because of the escalating tariffs and the scarcity of electricity from the conventional hydro- and thermal- power generation in the country. Rural Electrification Agency (REA) estimates that so far over 30,000 solar PV systems have already been installed in rural areas in the country and still there are huge unexploited solar energy resources.

The concept of PicoPV has matured over the last years and distributors have introduced a number of Pico solar systems designed for the charging and powering of smaller devices such as cell phones, tablets, lights and other portable devices on the Ugandan market. The solar home systems SHS and PicoPV products have established themselves firmly in the Ugandan energy sector, largely due to falling prices of solar components (panels, batteries, LEDs) and the introduction of innovative financing mechanisms such as Pay As You Go (PAYG).

A number of international and local companies have established outlets and sales hubs across Uganda. This development has already brought clean lighting to + 300,000 households and helped reduce the use of kerosene lamps and dry cell batteries, which are costly and degrade the environment.
The solar thermal industry offers a number of technologies for applications ranging from small scale applications e.g. domestic solar water heating, cooking etc.

Figure 4: Map showing the availability of solar energy for different sites across Uganda.



Data Source: MEMD 2007

Following this improvement and the introduction of Chinese and Taiwanese silicon solar PV products (70% of all solar cells and modules presently sold in the world), the GoU launched the Rural Electrification Strategy and Plan (RESP) in 2001. The RESP was designed to run from 2001 to 2010; however, it elapsed in 2012 due to delay in implementation. Although the project was geared toward increasing the use of solar PV in rural areas, the RESP could not meet expectations. The RESP could only install 7000 systems out of the anticipated 80,000 systems. This was a huge failure, as only 8.75% of the expected outcome was achieved despite the timeline of 11 years (Mawejje, J et al 2012).

However, as a result of the attractive feed-in-tariff (FiT) scheme and the announcement of the proposed construction of eight RE projects of about 83.7 MW in early 2014 by the Electricity Regulatory Authority (ERA), more foreign investors are now entering into the solar PV market in the country (Twaha, S., 2016).

These include the Solar Energy for Africa firm, which is presently exploring a 50 MW solar thermal plant that is located in the Namugoga area of Wakiso District (Pedersen, M.B., 2017), and Bukuzindu Power Plant is a 1.6 MW solar-diesel hybrid power plant that supplies power to the population of the Bugala Island in Lake Victoria. It was commissioned in December 2014 and began operations in March 2015. It currently supplies power to 2570 households and 33 commercial customers, including a few hotels and small enterprises (KIS 2019).

On the other hand, the majority of the installed solar PV systems in the country are mostly achieved through government- or donor-supported projects (Norton Rose Fullbright (NRFC, 2015). The core driver of most of the government introduced projects is the World Bank-supported rural electrification program, tagged “Energy for Rural Transformation (ERT)” (Pedersen, M.B., 2017). Presently, the number of solar PV systems for both institutional and home based-systems in the country can be estimated to be over 30,000 PV installations, now accounting for 1.25 MW installed capacity (CleanTechnol., 2018). This is gradually being distributed in the rural areas.

Furthermore, there have been significant efforts to create more awareness for the use of solar energy and small PV systems in the country. A major player in the sensitization process is the Joint Energy and Environment Projects (JEEP) Uganda Nordic Folkcentre for RE, an Non-governmental Organisation (NGO) from Denmark that has created awareness for RE in areas such as Tororo, Luwero, Arua etc.

In the 100% renewable energy scenario, we include a large growth in solar power to 600 MW in 2030, 10,000 MW in 2040, and 50,000 MW in 2050.

In the BAU scenario, we include a small growth to 300 MW in 2030, 500 MW in 2040 and 1600 MW in 2050.

2.2.7 Geothermal energy potential

Geothermal is heat energy that originates from a layer of hot rock often with hot water or steam below the earth's crust. The amount of heat generated from this crust contains about 50,000 times more energy than all the oil and natural gas resources in the world.

Uganda is among the few countries in the world endowed with the geothermal resource, situated in the western part of the country. Uganda offers potential for the development of its geothermal resources (see figure 5 below). The development allows this resource to provide both thermal and electrical energy. Geothermal energy resources constitute a clean and renewable energy resource.

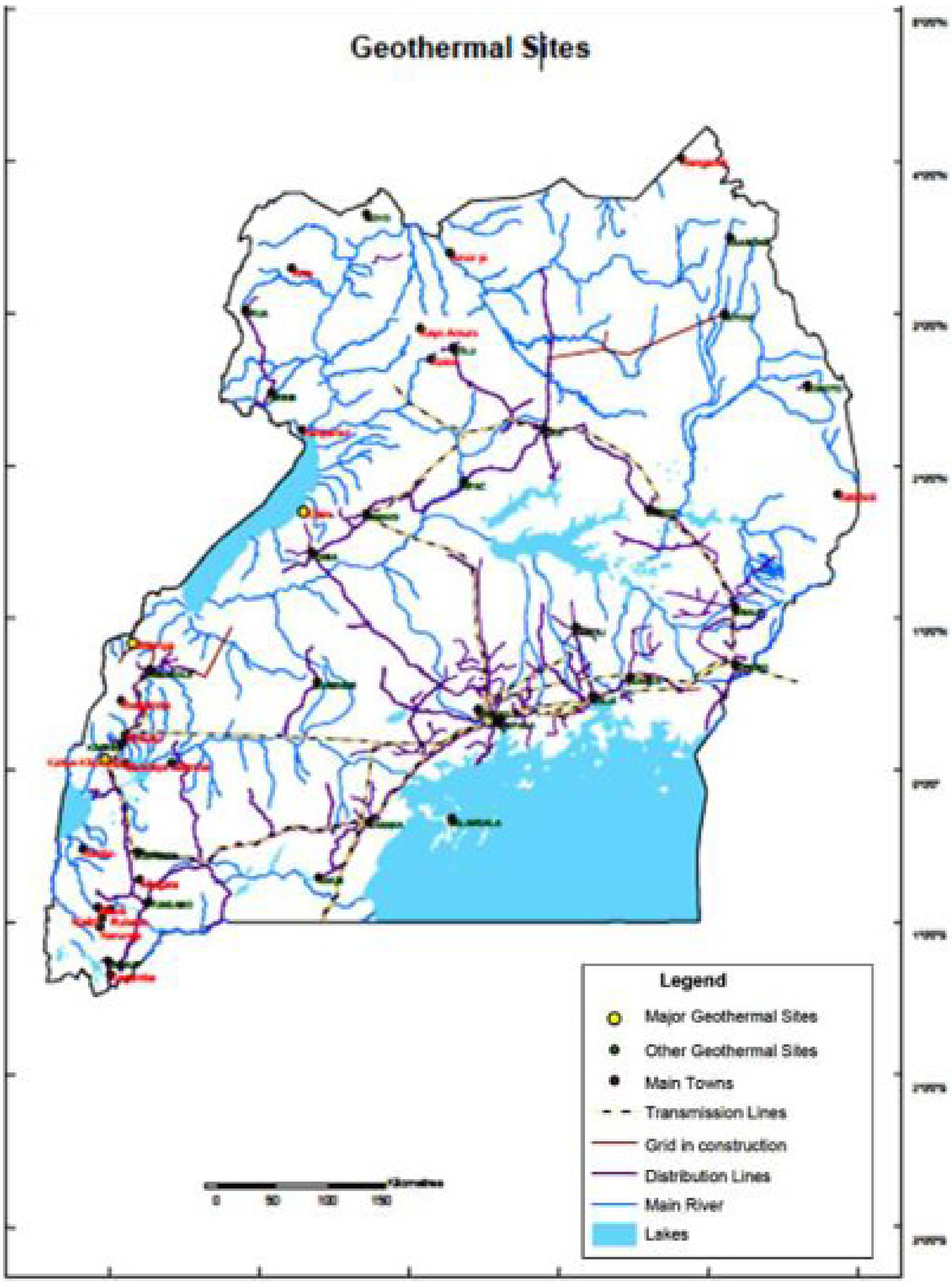
The exploitation of geothermal energy is currently at the exploration stage. Exploration has been carried out in the main geothermal areas of Kibiro, Panyimur and Buranga. Drilling of wells to determine the temperature gradient was expected to start in Kibiro and Panyimur in 2019. In order to attract private sector participation, the government is currently developing a geothermal policy and legislation.

The potential for electricity generation has been estimated to 1500 MW according to Mr Godfrey Bahati, commissioner Geothermal resources (See this article https://www.thinkgeoenergy.com/three-private-groups-with-geothermal-licenses-in-uganda/)

Other sources give the same potential (Geo-scientific studies at Kibiro and Panyimur prospects that estimated a potential of 1500 MW. – Chagaka Kalimbia & Julius Magala, Re-invest (2018)).. So far, three potential areas, all situated in Western Uganda, have been identified for detailed exploration. Geothermal energy is an eco-friendly and multipurpose RE resource that can support different developmental activities, ranging from raw material production and processing to mineral and agricultural production (Cleantechnol. 2018).

Until now, the actual progress of geothermal development in Uganda has been very minimal. Perhaps one reason for the small progress in geothermal development has been that Uganda is endowed with huge hydropower potential along the Nile River. More recently, discoveries of oil, and lack of clear and attractive results from the geothermal investigations done to date have played a role. Lack of government funds to finance aggressive exploration work has also been a major factor.

Figure 5: Map showing the identified geothermal sites in Uganda.



Data Source: MEMD 2007

Furthermore, the efforts of the GoU are currently focused on the development of the aforementioned area to a viability stage that will help acquire essential data for feasibility study. Further studies are also presently being carried out across other identified geothermal areas in the country. These preliminary studies involve the drilling of deep exploration wells that will help provide information on reservoir temperature, fluid chemistry and other petro physical parameters (Twaha ,S.; Et al 2016).

In the 100% renewable energy scenario, we include a development of geothermal power after 2030, reaching 1500 MW in 2040.

Thermal Power

Two heavy fuel oil thermal power stations exist in the country. Namanve Power Station is a 50 megawatt plant owned by Jacobsen Electricity Company (Uganda) Limited, a wholly owned subsidiary of Jacobsen Elektro, an independent Norwegian power production company. The plant cost US$92 million (€66 million) to build in 2008. WhileTororo Power Station is an 89 megawatt heavy fuel-oil powered plant owned by Electro-Maxx Limited, a Ugandan company and a subsidiary of the Simba Group of Companies, owned by Ugandan industrialist Patrick Bitature.

This plant is licensed to sell up to 50 megawatts to the national electricity grid. The two heavy fuel oil thermal power stations Namanve and Tororo are used as stand-by power sources to avoid load-shedding when hydropower generation fails to meet demand.

Five sugar manufacturers in Uganda have a total cogeneration capacity of about 110 megawatts, of which about 50 percent is available for sale to the national grid. The cogeneration power plants and their generation capacities include Kakira Power Station (52 megawatts), Kinyara Power Station (40 megawatts), Lugazi Power Station (14 megawatts), Kaliro Power Station (12 megawatts) and Mayuge Thermal Power Station (1.6 megawatts)

In both scenarios, we include that the capacity of 100 MW thermal power is maintained until 2050 and can be used to help balancing the power grid (the main balancing is with the hydro-power plants, but all plants participate in balancing)

2.2.9 Wind power

Uganda has no grid-connected wind systems. Currently wind power is being used for small scale electricity generation and for special applications, such as water pumping.

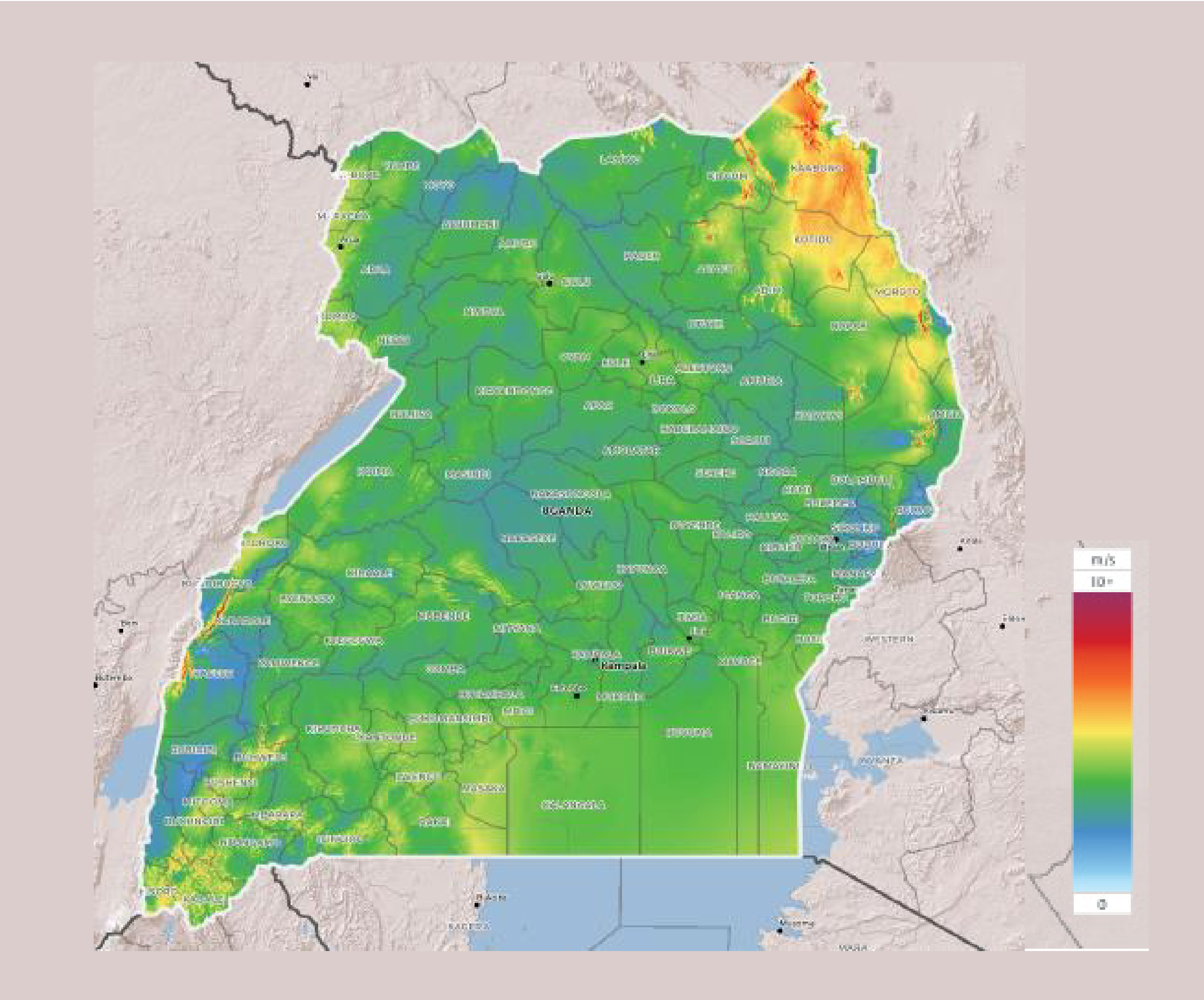
Off-grid solar and wind hybrid systems are currently operating and supplying power to rural communities in Kotido, Napak and Namayingo districts. These systems supply power to households, health centres and schools. The Ministry of Energy and Mineral Development is in the process of developing a wind resource map.

According to Uganda's renewable energy policy 2007, wind data collected by the country's meteorology department concluded that wind energy is available and sufficient for power generation especially in the south western part districts of Kabaale, Ntungamo, Kisoro and around Mt Elgon, Karamoja areas.

As shown on Figure 6 below, there are also good windpower potentials in the north-western districts of Kabong, Korito, and Moroto In these districts, wind energy can therefore be harnessed as an alternative power source and for diversification of Uganda's power sector.

In some other districts, wind energy can be used for special applications, such as water pumping and local energy use, for instance at the shores of Lake Victoria.

Figure 6: Global Wind Atlas, Mean Wind Speed at 100 m above ground in Uganda



Data Source & copyright: World Bank / ESMAP/DTU

We estimate the potential for utility scale windpower to 700 MW, respecting nature protection areas, not installing wind turbines in natural parks. This include the Kidepo Valley Natural Park the Matheniko Game reserve in Karamojo, Bokora Widlife Reserve, Pla Upe Game Reserve, Mount Elgon National Park. There are an estimated 3000 – 4000 km^2 with above 6 m/s average wind speed at 100 m height. With an assumption of a potential installed capacity of 7 MW/km^2 (Vimdmolleindustrien), and assuming that at least 100 km^2 of the area can be used for windt parks, the potential capacity is at least 700 MW, in reality over 1000 MW. The land between the windturbines can be used for agriculture, storages, and others.

We assume that the full load hours is 3300 (of the 8760 hours of the year), which is similar to an average wind speed of 6,5 m/s at 100 m hub height with wings of 63 m length (rotor diameter 126 m) for a 3,3 MW utility scale wind turbine. With an installed capacity of 700 MW, the annual windpower production will be 2,3 TWh, equal to 8 PJ.

In the 100% renewable energy scenario, we include that the 700 MW is installed in the period 2030 – 2040, in parallel with increasing power demands. In the BAU scenario there is no wind power installed.

3.0 Future Energy Efficiency and Energy Demands

The sustained industrial growth aspired to by the Vision 2040 will require steady energy supply and matching infrastructure investments. Several areas gazetted as industrial parks have limited or unstable electricity supply leading to suppressed demand in industries and inability to expand output and increase demand. There is generally inadequate financing of energy programmes and commercial banks have limited involvement in the provision of long-term lending for energy projects (Draft Energy Policy, 2019).

Therefore, for sustainable development, Uganda requires a steady supply of energy that is environmentally friendly, affordable and reliable. The basis for the scenarios in this report is that the demands for energy services will increase in line with population growth and in tandem with the Country's medium and long term development objectives as enshrined in and NDPIII and Vision 2040.

3.1 Household cooking demands

Household cooking demands are today responsible for two-third of Uganda's primary energy supply, including direct use of wood and other biomass, as well as charcoal production for cooking. Of the biomass demand, households are responsible for 90% of the demand for wood and residues, and also for two-thirds of the charcoal demands.

While the cooking will increase with increasing population, there are large potentials to increase efficiency of cooking, thereby lowering the energy demand for cooking.

The improvement of efficiency has already started with improved cook stoves, but there are still large potentials for increasing the efficiency with massive dissemination of improved cook stoves, new, high-efficient cook stoves, super-efficient electric cooking, biogas, and more efficient charcoal production. These five solutions are all included in this scenario. Some other solutions are not included, such as wood briquettes (that are not well known in East Africa), LPG (that are hard to afford for most of the population due to high costs and being a fossil fuel), though there are signals from the Government to promote it (for example it has been proposed to have LPG VAT exempt in the National Budget FY 2020 /21).

Within Uganda's NDC, a focus on energy through introduction of improved biomass cook stoves and biogas is already highlighted. As part of securing a more ambitious NDC in line with the Paris Agreement, Uganda needs to take this to another level through scaling up adoption of improved biomass cook stoves as well as their efficiency through Research and Development efforts.

Figure 7: Future cooking options: Improved Cookstove (ICS), high efficiency improved cookstove, high-efficient electric pressure cooker

In the scenarios, solid biomass use in households after 2020 is estimated based on the assumption that cooking demands are following population size. With the increase in efficiency, the energy demand for cooking will not follow population size. Instead, it will follow population size multiplied by specific demands.

In the 100% renewable energy scenario, the demand for biomass for cooking will also be lower because of an estimated change to super-efficient electric cooking of 25% of the cooking, while the remaining 75% will be with high-efficient wood and charcoal stoves with above 50% efficiency. Table 2 gives the cooking demand and the biomass demand for cooking relative to the year 2000.

Table 2: Demand for cooking and for biomass for cooking with estimated development of Specific energy demand for cooking, relative to year 2000, renewable energy scenario

Household cooking	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cooking demand	100	117	137	162	194	215	236	278	324	372	423
Solid biomass share of cooking	100%	100%	99%	99%	98%	98%	95%	89%	84%	79%	74%
Cooking demand covered with solid biomass	100	117	137	162	194	212	224	248	272	294	312
Solid biomass demand for cooking	100	116	135	150	170	169	138	111	88	73	63

In the BAU scenario, no electric cooking is included while the high efficient cookstoves are used by 37%, normal improved cookstoves will be used 42% and the remaining 20% will use traditional fires, all by 2050.

3.2 Household light and electricity

Electricity use is rapidly increasing in Uganda, mainly with increasing wealth. With efficient lamps (as LED), electric light is possible with affordable levels of energy consumption for many Ugandans. In addition to increased wealth, electricity is also replacing kerosene for light.

At the same time, the efficiency of electricity use has increased with efficient lamps and efficient equipment.

In both the scenarios, we include that demand for light and also other electricity services will increase 8 times between 2020 and 2050, but as the efficiency will increase a factor 2.7 with LED lamps etc., the household electricity demand, not including cooking will increase a factor 3 between 2020 and 2030.

3.3 Service sector, cooking demand

Regarding the development of the service sector's cooking demand, we estimate that the growth in the service sector cooking demand follows growth in population and that the change to high-efficient electric cooking and high efficient biomass cooking follow the same patterns as in households for each of the two scenarios.

3.4 Service sector, light and electricity demand

There has been a large growth in electricity use in the service sector according to energy statistics 2011-2018 while the preliminary data shows that consumption in 2020 is equal to 2018.

If this development 2011-2020 continues relative to GDP and population growth, and with the assumption that energy efficiency are increasing in service sector similar to household sector, the energy service demand for electricity in the service sector will increase 18 times 2020-2050 the value in 2020. Because the assumed increase in efficiency is a factor 2.7 in the period 2020-2050, the electricity consumption will "only" increase a factor 6.5 in this period. We include that in the scenarios.

3.5 Industry, fuel demands

The use of industrial fuel (coal, oil, and biomass) in industry has increased from 20 PJ in 2000 to 43 PJ in 2020 (estimated). In parallel, there has been an increase in energy efficiency, which we estimate to 28% in the period, equal to an annual increase of 1.6%.

After 2020, we assume a higher efficiency increase of 2%/year equal to 10% per 5 year, because of actions to increase energy efficiency. In addition, it is assumed that industrial fuel use is gradually replaced with heat pumps and direct electric heating with an average coefficient of performance of 3 (heat pumps and electric heating combined).

It is assumed that remaining fossil fuel use is replaced with biomass and solar heating. With the assumption of 28% increase in energy efficiency 2000 - 2020, the increase of fuel-based energy service demand correlates relatively well with 30% of the increase in GDP for the period 2000 - 2020. The correlation coefficient is 94.3%, which is a reasonably good correlation. This gives an annual biomass demand in the industrial sector 0.65 TWh (2.4 PJ) in 2050.

3.6 Industry, electricity demand

The use of electricity in industry has increased from 7.5 PJ in 2000 to 17 PJ in 2020 (estimated). In parallel, the end-use efficiency has increased, but not as much as in the household sector, where the LED lamps have revolutionised energy use for light. Instead we assume a 32% efficiency increase, equal to 2%/year. After 2020, we assume a higher efficiency increase of 2.5% per year equal to 12% per 5 year because of actions to increase efficiency.

With the assumption of 32% efficiency increase, the increase of electric energy service demand correlates well with 35% of the increase in GDP for the period 2000 – 2020. The correlation coefficient is 98.4%, which is a good correlation.

The resulting industrial energy demands are shown in the Table 3 below:

Industrial energy (PJ)	2020 (stat. estimate)	100% RE, 2040	100% RE, 2050	BAU, 2040	BAU, 2050
Fossil fuel(oil)	36	82	0	439	745
Biomass (not residues)	53	280	345	155	195
Residues from cops	88	146	148	122	123
Solar heat	0	30	70	0	0
Electricity	7,2	98	300	25	35

Table 3: Industrial energy use in the two scenarios and in 2020

3.7 Transport demand

The energy demand for transport has increased strongly from 40 PJ in 2000 to 177 PJ in 2020 (estimated). The technology has not changed much since the year 2000 and therefore we assume that efficiency has not changed much. Thus, the transport demand has increased as much as the transport energy use. Increase in transport demand correlates well with the population increase combined with 43% of the GDP increase 2000-2020.

With the shift to electric vehicles, efficiency will be around 5 times higher than for petrol and diesel cars. For hydrogen and electro-fuels, where traditional combustion engines can be replaced by fuel cells and electric motors, efficiency is around 2.5 times higher than for petrol and diesel cars.

An example is the Kayoola solar bus developed by Kiira Motors Corporation (KMC), it has a range of up to 300 kilometres making it capable of seamlessly handling the daily duty cycle, with a sitting capacity of up to 90 passengers. It seeks to facilitate a total sustainable mass mobility solution for Kampala and other Urban Centres in Uganda / Sub-Saharan Africa. The cost of electricity per Kilometre is about UGX 380 per kilometre versus UGX 1,600 for diesel-powered buses (Kiira Motors Corporation, 2020)

Kayoola solar bus‘s current charging technology is able to fill the battery of the buses from 0 to 100% within 2 hours. For this reason, KMC has to set up this charging infrastructure across the city. Other examples include the rapid growing use of electric two-wheelers that now have increasing popularity in Uganda.

ELECTRIC VEHICLES ARE COMING FAST

Figure 8: Examples of electric two-wheelers.

In the renewable energy scenario, we include that the transport sector is gradually changed to electric motors, and from 2040 also hydrogen vehicles. In 2050 the transport mix will then be 75% electric vehicles, 24% hydrogen vehicles and 1% biofuel vehicles, both for personal transport and for freight. In the BAU scenario, use of oil continues.

3.8 Other demands

In addition to the 4 main demand sectors, households, service sector, industry, and transport, Uganda agriculture and fishery has a small demand of oil. This has grown substantial, being 2.5 times as high in 2015 than in the year 2000, reaching 2.51 PJ. It has increased rapidly afterwards and is expected to continue to increase with GDP, though reduced with 30% with increased efficiency and is expected to reach 24 PJ in 2030. Electrification in agriculture and fishing is expected to start from 2030 and in 2050, ⅔ of the energy demand of these sector will be covered by electricity in the renewable energy scenario in 2050, with the rest being covered by hydrogen or fuels made from hydrogen. With the high efficiency of electric traction, the total energy demand is not foreseen to grow in the period 2030 – 2050. This is because the expected increase in mechanical power of 4 times 2030-2050 will be compensated by a 4- times increase in efficiency with the change from fossil fuel to electricity.

Uganda also has energy demands in the energy sector, which is mainly energy losses in the charcoal production sector, but there are also losses in electricity production

3.9 Total Final Energy demand

With the above expected developments of activities and energy efficiency in the sectors, the final energy demand will develop as in Table 3 (below) for business as usual (BAU) scenario and table 5 for the renewable energy scenario.

With the high efficiency in the renewable energy scenario, final energy demand for households and service sector will decrease in spite of a large increase in the energy service level.

Table 4: Final energy demands in PJ divided in sectors for business as usual (BAU) scenario

PJ	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport	12,0	17,1	27,8	37,0	42,5	57,6	77,5	100,9	128,5	160,9	198
Industry	14,4	40,9	80,8	157,4	184,4	291,2	428,4	577,5	741,0	918,6	1.099
Agric	1,0	1,4	2,3	2,5	9,6	16,6	24,8	34,4	45,5	58,4	59
Service	31,9	37,4	44,8	48,3	50,5	54,4	54,6	58,3	60,7	61,2	62
Househ	238,4	276,3	330,5	349,6	362,2	383,7	378,5	398,5	409,5	407,3	409,3

Table 5: Final energy demand in PJ, divided sectors for 100% renewable energy scenario

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport	12,0	17,1	27,8	37,0	42,5	57,6	72,0	82,4	80,0	78,9	62,1
Industry	14,4	40,9	80,8	157,4	184,4	289,3	416,9	538,4	635,6	770,6	862,5
Agric	1,0	1,4	2,3	2,5	9,6	16,6	23,9	30,3	32,8	32,1	23,2
Service	31,9	37,4	44,8	48,3	50,0	50,9	43,6	37,5	32,3	29,9	28,7
Household	238,4	276,3	330,5	349,6	362,2	360,9	299,6	247,0	201,8	176,9	162,5

In the proposal will also be a substantial change of energy carriers, in particular in the 100% renewable energy scenario. The change from fuels to electricity in all sectors leads to much more efficient end-use, allowing final energy to remain stable or even decrease in most sectors. There are less changes to electricity in the BAU scenario and therefore less efficiency and higher final energy demand, with same activity levels in both scenarios

The change in energy carriers is shown in the road transport sector in table 6 for the 100% renewable energy scenario. Similar changes are included in the other sectors for the 100% renewable energy scenario, but not in the BAU scenario.

Table 6: Final energy for road transport in PJ. This is different from the transport sector in table 4 and 5 that also include navigation and therefore has higher consumption than the totals in this table.

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport	12,0	17,1	27,8	37,0	42,5	57,6	72,0	82,4	80,0	78,9	62,1
Industry	14,4	40,9	80,8	157,4	184,4	289,3	416,9	538,4	635,6	770,6	862,5
Agric	1,0	1,4	2,3	2,5	9,6	16,6	23,9	30,3	32,8	32,1	23,2
Service	31,9	37,4	44,8	48,3	50,0	50,9	43,6	37,5	32,3	29,9	28,7
Household	238,4	276,3	330,5	349,6	362,2	360,9	299,6	247,0	201,8	176,9	162,5

The below figure 9 shows the results in table 6 in a graphical form.

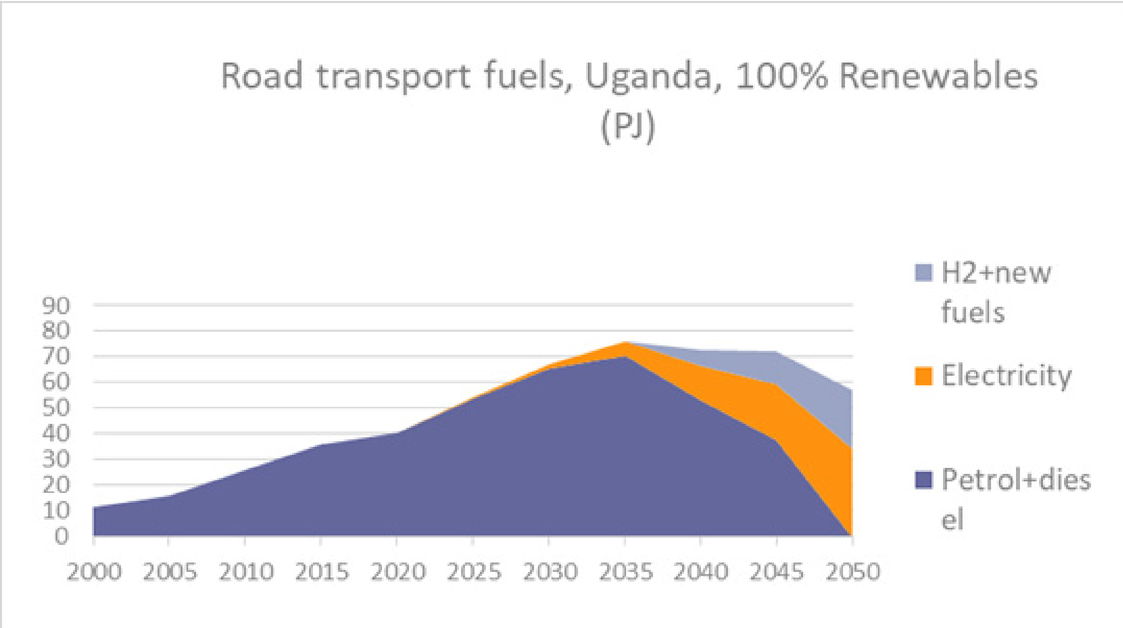


Figure 9: Development of road transport fuel demands in the 100% renewable energy scenario.

4.0 The Renewable Energy Use and the Scenarios

In the BAU scenario, the use of renewable energy is only increased following existing plans while in the 100% renewable energy scenario, renewable energy supply is increased to meet demands. In the current 100% renewable scenario, this will only happen in 2050, but it could happen earlier, if a stronger implementation is included both in renewable energy expansion and in transitions in the energy demands towards electricity and energy efficiency.

Given that there are plans for nuclear power, also a scenario for 2040 have been calculated, where

The renewable energy use in 2050 is given in Table 7 for the 100% renewable scenario.

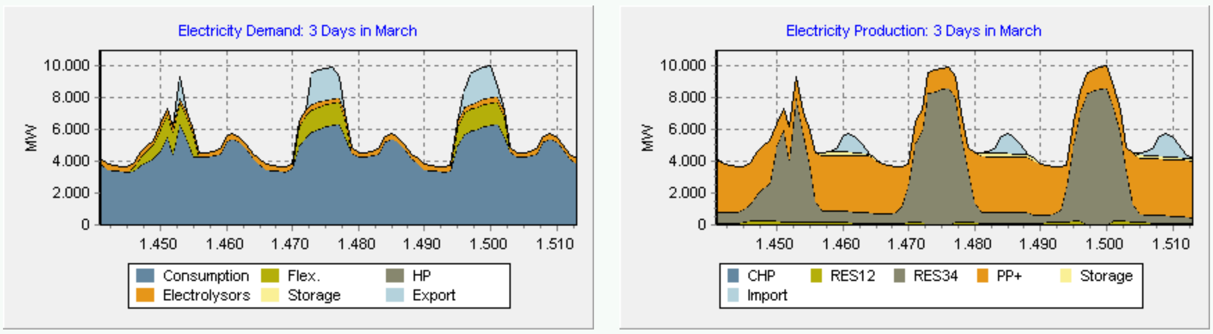
Table 7 Renewable energy supply for 100% renewable energy coverage in 2050

Energy source	Supply 2050 in PJ	Use of potential etc.
Windpower	9	Use of 700 MW of potential
Solar heating	70	Small fraction of potential
Solar electricity	365	Small fraction of potential
Hydropower	79	Using 4400 MW of potential
Geothermal electric power	42	Using potential of 1500 MW
Wood, existing	437	96% of sustainable level, 2.2.2
New plantations	71	Official plans for community planting
Agri residues	152	96% of the sust. potential, see 2.2.2
Biogas	10	Use 63% of potential, see 2.2.3
Liquid biofuels	3	Small increase

In the analysis, we have for the years 2030 and 2040 used a model that calculates the energy balance every hour of the year with the conclusion that it is possible to balance supply and demand with the proposed combinations of energy supplies in all scenarios, on the condition that is used smart charge for electric cars and that 10% of the normal power demand is flexible in time.

The variation in energy demand and supply is shown for three days in a typical March month in Figure 10 below

Figure 10: Electricity supply and demand for three days in a typical March, renewable energy scenario for 2040. PP+ is hydro power and the small 100 MW thermal power, RES34 is solar PV, Flex is flexible power demand



5.0 Energy balances, CO2 Emissions and Economy

5.1. Electricity Sector

In the 100% renewable energy scenario, electricity use is increased from present 18 PJ (5 TWh, 2020 preliminary data) to 495 PJ (138 TWh) of which 43 PJ is for hydrogen production.

The electricity sources in 2050 is expected to be:

- Hydropower: 79 PJ
- Solar PV 365 PJ
- Geothermal 42 PJ
- Windpower 9 PJ
- Biomass 1 PJ

The large dependence of solar electricity requires flexibility in the other energy sources and a pricing that favours electricity use during daytime. An analysis of the energy balance hour by hour with a typical variation in demand over the day and seasonal variation show that the power system can be in balance every hour of the year, mainly with daily variation in hydro-power production. This analysis is made for the project by INFORSE with the Energy Plan software from Aalborg University.

5.2. Total Primary Energy Demand

With the above assumptions, the 100% renewable energy scenario is expected to be as in the figure 11 for the BAU scenario and in figure 12 for the 100% renewable energy scenario.

Figure 12: Primary energy in the 100% renewable energy scenario. For geothermal electricity is only included electricity production, not waste heat

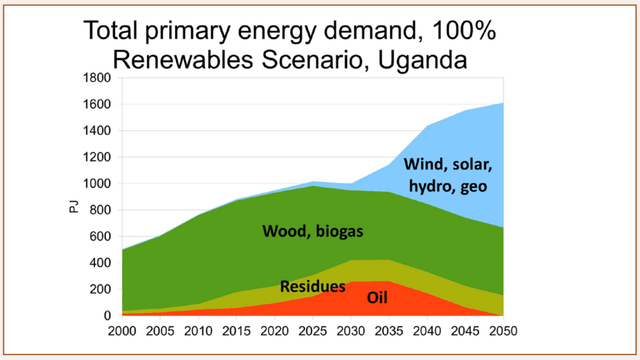
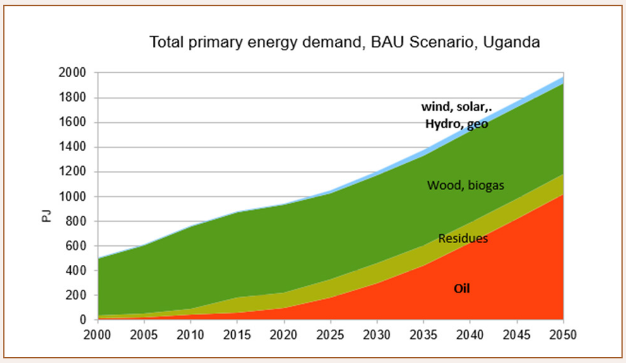


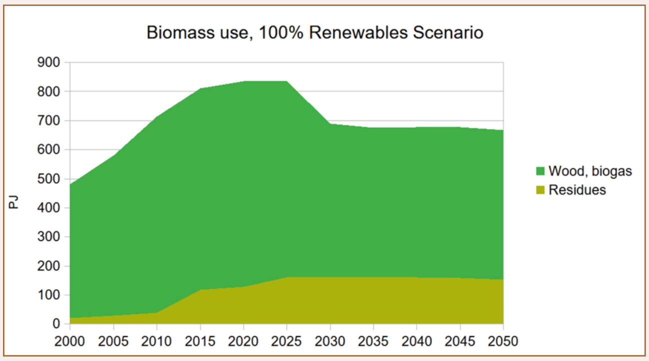
Figure 11: Primary energy demand in the BAU scenario



5.3. Biomass Sustainability

Uganda is using more wood than its sustainable level, leading to deforestation. In the 100% renewable energy scenario, this demand is reduced to the sustainable level, we have identified in 2.2.2. The development of wood use is shown in figure 13.

Figure 13: Development of biomass use in the 100% renewable energy scenario, with a return to a sustainable level of around 700 PJ, including residues and community planting, by 2030



5.4. CO2 Emissions from Energy

Ugandan CO2 emissions from fossil fuels are small today, but growing. In the BAU scenario they will continue to grow, while in the 100% renewable energy scenario, they will gradually be reduced until 2050. The developments are shown in figure 14.

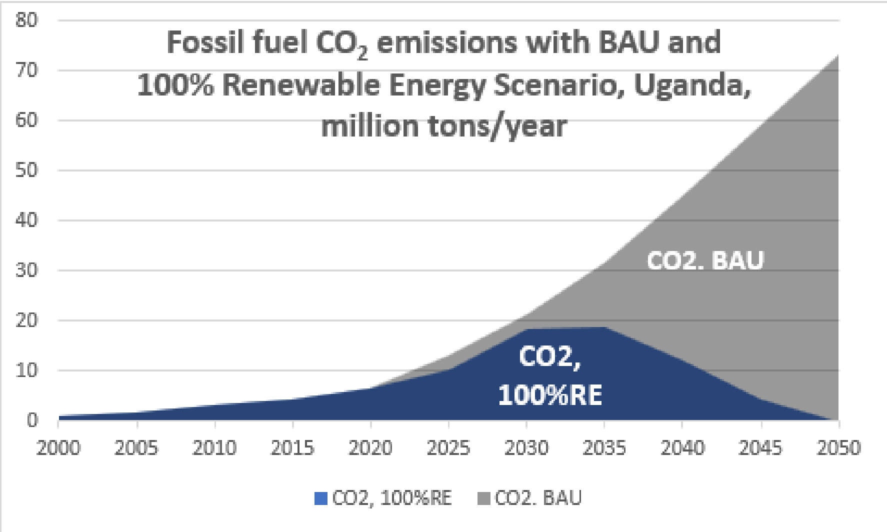


Figure 14: CO_2 Emmisions from fossil fuel in the BAU scenario and 100% Renewable Energy scenario in uganda.

Presently in Uganda, net emissions from unsustainable biomass use are much higher than emissions from fossil fuels, In the 100% renewable energy scenario, the net biomass emissions will be brought to zero by 2030 by tree planting, and the efficient cooking and heating technologies described above. The result is shown in figure 15 compared to the BAU Scenario in figure 16..

Figure 15: Total CO2 emissions in Uganda in the 100% renewable energy scenario from fossil and biomass energy use.

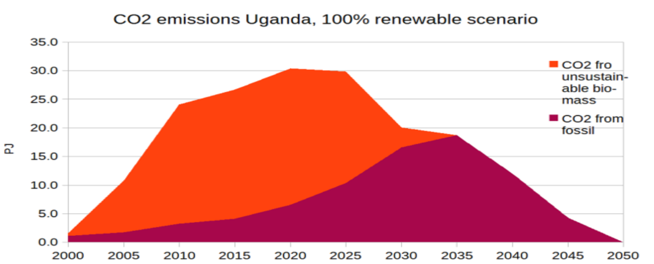
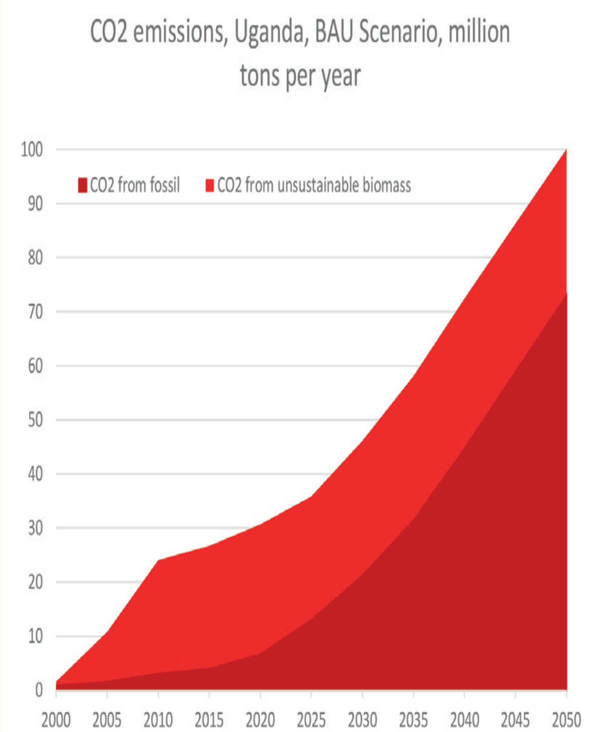


Figure 16: Total CO2 emissions in Uganda in BAU scenario from fossil and biomass energy use.



5.5. Scenario Economics

Future energy costs for the two scenarios is has been analysed based on official forecasts of technologies for renewable energy and for future costs of fuels, without the present (2022) price hikes in fossil fuels, The results are that the economy in the 100% renewable energy scenario is much better than the BAU scenario with lower energy costs and gradually less and less need for imports of fossil fuels into Uganda.

To illustrate the economy, we have made economic calculations for BAU and 100% renewable energy scenarios for 2030 and 2040. We choose the years 2030 and 2040 as cost estimates for 2050 are more uncertain than for the earlier years, even though only in 2050, the scenario reaches 100% renewable energy. The economic calculations are based on standard prices for technologies and international fuel prices. An oil price of 55 USD/barrel is used (2010-USD). An interest rate of 10% is used. See other economy figures in Annex A3.

The main results are in figure 17 and figure 18 below, showing the total costs of the energy supply respectively in 2030 and 2040, comparing the two scenarios. The higher costs in 2040 than in 2030 is because the energy demand is considerably higher in 2040.

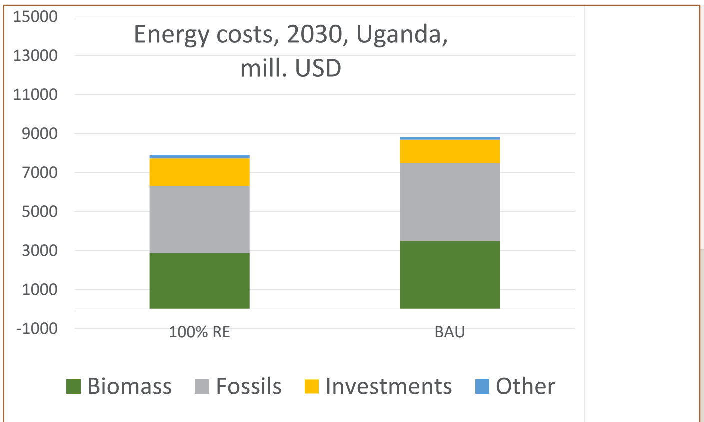


Figure 17: Total energy costs for Ugandan energy supply in 2030 in the two scenarios. The category "Other" includes operation and maintenance subtracted from a small income from sale of export power.

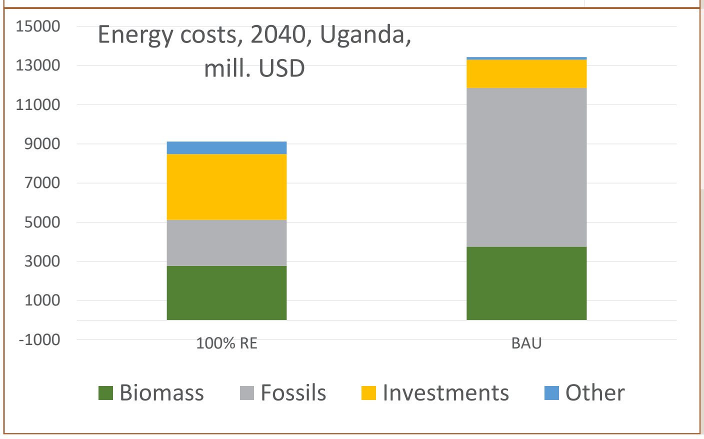


Figure 18: Total energy costs for Ugandan energy supply in 2040 in the two scenarios

It can be seen that the renewable energy scenario is cheaper, and the difference increases with time as the development get closer to 100% renewable energy. With higher oil prices and with lower interest rates than 10%, the economy would be even better for the 100% renewable energy scenario compared with BAU.

With the economic model, it is also possible to compare the costs of power in the renewable energy and the BAU scenario. The result is shown in figure 20 for the year 2040

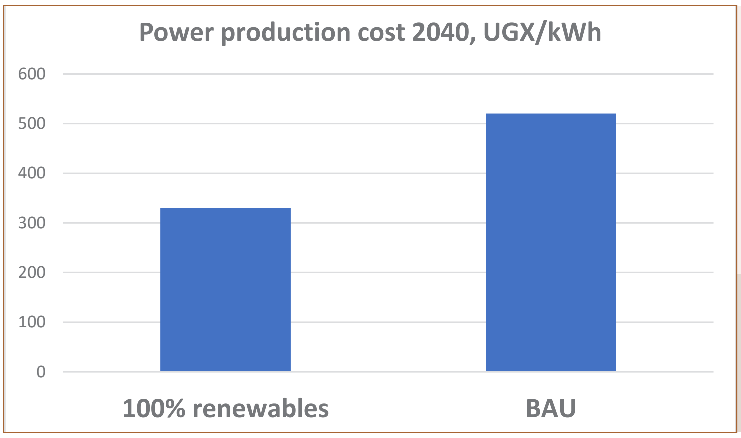


Figure 19 Power production costs in 2040 for the renewable energy scenario and the BAU scenario, in UGX/kWh, converted from USD with a rate of 1 USD = 3666 UGX

As shown in figure 19, the power costs are considerably lower in the 100% renewable energy scenario. The difference is because the renewable energy scenario has a mix of solar power, wind power, geothermal, and hydro, with in particular solar and wind being quite cheap while in the BAU scenario, power is mainly hydro-power, mainly from the already built or planned hydro power plants.

6. Key Challenges to the attainment of 100% RE Scenario

6.1. Political will:

If political will is low or is lacking, attainment of the 100% Renewable Energy Scenario remains in balance. The key question here is how the Government committed to attainment of a RE Future in the long run. For example a steady allocation of public finance alongside private inflows will be needed to ensure an increase the share of renewable energy in the national energy mix for the country, in the run up to 2050.

6.2. The Purchasing Power of Households:

The purchasing power of households remains very low – according to the Centre for Development Alternatives domestic customers of electricity increased by 17% from 2015 to 2016 while electricity sales grew by only 5% during the same time. The low purchasing power of households is tagged to their income levels, economic issues requiring an economic solution. A related issue is the cost of energy from the grid – which is out of reach of many Ugandans.

6.3. Technological Challenges:

Though rarely discussed, SID (2019), brings out this issue pointing out that East African countries still use 19th century and are poised to industrialise using 20th century models just when the global energy system is changing. They create a scenario where 'Mitumba' (second hand) machinery is used to develop large-scale power projects. (SID, 2018).

6.4. Environmental Degradation:

In Uganda the current rates of deforestation and Environmental Degradation are quite alarming. Studies conducted by Africa Natural Resources Institute indicate that forest cover loss is estimated at 200,000 hectares annually (Josepht M, 2018). Forests act as Water Towers that support water flows for hydro power generation. If the current levels of deforestation are not checked there is a likelihood of a negative effect on hydro power generation in future.

7.0. Actors and Recommendations

7.1 The Scenario Actors

In Uganda, individuals, groups, and/or institutions play different roles in influencing development policy and specifically the energy demand and supply. The choices they make or the decisions they take, often define the kind of future that they are likely to face. The key categories of players and their respective level of influence are as follows:

a) Government of Uganda

- The Ministry of Energy and Mineral Development (MEMD) is in charge of overall management of the energy and mineral sector. It formulates, implements and monitors policies.
- Uganda's Electricity Regulatory Authority (ERA) has a dominant role in regulating the electricity sector and issuing licences for energy generation. It is the sole actor responsible for transmission, distribution and sales of electricity and establishes an electricity tariff structure and tariff prices and changes.
- The Rural Electrification Agency (REA) is responsible for implementing the Rural Electrification Strategy and Plan to improve energy access rates in rural communities.
- The Uganda Electricity Transmission Company Limited (UETCL) is the country's system operator and sole actor for all transmission lines above 33 kV. UETCL is both a bulk supplier and the only buyer of power for the national grid and purchases all the power generated by IPPs in the country.
- National Forestry Authority – responsible for overseeing Uganda's forest estate (protected areas), some of which are under considerable human- induced stress in search of firewood, charcoal, timber and products
- Uganda Wildlife Authority – responsible for overseeing Uganda's wildlife that is in different ecosystems including protected forests, some of which are under considerable human- induced stress in search of firewood, charcoal, timber and products
- National Environmental Management Authority
- Local Governments
- Uganda National Bureau of Standards – level of involvement developing and setting standards for renewable energy devices like solar lamps, water heaters, etc.
- Intergovernmental Institutions like East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREEE), African Union

b) Private sector

- Large Industries / companies – investing in (renewable) energy projects
- SMEs – Research and development for improved biomass cook stoves
- Umbrella organisations like UNREEEA and its affiliates on Renewable Energy – influencing policy and plans

c) Schools, Hospitals, Army, Police and other current heavy biomass dependants

d) Development Partners that influence global and regional climate and energy policies as well as environmental standards

- Bilateral for example GIZ, UNDP, DANIDA, World Bank – financial support and technical assistance
- Multilateral agencies and processes – UNFCCC through its financing mechanisms like GCF, LDCF, etc.; UN CBD on nature-based solutions, World Bank that could impact on national energy policies and choices

e) Research Institutions like CREEEC – testing efficiency of devices that promote use of renewable energy options

f) Civil Society

- Individuals – consumer behaviour, choice of energy and spending patterns (determines their Carbon Footprints). Private forests are largely under their control
- Communities, cultural institutions and groups – culture and traditions determine the spatial and temporal energy forecasts. Private forests are largely under their control
- NGOs for example JEEP, RECSO Network, Environmental Alert, WWF Uganda, ECO, UCSD – public awareness, dissemination of improved biomass cook stoves, solar devices and technologies; influencing energy policy processes

7.1.1 The working terrain

The legal framework for renewable energy in the country is founded on the Constitution of the Republic of Uganda (1995, as amended) and specific laws and statutory instruments including the Electricity Act (1999) and the National Electrification Strategy (NES), which was concluded in 2022. These provide the regulatory framework for the electricity sub-sector and the Biofuels Act (2018) which regulates production, storage and transportation of biofuels and blending of biofuels with petroleum products. The Energy Policy (2002) is the primary policy framework for the country's entire energy sector, which the Government has continued to implement. Programmes such as the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, have also supported the development and implementation of the Energy Policy. (GIZ,2022).

The Renewable Energy Policy (2007) is the framework for renewable energy in the country. It is intended to increase the share of renewable energy in the national energy mix. The sector is governed by additional relevant sector policies including the Gender Policy (2007), Climate Change Policy (2015), Environment and Social Safeguards Policy (2018). The renewable energy sector in Uganda also subscribes to legal and policy frameworks of both regional and international scopes such as the Sustainable Development Goals, Sustainable Energy for All (SEforAll) and East African Community laws and policies.

The Government of Uganda, through the Ministry of Energy and Mineral Development (MEMD), is the lead institution overseeing the renewable energy sector in the country. MEMD works closely by implementing regulations, standards and quality together with stakeholders such as Electricity Regulatory Authority (ERA), National Environment Management Authority (NEMA), Directorate of Water Development (DWD), Uganda National Bureau of Standards (UNBS), Centre for Research in Energy and Energy Conservation (CREEC), Centre for Integrated Research and Community Development Uganda (CIRCODU) and Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA). Another critical player are the local governments, which have oversight of policy and co-ordination.

7.2 Policy recommendations

In order for Uganda to move towards **100% Renewable Energy by 2050**, there needs to be a supportive supportive agency and structure, which requires the following:

1. Development of plans with **a multistakeholder approach** to get the 100% RE Plan implemented at all levels from the grassroots (Local Councils) to the national level
2. **Grassroots communities need to be involved and sensitised** from the initial stages of energy projects to increase their participation in and contribution to the projects, as well as minimise the potential of conflicts or rejection of the energy technologies.
3. **Foster an enabling environment for private sector to play the crucial role** of investing capital and other resources into the energy sector, producing and selling energy technologies and products, consuming energy and thus generating government revenue.
4. **Civil society including non-governmental organisations (NGOs), the media and community-based organisations, play a critical role** in creating awareness, disseminating information, and serving as intermediaries for communicating needs, expectations, capabilities and culpability between society, government and the private sector should be highlighted and enabled. Civil society is instrumental in ensuring that social, economic and political obligations are met and any shortcomings brought to the limelight. Civil society helps in developing, implementing, monitoring, evaluating and reviewing the socio-economic and environmental impacts of the energy sector plans and programmes.
5. **The role of media to publicize information and articulate issues on the energy sector** should be supported so that they enable the population to understand issues related to the energy sector and to communicate these objectively, clearly and accurately.
6. **Research organizations and academia should** keep abreast of research developments regionally and internationally, and adopt best practices that are customised for the local situation.
7. **Local governments should take full responsibility for close supervision and monitoring of energy projects.** They should take full responsibility for promotion and implementation of government energy programmes such as energy efficiency programmes. They shall coordinate and supervise all energy utilities working in their localities to ensure good service delivery to the community. Leaders need to regularly report back to communities on their efforts to promote RE as part of development plans (often there is a communication gap).
8. **Government, CSOs and other actors should incorporate a sustainability plan in tree growing** - based on management objective / purpose (indigenous trees, fruit trees for nutrition purposes, etc.)
9. **Explore funding options** including climate funding and carbon credits in tree growing and efficient stoves.
10. **Central government should promote the efficient and sustainable use of energy in the country.** The government will create more favourable conditions for local enterprises to do energy business in the country including ensuring transparency and equity. For example, the legal and regulatory framework for developing energy activities and projects will be streamlined to attract more local private investors and operators, promote new energy projects and encourage innovative ideas.

11. **The Government should set up and ensure full implementation of standards for all energy systems, products and services**. It will ensure adherence to the standards for quality service.
12. **The Government should promote innovation and creative ideas in the energy sector.** It will enforce local manufacturing and appropriate fiscal policies promoting local manufacturing of systems and components, with emphasis on job creation.
13. **Development Partners should help the government through guidance and funding** to develop, implement, monitor, supervise and evaluate the policy.
14. **The Government should seek funding from development partners for specific programmes and/or projects** especially in areas less attractive to the private sector and complement self-help groups and private sector efforts in rural electrification projects.
15. **The development partners should be encouraged to provide or establish financial facilities for financing energy related projects at minimal interest rates** especially for renewable energy and energy efficiency projects.
16. **Multilateral agencies and processes need to focus on poverty reduction,** one way is through promotion of decentralized off-grid electricity in Uganda.
17. **Enable financial support to CSOs and other development partners to get the local solutions in more areas** (field demonstrations) across the country, especially interventions to counter the biomass over use

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A1.0. Current generation capacity of licensed plants under Operation (As of December 2019)

Name	Category	Purpose	Licensed Capacity_MW	Technology	District Located	Year Commissioned
Tibet Hima Mining Company – Mubuku I/ KML	Small Hydro	Grid supply	5.0	Small Hydro	Kasese	1956
Nalubaale Power Station	Large Hydro	Grid supply	180.0	Large Hydro	Buikwe	1954
Kasese Cobalt Company Limited-Mubuku III	Small Hydro	Grid supply	9.9	Small Hydro	Kasese	2008
Kiira Power Station	Large Hydro	Grid supply	200.0	Large Hydro	Jinja	2000
Jacobsen Thermal Plant	Thermal	Grid supply	50.0	Thermal (HFO)	Mukono	2008
Bugoye Hydro Limited- Mubuku II	Small Hydro	Grid supply	13.0	Small Hydro	Kasese	2009
Electromaxx Uganda Limit-ed	Thermal	Grid supply	50.0	Thermal (HFO)	Tororo	2010
Eco Power Uganda Limited-Ishasha	Small Hydro	Grid supply	6.4	Small Hydro	Kanungu	2011
Africa EMS Mpanga	Small Hydro	Grid supply	18.0	Small Hydro	Kamwenge	2011
Bujagali Energy Limited	Large Hydro	Grid supply	250.0	Large Hydro	Buikwe	2012
Hydromax Limit-ed – Buseruka	Small Hydro	Grid supply	9.0	Small Hydro	Hoima	2012
Access Uganda Solar Limited	Solar PV	Grid supply	10.0	Solar	Soroti	2016
Siti I Small Hydro Power	Small Hydro	Grid supply	5.0	Small Hydro	Bukwo	2017
Muvumbe hydro Limited	Small Hydro	Grid supply	6.5	Small Hydro	Kabale	2017
Tororo Solar North	Solar PV	Grid supply	10.0	Solar	Tororo	2017
Rwimi Hydro	Small Hydro	Grid supply	5.5	Small Hydro	Kasese	2017
Nyamwamba Hydro	Small Hydro	Grid supply	9.2	Small Hydro	Kasese	2018
Kakira Sugar Limited	Bagasse	Own use and grid supply	51.1	Cogeneration	Jinja	2009
Kinyara Sugar Limited	Bagasse	Own use and grid supply	14.5	Cogeneration	Masindi	2010
Sugar and Allied Industries Limited	Bagasse	Own use and grid supply	11.9	Cogeneration	Kaliro	2015
Sugar Corporation of Uganda Limited	Bagasse	Own use generation	9.5	Cogeneration	Buikwe	1998

Mayuge Sugar Limited	Bagasse	Own use generation	9.2	Cogeneration	Mayuge	2015
Nyagak 1 – WEN-RECo	Offgrid	Off Grid generation	0.0	Thermal (HFO)	Zombo	2002
Kalangala Infra-structure Services	Offgrid	Off Grid generation	1.0	Diesel	Kalangala	2015
Kalangala Infra-structure Services	Offgrid	Off Grid generation	0.6	solar	Kalangala	2015
Lubilia Small Hydro	Small Hydro	Grid supply	5.4	Small Hydro	Kasese	2018
Nkusi Small Hydro	Small Hydro	Grid supply	9.6	Small Hydro	Hoima	2018
Kisiizi Offgrid	Offgrid	Off Grid generation	0.360	Small Hydro	Rukungiri	2009
Kisiizi Offgrid	Offgrid	Off Grid generation	0.080	Diesel	Rukungiri	2009
Absolute-Kito-bo	Offgrid	Off Grid generation	0.23	Solar	Kalangala	2016
Bwindi Offgrid	Off Grid generation		0.064	Small Hydro	Kanungu	2014
Pamoja-Tiribogo	Offgrid	Off Grid generation	0.0	Biomass	Mpigi	2014
Pamoja-Ssekanyonyi	Offgrid	Off Grid generation	0.0	Biomass	Mityana	2014
Mahoma Hydro	Small Hydro	grid supply	2.7	Small Hydro	Kabarole	2018
Swam Offgrid	Offgrid	Off Grid generation	0.0	Small Hydro	Bukwo	2012
Waki HPP	Small Hydro	Grid supply	4.8	Small Hydro	Hoima	2018
Kabulasoke	grid connected			solar p.v power plant		
MSS Xsabo Power Limited	Solar PV	Grid supply	20.0	Solar	Kabulasoke	2018
Isimba HPP	Large Hydro	Grid supply	183.0	Large Hydro	Mukono	2019
Emerging Power U Ltd (Mayuge/ Bufulubi)	Solar PV	Grid supply	10.0	Solar	Mayuge	2019
Sindila (Butama)	Small Hydro	Grid supply	5.3	Small Hydro	Bundibugyo	2019
Siti II Small Hydro Power	Small Hydro	Grid supply	16.5	Small Hydro	Bukwo	2019
Ziba Limited (Kyambura)	Small Hydro	Gridsupply	7.6	Small Hydro	Rubirizi	2019
Ndugutu HPP	small Hydro	Grid supply	5.9	Small Hydro	Bundibugyo	2019
Achwa II	Large Hydro	Grid supply	42.0	Large Hydro	Bundibugyo	2019

Annex A2. General assumptions for scenario

This note includes the main assumptions for energy scenarios for Uganda by International Network for Sustainable Energy. This is development of population and economy and others.

Population

The population of Uganda has increased from 20 million in 1995 to 44 million in 2019. The population growth has increased in the period 3.0%/year in the period 1995 – 2000 to 3.7% since 2015. An estimation is that the population of Uganda will increase to 100 million in 2050, which is under the assumption that the growth rate will reduce gradually to just below 3.0%/year.[1]

This is one the highest population growth rates. In neighbouring Kenya, the population growth rate is around 2.1%/year and decreasing. If the growth rate in Uganda would decrease and follow the path of Kenya from 2025-2030, the population in 2050 would be 80 million.

Economic Growth.

The GDP of Uganda was 34.4 billion US$ in 2019, equal to a GDP/capita of 777 USD/capita. This places Uganda in the group of least developed countries, which include countries with GNI below 1025 US$ in 2018.
The economic growth has been variating in recent years according to World Bank, with individual years variating from -10% in 2016 to +13% in 2013. Part of this large variation might be statistical uncertainty, however. The average economic growth was 3,9% in the years 2010-2019.

If we assume no growth in 2020 because of Covid19 and an average growth of 4% thereafter, the GDP will grow to 109 billion US$ in 2050, equal to 1090 US$/capita.

This is a relative slow growth rate for a developing country. In neighbouring Kenya, the average economic growth was 5.7% since 2013.

In the scenarios, we will use 5%/year economic growth 2020 – 2050. This will make Uganda a middle-income country before 2050.

Grid losses

The electric grid loss was 29% of production in 2000 and was reduced to 21% in 2015. We assume that it will gradually be further reduced to 10% in 2050.

Charcoal Production efficiency

We estimate the conversion efficiency from wood to charcoal to have increased from 11% in 2000 to 12% in 2015 and that it will increase with improved technologies. The efficiency is expected to reach 15% in 2025, 20% in 2035 and 25% in 2045, where all charcoal will be produced in efficient ovens.

1] World Bank data, see https://data.worldbank.org/country/uganda?view=chart

Annex A.3 Development of energy Services and Energy Use in Uganda, 2000 – 2050

Note for scenario for 100% renewable energy Uganda, gbo, INFORSE Secretariat,

The general assumptions are that the population of Uganda increase to 100 million in 2050 (from 46 million today, end of 2020) while the GDP increases to 150 billion US$ (2010 US$), increasing 5%/year from 2020, where the GDP is estimated to 35 billion $. With these assumptions, the GDP/person will double and reach 1500 US$ per capita (2010 US$) and Uganda will move from the category of least developed countries to a middle-income country.

In the assumptions, the current average family size of 4.7 is maintained in the future.

Cooking in Household Sector

We assume that the development of energy services for cooking is developing with the population increase while the actual energy consumption is also depending on the increased energy efficiency with improved cookstoves and other modern cooking solutions.

For the action scenario, we assume that improved cookstoves that currently are used by 20% of the households continue to increase in use until 2040, where only 1% of population use traditional cooking, but the current improved cookstoves are combined with high-efficient cookstoves with twice the efficiency of current improved cookstoves and super-efficient electric cookers that increasingly are used throughout East Africa because of their low energy consumption. Also, biogas is used increasingly, increasing from 10,000 households today to 250,000 households in 2005, but this will be cover 1.2% of the population in 2050. With this development, today's efficient cookstoves will be replaced with the more efficiency solutions from 2035 to 2050. The resulting demands and efficiencies are given in the table below for the action scenario:

Table A3.1 Household cooking and its energy use, renewable energy scenario

Household cooking	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Household number, mill.	5,0	5,9	6,9	8,1	9,7	10,8	11,9	14,0	16,3	18,7	21,3
Household cooking demands	100	117	137	162	194	215	236	278	324	372	423
Improved cookstoves, mill.	0,01	0,1	0,2	1,0	2,0	3,5	6,5	7,5	7,5	2,9	0,2
Improved cookstoves %	0%	2%	3%	12%	21%	32%	55%	54%	46%	15%	1%
High-efficiency cookstoves, mill.	0	0	0	0	0	0,1	0,5	3	6	11,7	15,5
High-efficiency cookstoves,%	0%	0%	0%	0%	0%	1%	4%	21%	37%	63%	73%
Biogas cooking (families), mill	0	0	0	0,007	0,01	0,02	0,05	0,1	0,15	0,2	0,25
Biogas cooking (families), %	0%	0%	0,0%	0,08%	0,10%	0,2%	0,4%	0,7%	0,9%	1,1%	1,2%
Super efficient electric cooking, millions	0	0	0	0	0	0,1	0,6	1,4	2,4	3,7	5,3
Super efficient electric cooking, %	0%	0%	0%	0%	0%	1%	5%	10%	15%	20%	25%
Traditional cooking, %	100%	98%	97%	88%	79%	65%	36%	14%	1%	1%	0%

Average efficiency, all	10,0%	10,1%	10,2%	10,8%	11,4%	12,7%	17%	24%	35%	46%	58%
Specific demand, 2000 basis	100	99	98	93	88	79	59	41	29	22	17
Average, efficiency, solid biomass	10%	10%	10%	11%	11%	13%	16%	22%	31%	40%	49%
Specific demand, 2000 basis, solid biomass	100	99	98	93	88	80	62	45	32	25	20
LPG cooking	not included										
Solid biomass share of cooking	100%	100%	99%	99%	98%	98%	95%	89%	84%	79%	74%
Cooking demand covered with solid biomass, base 2000	100	117	136	160	190	210	224	248	272	294	312
Solid biomass demand for cooking, base 2000	100	116	134	148	166	167	138	111	88	73	63

In the business as usual (BAU) scenario, we assume that super-efficient electric cookers do not play a role and that the improved cookstoves, the high-efficient cookstoves as well as biogas are only introduced with half the success as in the action scenario. Given the slow introduction of more efficient alternatives, introduction of current models of improved cookstoves will continue, so the improved solutions replace around 80% of traditional fires in 2050, but then still 20% of the families will cook with traditional fires. This scenario is not a scenario without action, but it is a scenario that assumes that the Sustainable Energy for All targets will not be reached. Instead existing dissemination and market forces will gradually result in 80% of Uganda families using improved solutions in 2050. Without actions, this figure is likely to be lower.

The resulting demands and efficiencies are given in the table below for the BAU scenario:

Table A3.2 Household cooking and its energy use in the BAU scenario

Household cooking	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Household number, mill.	5.0	5.88	6.9	8.1	9.7	10.8	11.9	14.0	16.3	18.7	21.3
Household cooking demands	100	117.	137.	160	172	190.	210.	247	288	330	375
Improved cookstoves, mill.	0.01	0.1	0.2	1.0	2.0	2.9	4.7	5.7	7.1	7.3	9.0
Improved cookstoves %	0%	2%	3%	12%	21%	27%	39%	41%	44%	39%	42%
High-efficiency cookstoves, mill.	0	0	0	0	0	0	0.25	1.5	3	5.9	7.8
High-efficiency cookstoves,%	0%	0%	0%	0%	0%	0%	2%	11%	18%	32%	37%
Biogas cooking (families), mill	0	0	0	0.0065	0.01	0.015	0.03	0.06	0.08	0.1	0.13
Biogas cooking (families), %	0%	0%	0.0%	0.08%	0.10%	0.1%	0.3%	0.4%	0.5%	0.5%	0.6%
Super efficient electric cooking, millions	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0

Super efficient electric cooking, %	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Traditional cooking, %	100%	98%	97%	88%	79%	73%	58%	48%	38%	29%	20%
Average efficiency, all	10.0%	10.1%	10.2%	10.8%	11.4%	11.9%	13%	15%	17%	20%	22%
Specific demand, 2000 basis	100	99	98	93	88	84	75	67	59	51	45
Average, efficiency, solid biomass	10%	10%	10%	11%	11%	12%	13%	15%	17%	20%	22%
Specfic demand, 2000 basis, solid biomass	100	99	98	93	88	84	75	67	59	51	45
LPG cooking	not included										
Solid biomass share of cooking	100%	100%	99%	99%	98%	99%	100%	100%	100%	99%	99%
Cooking demand covered with solid biomass	100	117	136	158	168	188	209	246	286	328	373
Solid biomass demand for cooking	100	116	134	147	148	158	156	165	169	168	168

In the BAU scenario, wood use will increase from 284 PJ in 2020 to 320 PJ in 2050, including 20 PJ from energy plantations while use of residues will continue around present level (around 30 PJ). The charcoal demand will increase slightly from 36 PJ today to 44 PJ in 2050. As the BAU scenario does not include electric cooking, LPG will grow, but only to 8 PJ in 2050 from currently 1.2 PJ.

In the action scenario, wood use will decrease to 130 PJ, residues use to 3 PJ and charcoal to 3 PJ, but there will additional electricity use for cooking around 20 PJ, assuming the use of the super-efficient cookers.

The demands in 2010 and 2015 varies a up to 2 percentage point from these tables in the scenarios due to statistical variations between the actual development of energy and the population increase.

Electricity Demand in the Household Sector

The demand in households for light and other energy services driven by electricity is increasing faster than population or GDP. We have estimated that the electricity demand is households will follow 1.2 times population + 2.45 times GDP. This corresponds with actual increase 2011-2018 according to statistical data with a correlation of 99.4%. Since then, the Uganda Power Sector Investment Plan 2015 has started implementation, which is expected to lead to larger increases of household electricity demand until 2030 in parallel with an implementation plan to achieve universal access to electricity for households until 2030. We will use the stronger increase 2015-2030 included in these plans and then from 2030 when households has universal electricity access continue with the growth of 1.2 times population + 2-45 times GDP until 2050.

In this way these services will be 8 times larger in 2050 than in the year 2020. As the energy efficiency is also increasing rapidly, for instance with LED lamps and others, the electricity consumption will not increase that much. The efficiency is expected to increase a factor 2,7 from 2020 to 2050. With these assumptions, the increase in household electricity 2020-2050 will be a factor 3

The basic electricity demand and the efficiency increases are the same in the action scenario and the BAU scenario, but in the action scenario is the additional electricity demand for the super-efficient cookers.
The resulting demands and efficiencies are given in the table below for both scenarios.

Table A3.3 Household electricity demand, not including cooking, relative to year 2000 for both scenarios

Households, electricity	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Light and electricity service demand	100	148	184	324	468	757	1113	1601	2206	2953	3882
Electricity, specific demand	100	100	95	82	68	58	49	42	35	30	25
Electricity demand	100	148	175	266	319	437	547	669	783	891	970

While table A3.3 gives the demand relative to 2000, the actual demand will increase to 8 PJ in 2050 from 2.5 PJ today.

Cooking and Fuel Demand in the Service sector

The main fuel consumption in the service sector (private and public services combined) is wood (90%), followed by charcoal (8%). As statistics are not reliable enough to develop a trend, we will assume that in the service sector, the fuel consumption develop similar to household sector, based on a service sector fuel consumption of 50 PJ in 2020. The energy service demand is then increasing with population while efficiency increases as in the household sector, both for the action scenario and for the BAU scenario.

In the BAU scenario the use of wood and charcoal will remain constant at respectively 42-44 PJ and 4.5-5 PJ. As electric cooking is not introduced, the use of fossil fuel (LPG) is likely to grow, in the scenario we include a growth from 1.6 PJ today to 4 PJ in 2050.

In the action scenario the wood use will be reduced to 17 PJ and the charcoal use to 1 PJ while the electricity for cooking with the super-efficient cookers will be 8 PJ.

Electricity Demand in the Service Sector

The demand in service sector for light and other energy services driven by electricity is increasing faster than population or GDP. We will use the estimation that electricity services in households will follow 1 times population + 7.4 times GDP from 2010. This corresponds with actual increase 2011-2018 according to statistical data with a correlation of 99.4%. In this way these services will be 17,7 times larger in 2050 than in the year 2020. As the energy efficiency is also increasing rapidly, for instance with LED lamps, the electricity consumption will not increase that much. The efficiency is expected to increase a factor 4 from 2000 to 2050, including a 38% increase 2000 – 2020. With these assumptions, the increase in service sector electricity demand 2020-2050 will be a factor 6,5

The demand and the efficiency are the same in the action scenario and the BAU scenario, when the electricity demand for cooking in the action scenario is not included.

The resulting demands and efficiencies are given in the table below for both scenarios.

Table A3.4. Electricity demand in service sector, relative to 2000

Service sector	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Light and electricity service demand	100	135	184	328	402	967	1679	2616	3796	5281	7154
Electricity, specific demand	100	100	95	82	68	58	49	42	35	30	25
Electricity demand	100	135	175	269	273	559	825	1092	1347	1593	1789

Service sector	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Light and electricity service demand	100	135	184	328	86	207	360	560	813	1131	1532
Electricity, specific demand	100	100	95	82	68	58	49	42	35	30	25
Electricity demand	100	135	175	269	59	120	177	234	289	341	383

Industrial Fuel Demand

The main energy use in industry is biomass in the form of biomass and residues, 90%, while the remaining is fossil fuels. The fuel demand more than a doubed 2010-2018 and as the energy efficiency is also increasing, the energy service demand was increasing faster. We will assume that energy efficiency can increase 2.5 times from 2000 to 2050 and that it already has increased 23%. The best correlation between data for 2011-2081 and GDP is that energy service demand for fuel increases 4.8 times GDP increase. The correlation is 89%.
With these assumptions, the development in industry fuel demands will be as in the table below, with development 2000 – 2020 based on statistics and trend 2018-2020.

In the BAU scenario, there is a strong growth that we in the BAU scenario cover with increase of wood use in industry from 53 PJ in 2018 to 169 PJ in 2050 while the use of residues will grow from 92 PJ in 2018 to reach a limit of residues of 125 PJ (with around 30 PJ is used in household sector and for power, leaving 125 PJ for industry). As the limit of residues is reached and the use of wood is also limited, in the BAU scenario, energy for further expansion is met with fossil fuels in the form of fuel oil. With this assumption, the oil use will increase from 16 PJ in 2018 to 770 PJ in 2050. The provision of this oil will be quite costly, covering over 5% of the GDP in 2050 (with a fuel cost of 11 USD/GJ) compared with less than 1% today. It is likely that instead industrial development will be slower than in the past in a BAU scenario, given the high energy costs.

The demand and the efficiency are the same in the action scenario and the BAU scenario, but in the action scenario, some of the fuel demand is replaced with electricity in heat pumps and in electric motors to replace combustion engines. In this way, one unit of electricity can replace in 2-4 units of fuel with the highest efficiencies for low temperature heat and for traction. We include that 60% of the fuel demand can be replaced with electricity in 2050. Also, we include that 10% of the fuel can be replaced with solar heating. The remaining 30% is then covered with biomass as today.

The resulting demands and efficiencies are given in the table below, but the table does not include the replacement of fuel with electricity and solar heating. The electricity in the action scenario to replace fuels is reaching 337 PJ in 2050.

Industrial Electricity Demand

The demand in the industrial sector for energy services driven by electricity is increasing faster than population or GDP. We will use the estimation that electricity services in households will follow 2.4 times GDP from 2010. This corresponds with actual increase 2011-2018 according to statistical data with a correlation of 98.3%. In this way these services will be 37 times larger in 2050 than in the year 2000, but as they have already increased 4.4 times until 2020, the increase from today to 2050 will be 8.6 times. As the energy efficiency is also increasing rapidly, for instance with motor regulations, the electricity consumption will not increase that much. The efficiency is expected to increase a factor almost three times from 2000 to 2050, including a 23% increase 2000 – 2020. With these assumptions, the increase in industrial electricity demand 2020-2050 will be a factor 4.

The demand and the efficiency are the same in the action scenario and the BAU scenario.
The resulting demands and efficiencies are given in the table below for both scenarios. The table also includes development of industrial fuel demand.

Table A3.5 Energy use and energy efficiencies in industrial sector

Industry sector	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Industry energy service demand for fuels	100	332	702	1484	1652	3345	5505	8261	11780	16270	22001
Fuel, specific demand	100	95	90	85	75	69	62	56	50	45	40
industry fuel demand	100	315	632	1261	1239	2308	3418	4617	5925	7366	8800
Industry energy service demand for electricity	100	143	195	290	436	711	1061	1507	2078	2806	3735
Electricity specific demand	100	95	90	85	77	67	59	52	46	40	36
Industry electricity demand	100	135.85	176	247	334	478	628	786	953	1133	1327

In this way, the electricity demand will increase from 7.6 PJ today to 30 PJ in 2050, excluding the electricity used to replace fuel in the action scenario.

Agriculture

There is some use of fossil fuel use in the sector of agriculture and fisheries. There is also consumption of other forms of energy in agriculture, but as that has not been reported in statistics for the agricultural sector, we assume that it is reported for other sectors.

The fossil fuel consumption is increasing, and we assume that it is increasing with 3.6 times GDP, based on statistics 2011-2018 with a correlation of 69%. We assume that this increase in energy services in agriculture continues until 2050 and that there is an efficiency increase of 30% 2020-2050.

For the action scenario, we also assume that after 2030, the energy use is gradually changed to electricity and that this gives an efficiency increase of 3.7 times. From 2035, a smaller part is covered by hydrogen or electrofuels in fuel-cell driven equipment . With the development we assume that in 2050, 80% of the agricultures energy service demand is covered by electricity and 20% by hydrogen /electrofuels.
The development of energy service and fuel demand relatively to 2000 is given in the table below.

Table A3.6 Agricultural energy demand and efficiencies, relative to 2000

Agriculture and Fishery, BAU	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Traction etc. demand	100	210	381	728	949	1734	2736	4015	5648	7731	10390
Specific demand	100	100	100	100	100	95	90	85	80	75	70
Fuel demand, BAU	100	210	381	728	949	1647	2463	3413	4518	5798	7273

The oil demand will increase from 9.5 PJ today to 59 PJ in the BAU scenario for 2050 while in the action scenario, it will be replaced with 16 PJ electricity and 7 PJ hydrogen in 2050.

Road Transport

We do not have division of the transport sector in personal transport and freight transport, so we will analyse road transport trends as a combination of freight and personal transport. All land transport is by road, there are no railways in Uganda.

While there is no blending of biofuels in transport fuel today, there are plans of starting a blending. We assume blending to start until 2025 with 0.4% increasing to 0.8% in 2040 and in the BAU scenario 1% in 2050. The increase in transport demand correlated with 1.86 times of the increase in GDP with a correlation of 99% for the years 2011-2018. We will assume that this increase continues until 2050 in both scenarios and for the BAU scenario that there will be an increase in efficiency of 30% 2020 – 2050.

This give the following development of transport and fuel use for transport in the BAU scenario, with demand in 2010 and 2015 adjusted to statistics

Table A3.7 Road transport and fuel demand in the BAU scenario, relative to year 2000

Transport, BAU	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport demand	100	137.	223	307	331.	491.	696.	956.	1288.	1713	2254.
Fossil transport share	100%	100%	100%	100%	100%	99.6%	99.4%	99.3%	99.2%	99.1%	99.0%
Bio transport share	0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.6%	0.7%	0.8%	0.9%	1.0%
Transport specific demand	100	100	100	100	100	95	90	85	80	75	70
Transport fossil fuel	100	137.	223	307	331.	465.	622.	807.	1022	1273.	1562

With this scenario, oil use in road transport will increase from 40 PJ today to 184 PJ in 2050 of which 1.5 PJ will be liquid biofuels.

For the action scenario, we assume that there will be introduction of electrical vehicles to cover 10% of transport in 2030 and 75% in 2050. We also assume that there will be introduction of hydrogen or electrofuels in fuel cell vehicles, covering 10% of demand in 2040 and 24% in 2050.

This gives the below energy demand for road transport for the action scenario:

Table A3.8 Road transport and road fuel demand, renewable energy scenario

Transport, action	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Transport demand	100	137	223	307	332	492	696	957	1289	1713	2255
Fossil transport share	100%	100%	100%	100%	100%	100%	89%	74%	44%	25%	0%
Bio. transport share	0%	0%	0%	0.0%	0.0%	0.4%	0.6%	0.7%	0.8%	0.7%	0.6%
El.transport share	0%	0%	0%	0%	0%	0%	10%	25%	45%	57%	75%
H2 transport share	0%	0%	0%	0%	0%	0%	0%	0%	10%	17%	24%
Transport, specific demand	100	100	100	100	100	95	83	69	52	42	31
TRansport fossil fuel	100	137	223	307	332	465	560	604	456	325	0
Transport electricity	0	0	0	0	0	0	17	60	145	244	423
Transport Hydrogen	0	0	0	0	0	0	0	0	64	146	275

With the renewable energy scenario, the fossil fuel use will be replaced with 34 PJ electricity and 22 PJ hydrogen as well as 1 PJ liquid biofuel, while the transport volume will be the same as in the BAU scenario.

Other Transport, Navigation.

There is some navigation in Uganda, on lake Victoria and on other lakes and rivers. We assume that the development of demands and efficiencies for navigation follow road transport in the BAU scenario.
In the action scenario, we assume that the navigation will be electrified, starting with 10% in 2030 and fully electrified in 2050.

In the BAU scenario, the oil use will increase from 2.2 PJ today to 15 PJ in 2050 while in the action scenario, it will be replaced with 3.7 PJ electricity in 2050.

We include 1000 MW international interconnectors in the scenarios.

We do not include aviation in the scenarios.

There are no pipelines in Uganda, so we do not include pipeline transport

Annex A4: Economic parameters

The economic calculations in chapter 5 are based on economical and technical data for power supply technologies, power lines, and fuels.

The Table A4.1 gives the costs used for power and hydrogen production plants while Table A4.2 gives costs of energy storages, Table A4.3 gives costs of biogas plants, and A4.4 give costs of interconnectors.

Table A4.1 Cost parameters of power and hydrogen production units used in scenario

Power & H2 plants	Invest for use 2030	Invest for use 2050	Fixed O&M 2030	Fixed O&M 2050	Var O&M 2030	Var O&M	Sources
	mill USD/ MWe	mill USD/ MWe	% of invest	% of invest	USD/MWh	USD/MWh	EPT line
Large power plants, biomass	1,90	1,82	1,63	1,64	3,0	3,2	109-111
Windpower	1,06	1,02	3,24	3,34	0	0	132-134
PV-power, large	0,84	0,69	1,30	1,30	0	0	144-146
Hydro-power	2,53	2,55	1,25	1,25	3,3	3,3	170-172
Geothermal power	4,72	4,04	1,70	2,00	1,8	2,2	182-184
H2-electrolysis	0,58	0,53	5,00	5,00	0	0	239-241

Table A4.2 Cost parameters for energy storages in the form of water storages (dams) at hydro-power plants and hydrogen storages

Storages	Invest for 2030 use mill. USD/ GWh	Invest for 2050 use, mill. USD/ GWh	Fixed O&M 2030 % of invest	Fixed O&M 2050 % of invest	Var O&M	Sources	
Hydro-storage	7,50	7,50	1,50	1,50	0	174-176	
H2-storage	n.a.	7,00	n.a.	2,32	0	250-251	

Table A4.3 Costs of biogas plants

Biogas	mill. USD/ TWh gas/ year	mill. USD/ TWh gas/ year	% of invest	% of invest	Var O&M	Var O&M	Sources
Biogas plant	185,92	167,61	11,00	11,50	0	0	202-204

Table A4.4 Cost of interconnectors

	Invest for use 2030 USD/MWh	Invest for use 2050 USD/MWh	Fixed O&M % of invest	Variable O&M	Sources	
Interconnectors, 1000 km	1,19	1,07	1,50	0	EU JRC	

For the 2030 scenarios, the 2030 data are used. For the 2040 scenarios, the average between the 2030 and the 2040 data are used.

The sources for the information are:

Energy Plan Cost Database 4.0, Oct. 2018, the numbers indicate the line numbers in the database

EU Joint Resource Center (EU JRC), where costs in € are converted to USD with a factor 1 USD = 0,9 €, link https://publications.jrc.ec.europa.eu/repository/handle/JRC92496

For fuel costs, we use the costs in Table A4.5 and for fuel handling costs that should be added to the fuel costs, we use costs in Table A4.6

Table A4.5 Fuels costs without distribution costs.

Fuel costs	2030	2050		Source
Charcoal	13,9	12	USD/GJ	See note below
Fuel oil	9,6	10	USD/GJ	IEA Current policy Scenario 2018
Diesel oil	17	17,7	USD/GJ	IEA Current policy Scenario 2018
Petrol	22,5	25,2	USD/GJ	IEA Current policy Scenario 2018
Gas	22	22	USD/GJ	LPG gas, own estimate
Dry biomass	0,35	0,42	USD/kg	Wood, study for Vietnam
	2,5	3	USD/GJ	Wood, rice husk, study for Vietnam
Wet biomass	0	0	USD/GJ	

Charcoal price is biomass price divided by efficiency in charcoal production: 18% in 2030, 23% in 2040, 25% in 2050. For 2040 is used average of 2030 and 2050 biomass price divided by 23%, resulting in 12 USD/GJ (similar to 2050)

Study for Vietnam is "Fuel Price Projections . Bacground to Vietnam Energy Outlook 2019, EREA & DEA, available from https://ens.dk/sites/ens.dk/files/Globalcooperation/fuel_price_projections.pdf
Wet biomass is input for biogas plants, as manure, sludge.

Table A4.6 Fuel distribution costs to different users own estimate based on EnergyPlan data, see www.energyplan.eu.

USD/GJ	Households	Service	Industry	Transport
Charcoal	3	3	1,9	n.a.
Fuel oil	n.a.	n.a.	1,9	n.a.
Diesel oil, petrol	2,1	2,1	n.a.	2,1
Biomass	3	3	1,2	n.a.

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ISBN: 978-87-970130-7-6