UGANDA TECHNOLOGY NEEDS ASSESSMENT REPORT FOR MITIGATION

NOVEMBER 2019

TECHNOLOGY NEEDS ASSESSMENT REPORT

Abbreviations and Acronyms

ACODE	Advocates' Coalition on Development and Environment
BAEF	Barrier Analysis and Enabling Framework
BAU	Business as Usual
BIPV	Building Integrated Photovoltaic
CC	Climate Change
CCD	Climate Change Department
CCFL	Cold Cathode Fluorescent Lamp
CRT	Cathode Ray Tube
CTCN	Climate Technology Centre & Network
EIs	Educational Institutions
FID	Final Investment Decision
FIT	Feed-in-tariff
GEF	Global Environment Facility
GET-FiT	Global Energy Transfer Feed-in-Tariff
GHG	Greenhouse Gas
IHA	International Hydropower Association
INDC	Intended Nationally Determined Contribution
Ktoe	Thousand Tons of Oil Equivalent
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPG	Liquified Petroleum Gas
LULUCF	Land use, land use change and forestry
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MCA	Multi-Criteria Analysis
MEA	Multilateral Environmental Agreements
MEMD	Ministry of Energy and Mineral Development

MoES	Ministry of Education and Sports
MFPED	Ministry of Finance, Planning and Economic Development
MoGLSD	Ministry of Gender, Labour and Social Development
MOSTI	Ministry of Science, Technology and Innovation
MtCO2eq	Metric tons of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWE	Ministry of Water and Environment
NAMAs	Nationally Appropriate Mitigation Actions
NBI	Nile Basin Initiative
NDC	Nationally Determined Contribution
NDE	National Designated Entity
NDP	National Development Plan
NEMA	National Environment Management Authority
NPA	National Planning Authority
OPM	Office of the Prime Minister
PV	Photovoltaic
PVT	Private
REBI	Renewable Energy Business Incubator
REDD	Reducing Emissions from Deforestation and Forest Degradation
R&D	Research and Development
SDG	Sustainable Development Goal
SHS	Solar Home System
SNC	Second National Communication
TAP	Technology Action Plan
TFS	Technology Fact Sheet
TWh	Terawatt-hours
TNA	Technology Needs Assessment

UGGDS	Uganda Green Growth Development Strategy
UNBS	Uganda National Bureau of Standards
UNCCP	Uganda National Climate Change Policy
UNCST	Uganda National Council for Science and Technology
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
UNREEEA	Uganda National Renewable Energy and Energy Efficiency Alliance
USD	United States Dollars
USEA	Uganda Solar Energy Association

Executive Summary

Uganda has contributed little to the potentially catastrophic build-up of the human-derived greenhouse gases (GHG) in the atmosphere and yet the country is among the most vulnerable to global warming and climate change impacts. Similar to other developing countries, Uganda needs to utilize adequate clean energy technologies for its development as well as to mitigate the impacts of climate change; however, these technologies are inadequate and most are inefficient. The objectives of the TNA project are:

- To identify and analyse through a country-driven process, climate change mitigation and adaptation technology priorities for Uganda, the energy sector was selected for mitigation technologies.
- To identify, analyse and address the barriers hindering the deployment and diffusion of the prioritized technologies including enabling the framework for the said technologies
- To prepare Technology Action Plans (TAP) to support implementation of the prioritized technologies within the country to achieve the climate and development benefits.

The project is coordinated by Uganda National Council for Science and Technology (UNCST). The institutional set up is made up of the Steering Committee, National Coordinator, Sectoral Working Groups and the mitigation and adaptation National Consultants. For technology prioritization to be done effectively, existing national policies on climate change mitigation and development priorities were reviewed because they affect the criteria for selection of technology options. These included Uganda's Vision 2040; Nationally Determined Contribution, National Climate change Policy (2015); Second National Development Plan (NDP II) 2015/16 - 2019/2020 (2015); Uganda Green Growth Development Strategy (UGGDS), 2017/18 – 2030/31; Second National Communication and the Renewable Energy Policy 2007-2017.

The technology prioritization process involved development of Technology fact sheets (TFS) for eight technologies and holding of a stakeholder's prioritization workshop on 27th and 28th June 2019. Technology prioritization was done by the stakeholders working together with the mitigation consultants using the Multi-Criteria Analysis tool. The criteria used were; Costs, Benefits (economic, social and environmental), Technology and Institutional considerations. Weights were added under each technology option and criteria based on their importance as per the stakeholder's opinions. Using the total scores, the stakeholders ranked the technology options from the highest scored to the lowest and selected the three (3) highest ranked technology options as: Solar rooftop systems, Efficient institutional cook stoves and Bio-latrines for institutions (using biogas technology). The next step will be to identify, analyse and address the barriers hindering the deployment and diffusion of the prioritized technologies including enabling the framework for the said technologies.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

1.1 About the TNA project

The TNA project implementation in Uganda effectively commenced in February 2019 following the 1st Regional Training Workshop which took place in Entebbe, Uganda. During this workshop the consultants and National Coordinators were trained in selecting and prioritizing technologies for mitigation & adaptation using the Multi-Criteria Analysis (MCA) tool, stakeholder engagements during the prioritization to promote national ownership and understanding of the TNA, ensuring a gender responsive TNA, the process of reporting the outcomes in the "Technology Needs Assessment (TNA)", familiarization with database support – Climate Techwiki, Guidebooks and Helpdesk facility, overview of climate finance and Climate Technology Centre and Network (CTCN) Support for Technology Needs Assessment.

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1.2 Existing national policies on climate change mitigation and development priorities

These are the starting points of the TNA project, which affect the criteria and decisions for sector and technology prioritisation, as well as the setting of technology deployment targets.

Uganda is signatory to the United Nations Framework Convention on Climate Change (UNFCCC), ratified the Kyoto Protocol and is a party to a number of Multilateral Environmental Agreements (MEAs) that have strong links with climate change. This section highlights Uganda's national policies and development priorities on climate change mitigation.

(a) Vision 2040

Uganda's Vision aspires to change the country from a predominantly low income to a competitive upper middle-income country within 30 years with a per capita income of USD 9,500. It builds on the progress that has been made in addressing the strategic bottlenecks that have constrained the country's socio-economic development since her independence.

For several decades, development has concentrated on improvement and advancement of economic, socio-cultural and political conditions and less on preserving the environment. This has resulted into global warming and other adverse environmental conditions associated with climate change. The Vision recognizes that climate change affects all sectors of Uganda's economy, making the need for preparedness inevitable through adaptation and mitigation strategies in all sectors to ensure that the country is resilient to the adverse impact of climate change. In addition, developing guidelines for incorporating climate change in sectoral and local government plans and budgets is recognised. Due to climate change, emphasis will be on other renewable forms of energy including; wind, solar and biogas which will be harnessed and promoted. Government will invest in research and development (R&D) and provide incentives to encourage use of renewable energy.

Climate Change affects infrastructure through washing away of bridges, prolonged droughts reducing water levels thus affecting the volume of water required to run the turbines that produce hydroelectricity, floods result into epidemics like cholera and malaria while high temperatures affect the productivity of temperature sensitive crops like coffee and cotton. This implies that sectors and Local Governments must plan to adapt to climate change while undertaking mitigation measures in some cases. Critical measures to prevent erosion of climate security, including viable food production and personal health need to be assured. Over the Vision 2040 period, Government will develop appropriate adaptation and mitigation strategies on Climate Change to ensure that Uganda is sufficiently cushioned from any adverse impact brought by climate change. The use of the guidelines for incorporating climate change in sector and local Government plans and budgets will be popularized.

The Vision asserts that appropriate adaptation and mitigation strategies on climate change will be developed in all sectors to increase the country's resilience to the impacts of climate change. To this effect, knowledge and information sharing with the relevant stakeholders on climate change and variability will be the starting point in this endeavor. Government will develop policies and organizational structures to address climate change. Emphasis will be on strengthening coordination systems at both national and local levels and building the capacity of local governance and decision-making bodies. In addition, enabling strategies with legal instruments will also be put in place. Government will increase capacity to cope through upsurge of funding to climate change initiatives in a bid to reduce the level of vulnerability. This will be through liaison with development partners who will be identified and programs developed to strengthen partnership arrangements. Government will continue to participate in, and benefit from, international arrangements on climate change and variability and in particular focus on how to tap on the available global climate change funding mechanisms. A comprehensive Monitoring and Evaluation mechanism to observe the implementation of national guidelines will be established. The strategy will have clear milestones and analytical tools

b) Nationally Determined Contribution (MWE, 2015)

Uganda has contributed little to the potentially catastrophic build-up of the human-derived greenhouse gases (GHGs) in the atmosphere and yet the country is one of the most vulnerable to global warming and climate change impacts. The country's greenhouse gas (GHG) emissions per capita is estimated at 1.39 tonnes carbon dioxide (MWE, 2015), far below the global average of approximately 7.99 tonnes of carbon dioxide (MWE, 2015). Furthermore, Uganda's contribution to the world's total green-house gas emissions is estimated at 0.099% (MWE, 2015). Despite having one of the lowest GHG emissions per capita in the world, Uganda resolved to respond to the call by the global community to initiate domestic preparations for nationally determined contributions towards curbing temperature rise to below 2°C by the end of the century.

Uganda's priority is adaptation; the country will continue to work on reducing vulnerability and addressing adaptation in agriculture and livestock, forestry, infrastructure (with an emphasis on human settlements, social infrastructure and transport), water, energy, health and disaster risk management. For mitigation, Uganda is to focus on implementation of a series of policies and measures in the energy supply, forestry and wetland sectors. In the business-as-usual (BAU) scenario the estimated emissions in 2030 will be 77.3 million tons of carbon dioxide equivalent per year (MtCO2eq/yr). The estimated potential cumulative impact of the policies and measures could result in approximately 22% reduction of national greenhouse gas emissions in 2030 compared to business-as-usual. Uganda proposes to implement the identified policies and measures, and their impact may be higher or lower than these estimations illustrate.

For energy Uganda will focus on:

- Increasing the efficiency in the use of biomass in the traditional energy sector
- Promoting renewable energy and other energy sources
- Increasing the efficiency in the modern energy sector, mainly of electricity
- Ensuring the best use of hydropower by careful management of the water resources
- Climate proofing investments in electricity power sector

The Nationally Determined Contribution energy sector measures will increase the amount of renewable energy capacity by at least 1,100 Mega Watts compared to business- as- usual by 2030, generating an estimated 4.6 - 5.2 Terawatts (TWh) (billion watts) more than in the business-as-usual scenario case. Technologies include hydro, solar, biomass and geothermal. The mitigation impact is forecast to be between 2.7 million tons Carbon dioxide equivalent per year (MtCO2e/a) and 3.7 MtCO2e/a. The mid-point is taken as 3.2 MtCO2e/a.

The Government of Uganda will continue to commit resources to climate change-relevant strategies. However, the full implementation of these actions is conditional on the support of international community coming from both climate finance instruments and international market mechanisms.

c) Uganda National Climate Change Policy (MWE, 2015)

The policy recognizes that climate change is one of the greatest challenges facing humanity in the century, as the Earth's near surface temperatures continue to rise. Climate change is likely to disrupt the Earth's ecological systems and have serious negative consequences on agricultural production and productivity, forests, water supply, health systems and overall human development. Vulnerable populations (mainly the poor and most marginalised, including children, women, older persons and people with disabilities in developing countries) are particularly poorly equipped to cope with the adverse impacts of climate change. As temperatures throughout East Africa rise, precipitation is expected to increase, along with the frequency and intensity of droughts, floods, heat waves and landslides. Scientists predict that the rate of climate change will be more rapid than previously expected. Uganda, one of the countries that makes up the East Africa block has started experiencing the latter mentioned effects of climate change. Climate change impacts will be economically significant, especially for African countries, and investment to address climate change is well worth undertaking. Climate change is likely to impact on Uganda's macroeconomic stability and socioeconomic development, as well as its ability to achieve the Post 2015 Development Agenda. Key production sectors most affected by climate are agriculture, water, energy and transport. As agriculture, forestry and fisheries decline, people migrate to urban areas leading to the formation of slums.

This policy is Uganda's integrated response to climate change. This policy provides direction for key sectors and stakeholders to facilitate adaptation, mitigation and strengthen efforts towards building an overarching, more resilient national development process. The goal of the policy is to ensure a harmonized and coordinated approach towards a climate- resilient and low-carbon development path for sustainable development in Uganda.The overarching objective of the policy is to ensure that all stakeholders address climate change impacts and their causes through appropriate measures while promoting sustainable development and a green economy. This national policy emphasises climate change adaptation as the first priority for Uganda, while mitigation efforts are embraced by the policy as secondary.

Mitigation Policy Priorities are to:

- Support and accelerate the implementation of the Renewable Energy Policy (REP) in order to promote and develop new clean energy technologies and reduce GHG.

- Promote conservation and efficient utilisation of energy to reduce GHG emissions especially at consumer levels (industries, households, commercial and institutional buildings).
- Encourage the use of alternative fuels instead of heavily relying on biomass.
- Promote the development, approval and effective implementation of a long-term national transport policy and plan that will take GHG mitigation concerns into account.
- Effect a gradual shift to the use of less carbon-intensive fuels (including compressed natural gas, ethanol and LPG) in vehicles instead of relying heavily on gasoline and diesel fuels.
- Promote investment in clean energy generation under public–private partnerships
- Promote, encourage and incentivize co-generation by industries in the production of heat or steam and electricity from renewable biomass
- Provide tax incentives and other benefits to private sector companies that invest in cleaner energy generation
- Promote the use of alternative renewable energy sources such as solar, biomass, wind and bio fuels as well as their associated technologies
- Develop hydroelectric and geothermal power systems and integrate them into the East African Power Pool in the medium term
- Promote the development of energy conservation and efficiency projects in all sectors; for example, promote the use of stabilized bricks and efficient brick kilns in the building sector
- Enforce building codes with the aim of reducing energy consumption and encouraging designs that maximize the use of natural daylight in buildings
- Promote the use of energy-efficient technologies such as compact florescent lamps and other commercially viable high-efficiency lamps
- Promote efficient firewood/charcoal stoves, solar and LPG cookers, also address the high upfront costs of acquiring these technologies through household subsidies or tax waivers
- Reduce deforestation by providing alternative clean energy sources and efficient appliances for energy use, management and conservation

d) Second National Development Plan (NDP II) 2015/16 - 2019/2020 (NPA, 2015)

NDP II stipulates that climate change is one of the key cross-cutting issues that will be mainstreamed in government programmes and projects during its implementation, monitoring and evaluation. The plan also has to be mainstreamed in planning and budgeting. Promoting use of alternative sources of energy is one of the objectives of the NDPII and the intervention under mitigation is; Promote and facilitate the use of renewable energy technologies like bio-fuels, wind, solar, improved cook stoves and LPG at household and institutional levels.

e) Uganda Green Growth Development Strategy (UGGDS), 2017/18 – 2030/31 (NPA, 2017)

The strategy recognizes that Climate change is expected to increase climatic variability by shifting and intensifying extremes, which could lead to more severe drought and flood events. The UGGDS serves as a framework and/or guidance tool that aims at catalyzing economic growth through the efficient use of the country's natural, human, and physical capital in an inclusive manner along a low emissions development pathway. Its goal envisages an inclusive low emissions economic growth process that emphasizes effective and efficient use of the country's natural, human, and physical capital while ensuring that natural assets continue to provide for present and future generations. The main objective is to provide guidance and describe the governance framework on priorities and strategic interventions for implementation of the green economy, green growth and development in Uganda. The UGGDS will be the guiding document for all green growth initiatives in the country.

The strategy highlights that the impacts of climate change have plagued Uganda in the form of intense and more frequent prolonged droughts, torrential and poorly distributed rainfall and a rise in temperatures, as demonstrated by a significant reduction in the volume of glaciers on Mountain Rwenzori. These impacts have harmed infrastructure systems, human health, and agriculture and compounded existing poverty. Containing these impacts calls for a novel development approach that can sustain the economic growth while improving the social and environment development targets. Climate change adaptation and mitigation is a salient component of green growth and Uganda has demonstrated remarkable commitment in its national climate change response.

Some of the current climate change response initiatives that are related to green growth include: creation of an updated inventory of greenhouse gas emissions by sector; preparation of various Nationally Appropriate Mitigation Actions (NAMAs); the community tree planting project which entails distribution of free tree seedlings; development of a national REDD+ strategy; an environmental tax on old vehicles with large emissions; addressing the fiduciary requirements to make Uganda qualify for climate finance from the various climate finance windows; distribution of efficient charcoal saving cook stoves; and undertaking studies that quantify the economic cost of the climate change response compared with the cost of inaction. Climate change mitigation and adaptation is one of the eight development outcomes expected to be generated from the implementation of the UGGDS by 2030.

Energy for green growth is one of the five priority areas of the UGGDS. The planned strategic interventions are:

I. Support an increased focus on renewable energy investments including:

    - Biomass energy for electricity through cogeneration by sugar companies and other modern technology options by 2030;
    - Improved technology for enhanced efficiency in using biomass for domestic cooking and industrial uses by 2020;

- Enhancing solar power potential especially for on-grid and local supply over the transitional period for the country from the current 10MW to 5,000MW by 2030;
- Exploitation of geothermal energy based on current plans from base capacity of 450MW by 2030 to 1,500MW by 2040 (NPA, 2017);
- Support capacity utilization for large and mini-hydropower plants and encourage efficiency in evacuation of generated power. The efficiency of capacity utilization can be increased from about 50-60 percent to 80 percent and evacuation to 95 percent by 2020.

II. Support development and/or reinforcement of environmental, health and economic safeguards for energy generation in the country.

The UGGDS seeks to support energy supply growth while ensuring that options for energy efficiency, renewable and clean energy are maximized, and environmental pollution, risks and hazards associated, particularly with non-renewable energy sources, and with misuse of renewable energy are minimized. The strategy's energy target outcome is GHG emissions reduction of 18.5mton CO_2e. The results framework area for energy is to support the promotion of renewable energy investments and sustainable use other energy sources. The strategies under this area are renewable energy investments in biomass for electricity, technology efficiency for domestic cooking and industrial biomass energy, solar energy potential, geothermal, and mini and large hydropower generation and support development and/or reinforcement of environmental, health and economic safeguards for energy generation in the country.

f) Uganda Second National Communication (SNC), (MWE, 2014)

Uganda's key economic sectors such as agriculture, water resources, fisheries, tourism and health are dependent and sensitive to climate variability and climate change. Therefore, climate change (CC) has serious direct and indirect impacts on the social and economic development of Uganda. The SNC highlights that Uganda's efforts to develop and promote relevant strategies to mitigate climate change are demonstrated within the recently approved Uganda National Climate Change Policy (UNCCP).

Uganda's mitigation options and measures in response to climate change in line with the objectives and provisions of the UNFCCC were assessed based on assumptions of GHG emissions projections from 2005 to 2035 following two scenarios: a business-as-usual scenario and a mitigation scenario based on specific actions in the key sectors of energy and transport, agriculture, Land use, land use change and forestry (LULUCF) and waste. The business-as-usual scenario in the energy and transport sector showed that the transport sub-category will be the largest and fastest growing contributor of GHG emissions followed by residential, and manufacturing and construction sub categories. In the Mitigation scenario, it was projected that by 2035 transport sub category will dominate the total GHG emission. In order to reduce the projected GHG emissions, the SNC recommends the following mitigation options;

- Use of better technologies such as Adam Retort kilns for charcoal production;
- Increasing use of hydropower as a clean energy supply;
- Wider use of solar energy for low power electricity using photovoltaic systems and larger plants using steam or organic fluids in future;
- Accessing clean electricity energy supply through the East African Power Pool;
- Increased co-generation from sugar cane factories as well as production of ethanol for blending or direct use in the transport sector. Ethanol can also be used in the household sector;
- Develop biodiesel fuel from plants such as cotton, castor oil seeds or other non-edible crops;
- Use of agricultural crop residues in some industries such as cement, bricks and tiles, and oil processing;
- Exploitation of geothermal potential

g) The Renewable Energy (RE) Policy, 2007-2017, (MEMD, 2007)

The policy recognizes that emissions from coal and fossil fuels are responsible for global warming and climate change. The Policy that is currently under review is a concretization of Government's commitment to the development and use of renewable energy resources for both small- and large-scale applications (as spelt out in the Energy policy of 2002), setting out Government's policy vision, goals, principles and objectives for promoting sustainable utilization of renewable energy in Uganda. One of the major needs for this policy is to fulfil Government's commitment on greenhouse gas emissions reductions, under the Kyoto Protocol and contribute to the global fight against climate change. In particular, Government needs to provide the necessary framework for private sector investors in renewable energy projects to benefit from the available facilities in emissions trading.

Government's Policy Vision for renewable energy is "to make modern renewable energy a substantial part of the national energy consumption (MEMD, 2007)". The overall policy goal is "to increase the use of modern renewable energy, from the current 4% to 61% of the total energy consumption by the year 2017". This Policy is based on the need to address the challenges observed, while implementing the Energy Policy in general and the Power Sector Reform in particular; as well as those threats posed by the increasing energy prices, environmental degradation, climate change, as well as Government's commitment to poverty and gender responsive energy actions.

The commitment of Government to develop the use of renewable energy sources is clearly aimed at creating the means of socio-economic development, especially by transforming the rural areas. The implementation of the policy's objectives will, therefore positively respond to the various legal and policy instruments and programmes, which Government has put in place to address poverty issues, catalyze industrialization and protect the environment.

1.3 Sector selection

1.3.1 An overview of the sector, projected climate change, and GHG emissions status and trends of the sector

This chapter presents an overview of the energy sector, projected climate change and GHG emissions status and trends.

In Uganda, the Energy Sector plays a central role in the economy. Energy is the engine for economic growth and development, and a vital input into all the productive and social sectors of the economy. The sector has an estimated overall electrical power potential of about 5,300 MW; comprising of 2,200MW of hydropower, 1,650 MW from biomass, 200 MW from solar power, 450 MW from geothermal and 800MW from peat (MWE, 2014). Figure 1.1 shows the contribution of each technology source to the potential of electric energy generation in Uganda.

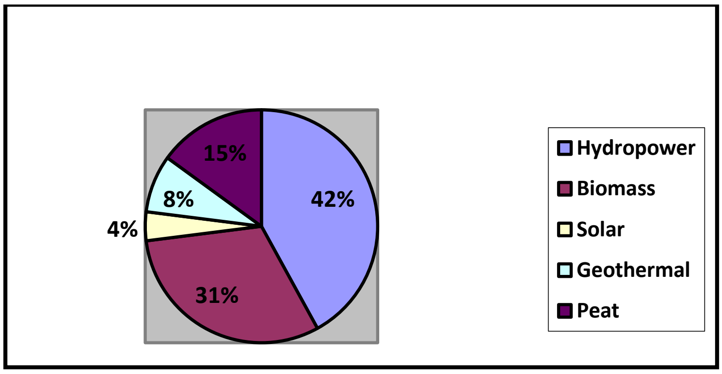

Figure 1.1: Uganda's estimated overall electrical power potential contribution (by Consultant)

The sector in Uganda comprises both traditional and conventional energy sources that include petroleum and renewable energy sources. The dominant locally produced energy sources are fuel wood and charcoal which have negative impacts on vegetation cover. The increased urbanization and high cost of electricity have continued to increase the demand for charcoal in urban areas. Uganda generates its own electricity, mostly from hydroelectric power stations supplemented with power from thermal plants. It also generates small quantities of power from other sources like biomass and solar. According to the Ministry of Energy and Mineral Development, electricity needs are growing by an average of 8% each year.

Uganda's hydroelectric Power Potential

The potential for hydroelectric power in Uganda is huge. The White Nile drops some 500 metres between Lake Victoria and Lake Albert, representing an estimated capacity of over 4,000 MW (NBI, 2012). There are also numerous rivers in the mountainous regions of Uganda. The rivers are vulnerable to climate change. However, development of some hydropower potential may not be done because of other reasons which may be economical or environmental.

Uganda's total installed capacity

The current (as of May 2019) total installed capacity of Uganda is1182.2 MW, having increased from 984.0 MW as at the end of December 2018. This growth was due to the commissioning of Isimba Hydro Power Plant (183MW), Emerging Power U Ltd (Mayuge Solar PV) (10.0MW) and the Sindila (Butama) HP (5.25MW) during the period January to March 2019. About 7.5 MW of the installed capacity was accounted for by Off Grids that generated and sold their own electricity (ERA, 2019). See annex II for the installed capacities and generation companies of the various technologies. The distribution of installed capacity is as shown in Figure 1.2.

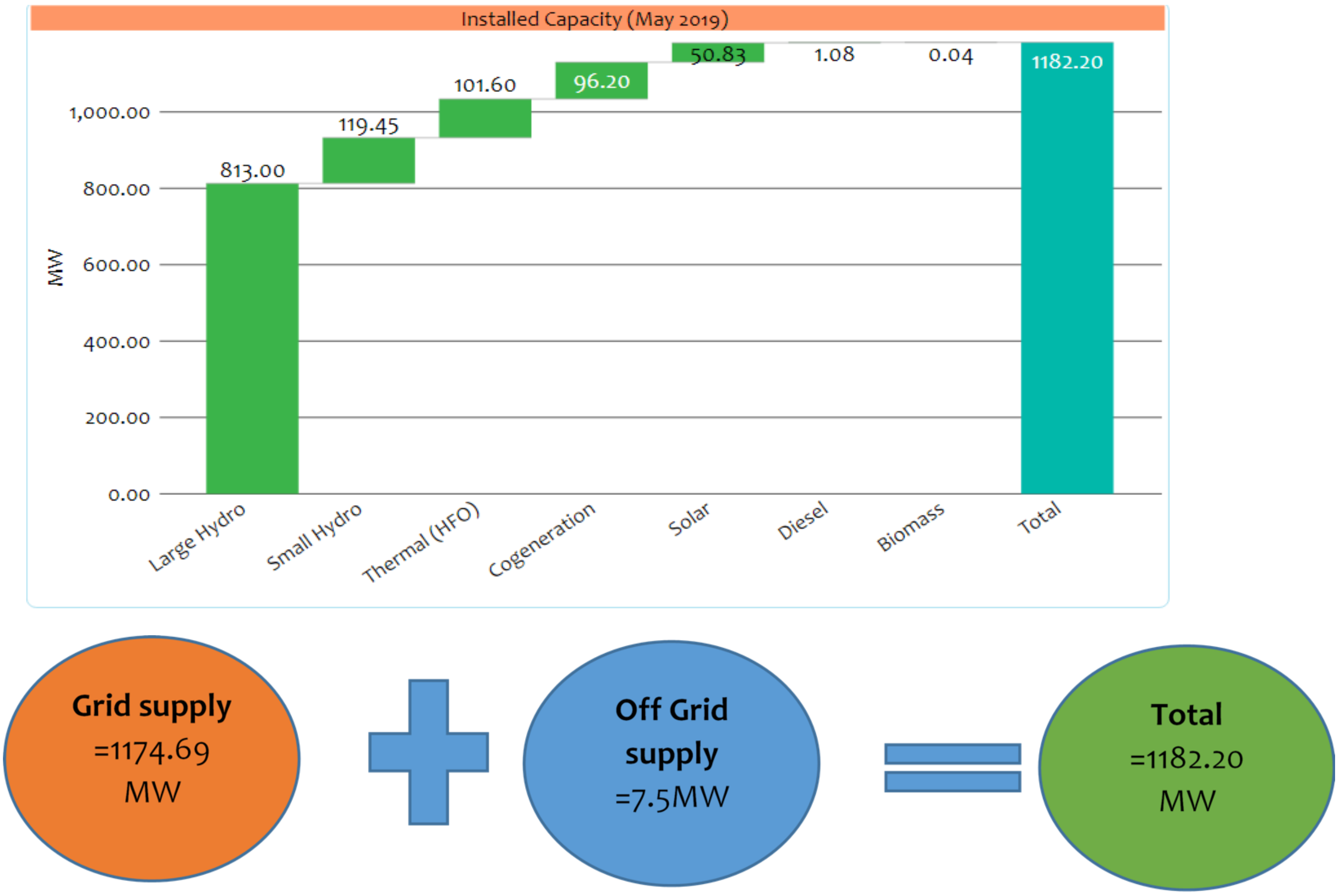

Figure 1.2: The distribution of Uganda's Installed Capacity
Source: Electricity Regulatory Authority (ERA, 2019)

Uganda's Renewable Energy Resource Base

Uganda is richly endowed with renewable energy resources for energy production and the provision of energy services. The total estimated potential is about 5,300 MW. These resources, however, remain largely unexploited, mainly due to the perceived technical and financial risks. Hydro and biomass are considered to have the largest potential for electricity generation. But also, solar power receives increasing attention by investors. Moreover, located in the East African Rift Valley, Uganda has promising potential for the exploitation of geothermal energy. Wind speeds are generally low and wind power potential is thus negligible. Detailed studies are going on to establish the viability of wind power generation in the country.

Biomass

Biomass contributes 88% of the total primary energy consumed through firewood, charcoal and crop residues (MEMD, 2019). Fuel wood requirements have contributed to the degradation of forests as wood reserves are depleted at a rapid rate in many regions. Charcoal consumption increases at a rate close to the urban growth rate of 6% per year (FAO, 2017). Most of the traditional biomass energy technologies; which include wood and charcoal stoves, ovens and kilns used in Uganda are inefficient. Limited availability of electricity and high prices of petroleum products constitute barriers to a reduction in the demand for biomass. Trading in biomass especially charcoal contributes to the rural economy, in terms of rural incomes, tax revenue and employment.

Charcoal is mainly used in the urban areas while firewood, agro-residues and wood wastes are widely used in the rural areas. Firewood is used mainly on three-stone fires in rural households and in food preparation by commercial vendors in urban areas. The same applies to the burning of farm residues. Firewood in some institutions like schools and hospitals is however used in improved stoves. Charcoal is mainly used on a metallic stove traditionally known as a *'sigiri'* though the use of the clay *sigiri* is picking up. For the conversion of firewood into charcoal, earth mounds and pits are used as charcoal kilns. These have a wood conversion efficiency of 10 to 12% on weight-out to weight-in basis. This implies that about 9 kg of wood are needed to produce 1 kg of charcoal, which translates into 22% efficiency on an energy output to energy input basis (Energypedia, 2019). Introducing improved technologies may increase efficiency to achieve 3 to 4 kg of wood per kg of charcoal, which corresponds to 60% to 50% efficiency respectively on an energy basis.

Biomass is abundant and diverse due to different vegetation and land use types. The total standing biomass stock is stated with 284.1 million tons with a potential sustainable biomass supply of 45 million tons (GET.invest, 2019). The major sources are hardwood plantations, which consist of eucalyptus (50%), pine trees (33%) and cypresses (17%). Current accessible sustainable wood biomass supply lies at 26 million tons. The theoretical potential production of agriculture residues lies between 1.186 million and 1.203 million tons annually. The only sub-sector that utilizes biomass residues for electricity production yet is the sugar industry. A small amount of coffee and rice husks is also utilized for heat production in cement and tiles manufacturing and the production of briquettes.

Ethanol and bio diesel are biofuels that can be used in the transport sector as fuel for vehicles; these can be blended with fossils fuels. Kakira Sugar Limited, Kinyara Sugar Works Limited, Sugar & Allied Uganda Ltd, SCOUL and Mayuge Sugar Ltd are local sugar companies engaged in ethanol production. Blending with ethanol shall take a shorter lead time than biodiesel; ethanol blending was projected to start by 2020. Uganda has the potential to produce substantial amounts of biodiesel from a variety of oil seed crops, which are either already grown for oil extraction or growing wildly. It is assumed that fossil diesel will be blended with 5%

biodiesel. According to Uganda's Second National Communication, it is assumed that biodiesel blending in the transport sector would start in 2025 (MWE, 2014).

Hydropower

Hydropower is the major source of electricity generation in Uganda (GET.invest, 2019). Of the total installed generation capacity of 1182.2 MW (as of May 2019), 932.45 MW are from hydro power accounting for about 78.8% of the generation capacity (ERA, 2019). The total hydropower potential is estimated at over 4,000 MW along the River Nile. Extending electricity access nationwide is a primary policy objective for Uganda. This includes increasing access to 30 percent in 2020 and 80 per cent in 2040 (at 6 per cent annual increase), with off-grid electricity playing only a minor role. While this is expected to be mainly low-carbon due to large hydropower resources, there is potential to achieve 100 per cent access cost-effectively by 2040 with a greater emphasis on small-scale off-grid renewable solutions.

To fast-track the development of on-grid small renewable energy projects, Uganda took an early lead in East Africa in implementing the feed-in-tariff (FIT) system, adopting the Global Energy Transfer Feed-in-Tariff (GET-FiT) Program launched in 2013. The total planned installed capacity from the GET-FiT projects currently under construction is 86 MW (IHA, 2018). Moreover, 6.5 MW Muvumbe and 5 MW Siti I became operational in March and May 2017 respectively. The government's grid development plan set a target to increase hydropower generation mix from 78 per cent to 90 per cent by 2030 (IHA, 2018). A new large hydropower facility of 600 MW at Karuma is under construction and a 600 MW Ayago plant has been proposed. Despite the high potential and increasing constructions, climate change affects hydropower generation due to prolonged droughts that reduce water levels thus affecting the volume of water required to run the turbines that generate hydroelectricity.

Solar

Solar energy resource in Uganda is high throughout the year with an average solar radiation of 5.1 kWh/m^2/day. The data indicate a yearly variation (max month / min month) of only about a maximum of 20%, which is due to the location near the equator (Edmond Mark Mpagi, 2012). The insolation is highest in the dryer area in the north-east and very low in the mountains in the east and south-west. While the Government of Uganda is making significant efforts to add additional generation capacity and to extend the grid to various parts of the country, majority of the low-income households will still need alternative sources of energy due to the cost of grid power or the high costs incurred in extending the grid. 50.83MW (4.3%) of Uganda's installed generation capacity is from solar energy (ERA, 2019). The highest generation is from on-grid projects from Access Uganda Solar Ltd (10 MW), Tororo Solar North Ltd (10MW), MSS Xsabo Power Limited (20 MW) and Emerging Power U Ltd (10 MW).

The Solar Home Systems (SHS) market is regarded as one of the biggest areas in Uganda for off-grid commercially driven solar PV business, and considered to have high potential. There are a number of local and international sellers of SHS across the country especially in rural communities. In Uganda the technology is implemented with different options; one can purchase a system with an upfront payment while others use a Pay as You Go system where customers pay a small amount of money to the vendor/distributor every day for an agreed upon period of time. Despite the high potential, uptake of off-grid solar systems is still low due to high upfront investment costs; although the Pay as You Go System has tried to solve the challenge of high upfront investment costs. The purchasing power of rural households is highly affected by climate change since majority do farming for livelihood. Hence the purchasing power is higher during harvest season when they sell their farm produce, most especially during July/August and November/December. If the crops are affected by low rains, the yields are low hence low purchasing power.

Geothermal

Uganda is one of the East African countries with high geothermal potential. With 24 geothermal sites identified in the regions of Kibiro, Panyimur, Buranga and Katwe and several private players working on projects, Government is optimistic on reaching a 100 MW of geothermal power generation capacity target by 2025 (Thinkgeoenergy, 2019). The government's objective is to develop geothermal energy to complement hydropower and other energy sources to meet Uganda's electric energy demand in a healthy environment. With its ongoing economic growth, the country sees increasing energy demand. Geothermal energy could be a key source for electricity generation and counter the over-reliance on hydropower and thermal power. Currently some private developers are engaged in exploration and drilling.

Peat

It is estimated that the total area of peatlands in Uganda is about 4,000 km^2, while the average thickness of peat deposits is about 1.5 metres (NEMA, 2008). The total peat volume is estimated to be 6,000 million cubic metres. According to the laboratory analyses, the dry bulk density is on average 100 kg/m^3 and the net calorific value 17 GJ/tonne. The estimated theoretical peat volume represents about 250 Mtoe (million tonnes of oil equivalent). Taking into consideration, the varying quality of peat and the Wetland Policy of Uganda, as well as the possibility of using conventional peat production methods, about 10% could probably be used for power production. The available stock of peat resources, would therefore, be adequate for the generation capacity of about 800 MW. However, because of the dispersed nature of the available fuel peat resources, peat generation units, could be small (typically less than 20 MW) and dispersed mainly to Western and South-Western Uganda, where the desired resource characteristics are better than in other regions.

Wind

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 with the average wind speed at 4m/s (meters per second). Wind energy potential can therefore be harnessed as an alternative power source and for diversification of Uganda's power sector. In 2017, the Electricity Regulatory Authority approved the Award of an 18 (Eighteen) months Permit Extension to Senok Trade Combine (PVT) Limited to enable the company undertake Feasibility Studies and other activities which may lead to the development of the 20 MW Wind Power Project in the Karamoja sub-region.

Non-renewable sources

Oil and Gas

Oil has been detected in six sedimentary basins in Uganda, the most prospective being the Albertine Graben covering 23,000 km^2 in the Western Rift Valley along Uganda's Border with the Democratic Republic of Congo (Energypedia, 2019). Two other basins, Hoima basin and Lake Kyoga basins are still under investigation. Currently the amount of oil discovered is about 6.5 billion barrels of which 1.4 billion barrels are recoverable. This discovery is placing Uganda among the foremost African oil producers. French firm Total, S.A., CNOOC, and U.K. firm Tullow Oil, hold licenses to develop these resources, but have yet to reach a Final Investment Decision (FID) as protracted negotiations with the government continue.

Petroleum products

Uganda imports all its petroleum products from overseas since there is no local production yet. About 95% of Uganda's petroleum imports are routed through Kenya and only 5% come through Tanzania.

Greenhouse gas emissions status

According to Uganda's Second National Communication (MWE, 2014), mitigation options and measures in response to climate change in line with the objectives and provisions of the UNFCCC were assessed based on assumptions of GHG emissions projections from 2005 to 2035 following two scenarios: a business-as-usual scenario and a mitigation scenario based on specific actions in the key sectors of energy and transport, agriculture, LULUCF and waste. The business-as-usual scenario in the energy and transport sector showed that the transport sub-category will be the largest and fastest growing contributor to GHG emissions followed by residential, and manufacturing and construction sub categories. Under this scenario, the total GHG emission was estimated to increase from 3.2 million mtCO_2eq in the base year (2000) to 24.9 million mtCO_2eq by the year 2035.

The projected contribution to the total GHG emissions from the energy industry, manufacturing and construction source categories will, respectively, increase from 4% and 11% in the base year to 5% and 22% of the total GHG emissions by 2035. There will be a slight decrease in the contribution by the transport sector from 64% to 61% over the same period. The contributions of emissions due to residential and agriculture sub categories will decrease from 8% and 4% in 2000 to 3% and 1% by 2035, respectively. The increase is expected to be more pronounced after 2020; when petroleum and gas will be playing a major role in Uganda's economic development.

In the Mitigation scenario, it was projected that by 2035 transport sub category will dominate the total GHG emission. The total GHG emissions will increase from 3.230 million mtCO_2eq in the base year to 20.977 million mtCO2e in 2035. There will be a general overall increase in the efficiencies from about 5% in 2000 to 20% by the year 2035. Blending with ethanol will take a shorter lead time than biodiesel. Ethanol blending was projected to start by 2020 and to be followed by biodiesel after 2025. The contribution of the transport, manufacturing and construction sub categories was expected to increase from 25 percent and 6 percent in the base year to 44 percent and 18 percent by 2035, respectively.

Energy industry's GHG emissions were projected to increase from 1% to 4% over the same period. Contribution of the residential as well as commercial and institutional source categories was expected to reduce from 53 percent and 10 percent in 2000 to 24% and 5%, respectively, by 2035. There will be an upward trend of GHG emissions by fuels used in different source categories. Diesel is increasingly a major source of energy and its contribution to GHG emissions is projected to increase from 15% in 2000 to 44% by 2035. Likewise, fuel oil's GHC, emissions was projected to increase from 4% in 2000 to 17% by 2035. However, the gasoline and biomass emissions will decrease from 13% and 55% to 4% and 24%, respectively, over the same period.

1.3.2 Process and results of sector selection

Uganda National Council for Science and Technology (UNCST) (TNA Coordinator) held an Inception Workshop in August 2018. During the workshop, stakeholders were given information about the TNA project. It is during this same workshop that stakeholders prioritised Agriculture, Forestry, and Water sectors for adaptation; and Energy sector for the mitigation within the TNA Uganda Project.

Chapter 2 Institutional arrangement for the TNA and the stakeholder involvement

During the formulation of the Uganda National Climate Change Policy (MWE, 2015), various institutions which could play critical roles in its implementation were identified. It is envisaged that similar institutions can be useful in implementation of TNA. National institutions involved in climate change policy making and implementation, and their roles in the TNA project. The institutions and their roles are as shown in Table 1.1

Table 1.1: The institutions and their roles in TNA

No.	Institution	Role in the TNA project
1	Ministry of Finance, Planning and Economic Development (MoFPED)	Steering Committee member
2	Ministry of Water and Environment (MWE)	Steering Committee member
3	Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)	Steering Committee member
4	Ministry of Gender, Labour and Social Development (MoGLSD)	Steering Committee member
5	Ministry of Science, Technology and Innovation (MOSTI)	Steering Committee member
6	Office of the Prime Minister (OPM)	Steering Committee member

2.1 National TNA Team

The Steering Committee

This is the key body guiding the project. Their role is to provide high-level guidance to the national TNA team and help secure political acceptance for the Technology Action Plan (TAP). Uganda's steering committee comprises of members responsible for policy making from relevant ministries, departments and agencies (MDAs), the National Designated Entity (NDE), academia, private sector and civil society organizations as indicated in Table 1.2.

Table 1.2: National Designated Entity

Name	Position	Institution
1. Dr. Maxwell Otim Onapa	Deputy Executive Secretary/NDE Focal Point	Uganda National Council for Science and Technology (UNCST)

2. Mr. David O.O. Obong	Permanent Secretary and Chair of Steering Committee	Ministry of Science, Technology and Innovation - MOSTI
3. Mr. Alfred Okot Okidi	Permanent Secretary	Ministry of Water and Environment - MWE
4. Bob Natif	Assistant Commissioner Climate Change	Climate Change Department CCD/MWE
5. Prof. Joseph Obua	Professor	College of Agriculture and Environmental Sciences, Makerere University
6. Ms. Maris Wanyera	Commissioner, Development Assistance and Regional Cooperation/ NDA	Ministry of Finance, Planning and Economic Development – MFPED
7. Mr. Joseph Epitu	Assistant Commissioner Sector Capacity Development	CCD/MWE
8. Ms. Rose Nakabugo	Asst. Commissioner Disaster Management	Office of the Prime Minister – OPM
9. Mrs. Esther N. Nyanzi	Chief Executive Officer	Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA)
10. Dr. Tom Okia Okurut	Executive Director	National Environment Management Authority - NEMA
11. Mr. Stephen Muwaya	Senior Range Ecologist	Ministry of Agriculture, animal Industry and Fisheries - MAAIF
12. Executive Director	Chief Executive Officer	Advocates' Coalition on Development and Environment – ACODE

The National TNA Coordinator

Uganda National Council for Science and Technology (UNCST); the National Designated Entity (NDE) is the National TNA Coordinator. This is the focal point for the effort and management of the overall TNA process. The Coordinator provides vision and leadership for the overall effort, facilitating communication tasks with the National TNA Committee members, National Consultants and stakeholder groups, forming networks, information acquisition and the coordination and communication of all work products.

Sector Working Group

This group is made up of the energy sector technical experts who provide input into the technology prioritization, the barrier analysis and ideas or inputs for the enabling framework for energy technologies.

The Mitigation Consultants

These conduct the substantive analytical work that informs the TNA process, work closely with and report to the National Coordinator. Uganda has two (2) mitigation consultants. Their roles are:

- Organizing consultative stakeholder meetings
- Identifying and prioritizing technologies for the energy sector through a participatory process with the broad involvement of relevant stakeholders
- Leading the process of analysing, along with the stakeholder groups, how the prioritized technologies can be implemented in the country and how implementation conditions can be improved by addressing the barriers and developing an enabling framework based, inter alia, on undertaking local market and other assessments, as may be required
- Preparing deliverables, including the TNA, BAEF and TAP reports
- Preparing working papers and other TNA-related documents as may be required to ease the consultative process
- Harnessing inputs from stakeholders during meetings and workshops, among others
- Participate in capacity-building workshops
- Work in close partnership with the National Coordinator to facilitate communication within the national TNA Team (coordinator, consultants, sectoral working groups), engage with stakeholders, form networks, and coordinate and communicate all deliverables.

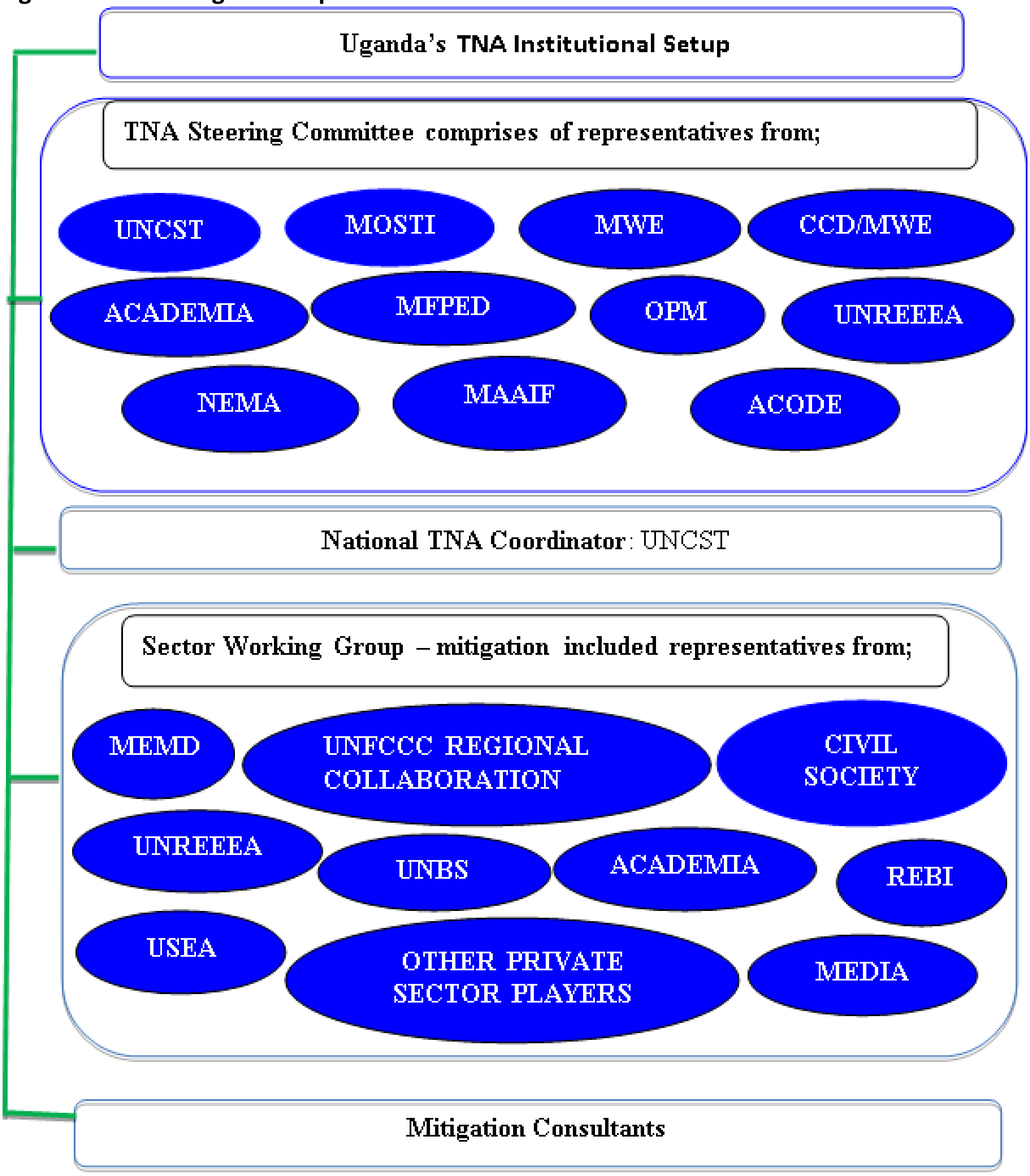

Figure 2.1: The Institutional Setup of TNA

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Stakeholders engaged in the TNA process included those from the public, private sector and civil society organizations. Stakeholder engagement was done from the time of technology identification where the national consultant submitted the list of 12 technologies to the Ministry of Energy and Mineral Development (MEMD) to gather the Ministry's views on the priority technologies based on the sector plans and strategies. This list was reviewed and feedback was received on the Ministry's priority technologies.

National consultants/experts had routine engagements with the National Coordinator through meetings. The TNA prioritisation workshop was held jointly with the adaptation group for synergies and also due to the fact that some stakeholders were cross cutting. The National Coordinator together with the Consultants organized a two-day TNA prioritization workshop which was held on 27th and 28th June 2019. During the workshop UNCST shared a brief overview of the TNA Uganda with the stakeholders, both mitigation and adaptation teams presented the technology shortlists and the process of development, technology fact sheets (TFS) and an introduction to Multi-Criteria Analysis (MCA) tool. The TFS and MCA tool were used in the final selection of 3 priority technologies. The list of consulted stakeholders is provided in Annex III.

Stakeholders primarily from the private sector were consulted on the costs of the different technologies during the development of technology fact sheets. This was done because of data gaps in the sector.

2.3 Consideration of Gender Aspects in the TNA process

According to UNFCCC, Climate change has a greater impact on those sections of the population, in all countries, that are most reliant on natural resources for their livelihoods and/or who have the least capacity to respond to natural hazards, such as droughts, landslides and floods. Women commonly face higher risks and greater burdens from the impacts of climate change in situations of poverty, and the majority of the world's poor are women (UNFCCC, 2019). Women's unequal participation in decision-making processes and labour markets compound inequalities and often prevent women from fully contributing to climate-related planning, policy-making and implementation.

Yet, women can (and do) play a critical role in response to climate change due to their local knowledge of and leadership in e.g. sustainable resource management and/or leading sustainable practices at the household and community level. Women's participation at the political level has resulted in greater responsiveness to citizen's needs, often increasing cooperation across party and ethnic lines and delivering more sustainable peace. At the local level, women's inclusion at the leadership level has led to improved outcomes of climate related projects and policies. On the contrary, if policies or projects are implemented without women's meaningful participation it can increase existing inequalities and decrease effectiveness.

In line with the above, gender aspects have been considered in the whole TNA process starting with selection of the TNA teams. The National Coordination team is gender balanced as well as the TNA National Consultants/experts. 50% of the members of the sector working group are female, views of both men and women were valued equally during the technology prioritization process. In addition, gender considerations were analysed in all technology factsheets (see Annex I) that were shared with and used by the stakeholders in the technology prioritization process.

Chapter 3 Technology Prioritisation for the Energy Sector

The process started with a literature review of Uganda's climate and development national/sectoral strategies and plans. These included; Vision 2040, Nationally determined contribution (NDC), Uganda National Climate Change Policy (UNCCP), 2015, Second National Development Plan (NDP) II 2015/16 - 2019/2020 (2015), Uganda Green Growth Development Strategy (UGGDS), 2017/18 – 2030/31, Second National Communication, and Uganda's Renewable Energy Policy 2007-2017. Based on the information gathered from these documents on the national priorities and commitments, the consultants developed the initial list of eighteen (18) mitigation technologies. The list of technologies is as shown in Table 2.1

Table 2.1: List of Identified Technologies

No.	Technology	No.	Technology
1	Micro Hydropower: off grid capacity up to 100 kW	10	Improved Cook stoves (household)
2	Off grid solar 500 kW	11	Efficient Institutional Cook stoves
3	Large scale solar	12	Carbonized Briquettes
4	Solar rooftop systems	13	Non-carbonized briquettes
5	Bio latrines for institutions (Biogas)	14	Biodiesel (transport)
6	Biogas (electricity)	15	Gasification (electrical)
7	Geothermal (electricity)	16	Gasification (thermal)
8	Ethanol for (cooking)	17	Wind energy
9	Ethanol for blending with gasoline	18	Hybrid (solar-gasification)

Further analysis of the technologies was done by the consultants based on the factors below and the list was scaled down to twelve (12) mitigation technologies based on;

- Maturity of the technology in Uganda. Based on this factor, the following technologies were eliminated: wind energy, geothermal, hybrid solar-gasification and biogas (electricity).
- Technology transfer; hydropower, large-scale solar were eliminated, since they are already under implementation in Uganda.

Due to low market demand; off-grid solar of up to 500kW was reduced to solar mini-grids of up to 100kW. Most of Uganda's off-grid communities use solar energy for lighting yet a system of 500kW would require demand for power for productive use for various purposes and businesses. The cost of the solar technology would be very high as per the current market price. This envisages the price will be lower in the near future. List of twelve technologies based on the factors above are as seen in Table 2.2.

Table 2.2: List of technologies

No.	Technology	No.	Technology
1	Solar mini-grids of up to 100kW	7	Efficient Institutional Cook stoves
2	Solar rooftop systems	8	Carbonized Briquettes
3	Bio latrines for institutions (Biogas)	9	Non-carbonized briquettes
4	Ethanol (cooking)	10	Biodiesel (transport)
5	Ethanol for blending with gasoline	11	Gasification (electrical)
6	Improved Cook stoves (household)	12	Gasification (thermal)

Deeper analysis was done by the consultants and the list was further scaled down to eight (8) mitigation technologies based on;

- Maturity of the technology in Uganda (eliminated gasification (thermal), ethanol for cooking.
- High requirements for green major raw materials, inefficiency in current production (eliminated carbonized briquettes) because the technologies used for carbonizing materials are very inefficient.
- Cook stoves for households were eliminated due to many players and funders focusing on the technology in the country.
- The solar energy 100 kW capacity was reduced to 50 kW, to march a typical small trading center in Uganda.

The list of eight (8) technologies were presented to the stakeholders during the prioritization workshop. The list of projects presented to the stakeholders is as shown in Table 2.3

Table 2.3: The list projects presented for consideration.

No.	Technology	No.	Technology
1	Solar mini-grids of up to 50 kW	5	Non-Carbonized Briquette Production for households and institutions
2	Solar rooftop systems	6	Efficient Institutional Cook stoves
3	Bio latrines for institutions (Biogas)	7	Biodiesel (transport)
4	Ethanol for blending with gasoline	8	Gasification for electricity generation

3.1 GHG emissions and existing technologies of the Energy Sector

According to Uganda's Second National Communication (MWE, 2014), the projected contribution to the total GHG emissions from the energy industry, manufacturing and construction source categories will, respectively, increase from 4% and 11% in the base year (2000) to 5% and 22% of the total GHG emissions by 2035. There will be a slight decrease in the contribution by the transport sector from 64% to 61% over the same period. The contributions of emissions due to residential and agriculture sub categories will decrease from 8% and 4% in 2000 to 3% and 1% by 2035, respectively. The increase is expected to be more pronounced after 2020; when petroleum and gas will be playing a major role in Uganda's economic development. Diesel is increasingly a major source of energy and its contribution to GHG emissions is projected to increase from 15% in 2000 to 44% by 2035. Likewise, fuel oil's GHC, emissions was projected to increase from 4% in 2000 to 17% by 2035. However, the gasoline and biomass emissions will decrease from 13% and 55% to 4% and 24%, respectively, over the same period.

The main existing technologies in use in the sector are biomass, hydropower and solar.

Biomass

Biomass contributes 88% of the total primary energy consumed through firewood, charcoal and crop residues (MEMD, 2019). Traditional biomass energy technologies include wood and charcoal stoves, ovens and kilns. Charcoal is mainly used in the urban areas while firewood, agro-residues and wood wastes are widely used in the rural areas. Firewood is used mainly on three-stone fires in rural households and in food preparation by commercial vendors in urban areas. The same applies to the burning of farm residues. Firewood in some institutions like schools and hospitals is however used on improved stoves. Charcoal is mainly used on a metallic stove traditionally known as a *'sigiri'* and on improved cook stoves which are picking up. For the conversion of firewood into charcoal, earth mounds and pits are used as charcoal kilns. Gasifier stoves are also used at small scale; these utilize firewood and agricultural residues such as maize cobs. Some renewable energy fuels are being used; non-carbonized briquettes are used as alternatives to firewood in energy efficient institutional stoves and carbonized briquettes which are an alternative fuel to charcoal are used in both improved cook stoves and the traditional metallic stoves. In addition, LPG cookers are used by a few urban dwellers who can afford to purchase LPG.

Hydropower

Hydropower is the major source of electricity used in Uganda. This is majorly utilized for lighting in cold cathode fluorescent lamps (CCFL), fluorescent tubes and Light Emitting Diode (LED) bulbs, televisions (Cathode Ray Tube (CRT) and LCD and LED), radios, telephone chargers, refrigerators and other electric appliances. A very small percentage of Ugandans use hydroelectricity for cooking using electricity cookers and ovens due to the high-power tariffs. Hydropower is also used to charge computers, phones and other purposes. It is also used in industries and other commercial setups to run machines and other electrical appliances.

Solar

50.83MW (4.3%) of Uganda's installed generation capacity is from solar energy (ERA, 2019). The highest generation (50 MW) is from on-grid projects from Access Uganda Solar Ltd (10 MW), Tororo Solar North Ltd (10), MSS Xsabo Power Limited (20 MW) and Emerging Power U Ltd (10 MW). Similar to hydropower, this on-grid power is used for the purposes of lighting, televisions, radios, telephone chargers, refrigerators, computers and in other electric appliances both in households and industries. The remaining 0.83 MW are used in rural off-grid areas and those areas with unreliable grid-power supply. Solar technologies include; Solar rooftop systems/Solar Home Systems (SHS), pico-solar systems such as lanterns, televisions, radios, chargers and torches. Solar rooftop systems are majorly used by households that have higher energy needs that cannot be met by pico-solar systems. Solar water heaters are majorly used in hotels, solar energy hair clippers are used in saloons, solar cookers, fridges and dryers are also used.

3.2 Decision context

According to Uganda's NDC, the target is to implement policies that will result in approximately 22% reduction of national greenhouse gas emissions in 2030. For energy Uganda will focus on

- Increasing the efficiency in the use of biomass in the traditional energy sector
- Promoting renewable energy and other energy sources
- Increasing the efficiency in the modern energy sector, mainly of electricity
- Ensuring the best use of hydropower by careful management of the water resources
- Climate proofing investments in electricity power sector.

The major challenges include over reliance on biomass using traditional technologies. For the electricity sector, 78.8% of the current generation capacity of 1182 MW is from hydropower (ERA, 2019). Despite the high potential and increasing constructions, climate change affects hydropower generation due to prolonged droughts that reduce water levels thus affecting the volume of water required to run the turbines that produce hydroelectricity. Solar technology uptake is still low due to the high upfront costs required to acquire solar systems.

The main goals of the analysis in TNA is increasing the provision, promotion and uptake of renewable energy and using efficient and modern technologies in the energy sector. This is expected to greatly reduce the national GHG emissions.

3.3 An overview of possible mitigation technology options and their mitigation potential and other co-benefits

Government of Uganda is in the forefront of implementing mitigation technologies. Most of these technologies have adaptation co-benefits. GHG emissions can be reduced with increased uptake of renewable energy and use of modern technologies in the energy sector. The technology options are; use of solar rooftop systems, increased utilization of efficient institutional cook stoves, building of bio-latrines for institutions to utilize biogas technology, production and utilization of ethanol for blending with gasoline, use of non-carbonized briquettes in households and institutions as a replacement for firewood, development of gasification technology for electricity generation, development of solar mini-grids for both household and productive use and production and utilization of biodiesel (blended) for transport as a replacement of fossil fuels. These technology options and their benefits are in the attached technology fact sheets (see annex I).

3.4 Criteria and process of technology prioritisation for the energy sector

The technology prioritization process included the development of Technology Fact Sheets (TFS). These were developed for eight technologies through intensive literature review of the country's development priorities, plans and strategies, most descriptions of the technology options were got from climatetechwiki.org, sector reports, Sustainable Development Goals (SDG) country reports, costs were majorly got from entrepreneurs who are involved in the production and sale of the various technologies.

GHG emissions were computed based on the estimated number of users, watts utilized per household, litres of fuel used, number of stoves in use, hours of utilization and technology lifetime and other activity data. The technologies included: solar rooftop systems, efficient institutional cook stoves, bio-latrines for institutions (using biogas technology), ethanol for blending with gasoline, non-carbonized briquettes (pellets) for households and institutions, gasification technology for electricity generation, off-grid solar mini-grids and biodiesel (blended) for transport. A prioritization workshop was held on 27th and 28th June 2019. During the workshop, information in the TFS was explained to all stakeholders. Technology prioritization was done by the stakeholders working together with the mitigation consultants. The Multi-Criteria Analysis tool was used in the technology prioritization, stakeholders were inducted on the usage of the MCA tool. The criteria used were:

i) Costs (capital and operations)
ii) Benefits: economic (job creation, fiscal support, poverty reduction, investment potential), social (gender, clean energy access, education and health), environmental (reduce pollution, conservation, biodiversity)
iii) Technology (capacity building, maturity, quality, diffusion)
iv) Institutional considerations: Bureaucracy, institutional framework, institutional capacity
v) Climate related: Greenhouse Gas emissions reduction

All the eight technology options were entered in the MCA tool vertically and the criteria added horizontally. Weights were added under each option and criteria based on their importance as per the stakeholder's opinions. Total results per option were automatically computed by the tool.

3.5 Results of technology prioritisation for the energy sector

The MCA tool was used for technology prioritization by both the stakeholders and the consultants. Weights were added to the various criteria (see Table 2.4) and scores were assigned to the different technology options (see Table 2.5).

Table 2.4: Weights per criteria

Criteria	Weights
Costs (capital and operational)	23
Benefits (economic, social, environmental)	32
Technology	20
Institutional	10
Climate related	15
Total	**100**

Table 2.5: Scoring Matrix (scores for each criterion was between 0-100)

Technology option	Criteria						
	Costs	Benefits; Economic (E), Social (S), Environmental (Env)			Technology	Institutional	Climate related
		E	S	Env			
Non-Carbonised Briquette Production (pellets)	80	85	70	60	65	90	50
Bio latrines for Institutions (using biogas technology)	80	80	100	90	80	100	50
Gasification for electricity generation 50 kW	35	75	75	65	65	100	60
Ethanol for blending with gasoline	85	100	90	40	100	80	50
Off-grid solar mini-grids up to 100 kW	100	100	90	100	80	40	80
Solar rooftop systems	85	100	100	90	100	80	90
Efficient institutional cook stoves	100	60	95	85	70	90	60
Biodiesel production for the transport sector (blending)	35	60	35	35	35	30	5
Criterion weight	23	32			20	10	15

Table 2.6: Weighted scores with ranks

Technology Option	Weighted score	Rank
1. Non-Carbonised Briquette Production (pellets)	3095	5
2. Bio latrines for Institutions (using biogas technology)	3255	3
3. Gasification for electricity generation 50 kW	2675	6
4. Ethanol for blending with gasoline	3130	4
5. Off-grid solar mini-grids up to 100 kW	1812	7
6. Solar roof top systems	3895	1
7. Efficient institutional cook	3370	2
8. Biodiesel production for the transport sector (blending)	1170	8

Based on the above weighted scores, the three (3) selected technologies were:

1. Solar rooftop systems
2. Efficient institutional cook stoves
3. Bio-latrines for institutions (using biogas technology)

Below is a brief about the mitigation technologies that were selected by the stakeholders during the technology prioritization workshop:

1. Solar rooftop systems

These solar systems are the most suitable technology used in remote and rural areas, which are not served by the electricity grid or in places with frequent power outages/interruptions. Electricity access in Uganda stands at 22.4%, (ERA, 2019) with the majority of the consumers in urban areas. This justifies the selection of solar rooftop systems as viable alternatives that can provide electricity to majorly off-grid rural communities and to grid connected areas with unreliable power supply. Solar technologies perform better in regions and seasons with the highest sun intensity and long sunlight hours. Building rooftops are the most logical location for the installation of solar thermal and PV technologies.

Prior to the installation of a large number of solar panels, it is important to ensure a roof's structure is strong enough to hold its weight. Accessibility for maintenance should also be planned for. It is recommended that preventive inspections and maintenance are carried out every 6 to 12 months. Inspection includes checking for signs of damage, dirt build-up or shade encroachment. The crucial condition of PV applications is that the locations must be exposed directly to sunlight and are not shaded. The reason is that PV modules, crystalline silicon technologies in particular, are very sensitive to shading.

Preventive measures include periodic maintenance to clean the surface of the modules (e.g., accumulated dust and/or bird droppings). In order to maximize the yield, PV panels should be mounted so that they face the sun directly.

Benefits of solar rooftop systems include: access to energy in areas where there's no electricity network or where grid power supply is unreliable, quick installation and removal if necessary, little maintenance, cheaper per kWh than candles, batteries and/or paraffin and no emission of harmful substances, improved health due to the fact the systems do not emit and can also be used to provide light in the rural off-grid health facilities, better education as students can learn for longer hours in the evenings, improved skills/capacity due to training opportunities especially for solar technicians, improved quality of lives due to increased information flow and entertainment in the homes (televisions, radios, phones), increased home safety as it reduces fire hazards that would have resulted from using candles or kerosene lamps, improved security and reduced crime which occurs after nightfall, job creation for distributors and retailers of solar rooftop systems and those in the business value chain to mention.

2. Efficient institutional cook stoves

Institutional stoves are used where larger amounts of food than can be accommodated on a standard kitchen stove can be cooked. Typical examples are schools, hospitals, prisons and other institutions. Institutional stoves are also used in refugee camps, particularly in the early stages when large influxes of people require food urgently. Typically, these groups will use institutional stoves with a cooking capacity of 50 litres to 200 litres (Appropedia, 2019). Another very different group of users are entrepreneurs who own cafés or restaurants, selling street foods, or selling staple foods such as bread or chapattis. In such cases, the stove is likely to be used for several hours each day. Uganda has over 30,000 educational institutions and these mostly depend on firewood for cooking. Schools are open for a minimum of nine (9) months annually.

The longer school periods translate into higher demand for firewood. The refugee influx in the country also increases the demand for cooking fuels. These high demands translate into increased destruction of forests and environmental damage. The growing institutions' needs for firewood justify the selection of efficient institutional cook stoves as a viable technology option to reduce the adverse impacts of climate change since they require less firewood to do more cooking. Uganda's NAMA "NS-151, The Promotion of the Use of Efficient Institutional Stoves in Institutions" is a good policy indicator that the technology will be promoted. It details that the promotion of energy efficient cook stoves will be achieved through developing a policy instrument that ensures all educational institutions (EIs) in the country use such stoves. This policy instrument could include incentives in the form of grants and loans for compliance.

Benefits include: reduced deforestation given that institutions use less firewood for more cooking, reduced GHG emissions since they are more efficient, minimized health risks due to reduced indoor air pollution, health effects of carrying wood for long distances by children and other institutional staff are also avoided, gender considerations: both men and women can be engaged in the construction of the institutional stoves, better education as students can stay longer in school instead of spending some hours collecting firewood, improved skills/capacity due to training opportunities in stoves construction, job creation given that the manufacturing and back-up services are provided by locals and increased establishment of businesses engaged in efficient institutional cook stoves construction.

3. Bio-latrines for institutions (using biogas technology)

Biogas is one of the oldest technologies which was disseminated in Uganda over the last 40 years. Biogas is a combustible gas produced by the anaerobic fermentation of cellulose containing organic materials. Biogas normally consists of 45% to 75% methane, 25-45% carbon dioxide and 2%-3% moisture and about 1% trace gases (Ghimire & Prakash, 2013). It can be used as fuel for cooking, lighting, and heating. Biogas from faecal matter has been used in many countries. It is suitable for schools, prisons, barracks and other institutions. It can be used to supplement firewood use in institutions. In most cases faecal matter is not enough to provide the necessary amount to meet energy demand in an institution. The most suitable type is the dome type digester. The performance of the digester can be improved by having a steerer, pH. meter and temperature sensors.

Benefits of biogas technology include; smoke-free and ash-free kitchen, so women and their children are less prone to respiratory infections, students are spared the burden of gathering firewood hence students have more time for schools translating into improved education, construction of a bio-latrine improves sanitation and hygiene conditions which is essential for the overall health and well-being of the students, reduced deforestation because biogas is an alternative clean fuel, the sludge remaining after digestion is a good fertilizer which increases land productivity, the release of methane is avoided thus contributing to climate mitigation, switching from traditional biomass resources (e.g. in developing countries) or fossil fuels (e.g. in industrialized countries) to biogas fired generation capacity improves security of energy supply (locally as well as nationally or regionally) as the feedstock can mostly be acquired locally, biogas can replace fossil fuels, thus reducing the emission of GHGs and other harmful emissions, it's a natural waste treatment process.

Chapter 4 Summary and Conclusions

Uganda has contributed little to the potentially catastrophic build-up of the human-derived greenhouse gases (GHGs) in the atmosphere and yet the country is among the most vulnerable to global warming and climate change impacts. Similar to other developing countries, Uganda needs to utilize adequate clean energy technologies to mitigate the impacts of climate change however; these are very few and most are inefficient. It is for this reason that a Technology Needs Assessment has been conducted in order to identify and prioritize technologies that have to be deployed in the country to achieve a low-carbon development path for sustainable development.

The technology prioritization process involved development of technology fact sheets (TFS) for eight technologies and holding of a stakeholder's prioritization workshop. Technology prioritization was done by the stakeholders working together with the mitigation consultants using the Multi-Criteria Analysis tool. The criteria used were; Costs, Benefits (economic, social and environmental), technology and institutional considerations. Weights were added under each option and criteria based on their importance as per the stakeholder's opinions. Total results per option were automatically computed by the tool. Using the total scores, the stakeholders ranked the technology options from the highest scored to the lowest and selected the three (3) highest ranked technology options as; (I) Solar rooftop systems, (2) Efficient institutional cook stoves and (3) Bio-latrines for institutions (using biogas technology).

Solar rooftop systems were selected because Uganda's location astride the equator makes solar energy an increasingly viable potential power supply over much of the country. The systems are the most suitable technology used in remote and rural areas, which are not served by the electricity grid or in places with frequent power outages/interruptions. The technology option has enormous benefits including; no emission of harmful substances, improved health, better education, improved skills/capacity due to training opportunities especially for solar technicians, improved quality of lives due to increased information flow and entertainment, increased home safety as it reduces fire hazards, improved security and reduced crime which occurs after nightfall and job creation for distributors and retailers of solar rooftop systems.

Efficient institutional cook stoves are a suitable technology for cooking larger amounts of food than can be accommodated on a standard kitchen stove in schools, hospitals, prisons, refugee camps and other institutions. The technology option's benefits include; reduced deforestation given that institutions use less firewood for more cooking translating into reduced GHG emissions, minimized health risks, gender considerations since both men and women can be engaged in the construction of institutional stoves, better education, improved skills/capacity and job creation.

Bio-latrines for institutions (using biogas technology) is a viable technology option due to availability of cheap feedstock (human waste) at the schools. The technology provides smoke free fuel hence reduces respiratory infections among the students and staff of the schools, better education since students are spared the burden of gathering firewood, improve sanitation and hygiene conditions which is essential for the overall health and well-being of the students, the release of methane is avoided thus contributing to climate mitigation, and savings on cooking fuel by the school administrations.

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Annex I: Technology Factsheets for selected technologies

TFS 1

Technology name	Solar rooftop systems
Subsector GHG emission	7,607 tCO_2 eq.
Background/Short description of the technology option	Solar rooftop systems are developed based on photovoltaic (PV) technologies and integrated with DC-electricity-based appliances. It is the most suitable technology used in remote and rural areas, which are not served by the electricity grid. A typical system consists of a 10 to 50Watt Peak PV module, charging controller, storage battery, and various end-use equipment that operate with DC electricity (e.g. fluorescent lamps, radio, television, fan, etc). Solar technologies perform better in regions and seasons with the highest sun intensity and long sunlight hours. Building rooftops are the most logical location for the installation of solar thermal and PV technologies. Prior to the installation of a large number of solar panels, it is important to ensure a roof's structure is strong enough to hold their weight. Accessibility for maintenance should also be planned for. It is recommended that preventive inspections and maintenance are carried out every 6 to 12 months. Inspection includes checking for signs of damage, dirt build-up or shade encroachment. The crucial condition of PV applications is that the locations must be exposed directly to sunlight and are not shaded. The reason is that PV modules, crystalline silicon technologies in particular, are very sensitive to shading. Taking a module consisting of 36 PV cells as an example, if one cell is shaded, the cell, instead of producing, can consume the energy produced by other cells, due to their string connectivity. Electricity production of the whole module, in this case, can be reduced by up to 50%. Therefore, shading must be avoided. Preventive measures include periodic maintenance to clean the surface of the modules (e.g., accumulated dust and/or bird droppings). In order to maximize the yield, PV panels should be mounted so that they face the sun directly. In the tropical regions, especially in the regions near the equator, flat-mounted PV panels provide the best yield. However, the flat-mounted PV panels will result in poorer self-cleaning performance and tend to accumulate dust, which in times causes shading to the cells and diminishes the system's outputs. A slight inclining angle of 3 to 5 degrees, to allow for rainwater properly drained off and promote self-cleaning, is useful and acceptable. Regular maintenance is required. Benefits of a solar rooftop system include; access to energy in areas where there's no electricity network, quick installation and removal if necessary, little maintenance, cheaper per kWh than candles, batteries and/or paraffin and no emission of harmful substances. The technology has some restrictions; only small electrical appliances can be connected; cooking, heating and cooling is not possible.

Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	While the Government of Uganda is making significant efforts to add additional generation capacity and to extend the grid to various parts of the country, majority of the low-income households will still need alternative sources of energy due to the cost of grid power or the high costs incurred in extending the grid. The solar rooftop system market is regarded as one of the biggest areas in Uganda for commercially driven solar PV business, and considered to have high potential. There are a number of local and international sellers of solar rooftop systems across the country especially in rural communities. In Uganda the technology is implemented with different options; one can purchase a system with an upfront payment while others use a Pay as You Go system where customers pay a small amount of money to the vendor/distributor every day for an agreed upon period of time. This has solved the challenge of high upfront investment costs. The assumption for increased implementation of this technology is that ongoing Government grid power expansion plans especially for rural areas should be clearly communicated to the public. The purchasing power of rural households is highly affected by climate change since majority do farming for livelihood. Hence the purchasing power is higher during harvest season when they sale their farms produce most especially during July/August and November/December. If the crops are affected by low rains, the yields are low hence low purchasing power.
Implementation barriers	Uganda does not manufacture but imports solar rooftop systems. • The technology comes with high initial investments. • Low rural consumer ability to pay due to low disposable income This is coupled with lack of affordable financing schemes most especially for end users. Available loan terms are unfavorable to clients • Limited access to working capital throughout the distribution chain • Low quality products. • Limited power supply, cannot power appliances with higher energy requirements e.g. electric kettle • Poor infrastructure and high cost of setting up distribution networks • Theft of solar panels scares off some potential customers • Vendors/technical providers are mainly based in urban areas, quite far from their clients thus making it difficult for clients to access prompt after-sales services; • Lack of business management skills; limited technical & institutional capacity; enforcement of standards and quality
Reduction in GHG emissions	If implemented the technology will result in a reduction of 7,607t CO_2 eq. over a 15years period.
Impact Statements: How this option impacts the country development priorities	

Country social development priorities	• Gender considerations: Both men and women are engaged in the sale of solar rooftop systems • Improved health due to the fact the systems do not emit and can also be used to provide light in the rural off-grid health facilities • Better education as students can learn for longer hours in the evenings • Improved skills/capacity due to training opportunities especially for solar technicians • Improved quality of lives due to increased information flow and entertainment in the homes (televisions, radios, phones) • Increased home safety as it reduces fire hazards that would have resulted from using candles or kerosene lamps • Improves the security and reduces crime which occurs after nightfall.
Country economic development priorities	• Job creation for distributors and retailers of solar rooftop systems and those in the business value chain. The implementation of solar charging stations provides opportunities for new businesses that are environmentally friendly. Solar lighting extends the work day and allows merchants longer time periods to sell their goods. • Attracting investments
Country environmental development priorities	• Reduced GHG emissions • Reduced pollution • Conservation of eco systems
Other considerations and priorities	**Technology related** • Resource availability (sun is abundantly available in Uganda) • Availability of rooftop systems on the market • Reliability of the technology **Political benefits** Alignment to national sector instruments such as Vision 2040, The Uganda Green Growth Development strategy 2017/18-2030/31. Solar rooftop systems are vital for social-transformation especially for the rural off-grid communities.
Costs	
Capital costs	$400 per Solar system of 100 watts; 4 Lights for 4-6 hours per day – replaces 4 kerosene lamps; radio more than 6 hours – this replaces use of disposable dry-cell batteries; TV for 3-6 hours – displaces diesel.
Operational and maintenance costs	$300 over the lifetime of 15 years
Cost of GHG reduction	36.97 USD/t.CO2 eq.
Lifetime	15-20 years

TFS 2

Technology name	**Efficient institutional cook stoves**
Subsector GHG emission	84,171.8 Tonnes CO2 eq.
Background/Short description of the technology option	Institutional stoves are used where larger amounts of food than can be accommodated on a standard kitchen stove can be cooked. Typical examples are schools, hospitals, prisons and other institutions. Institutional stoves are also used in refugee camps, particularly in the early stages when large influxes of people require food urgently. Typically, these groups will use institutional stoves with a cooking capacity of 50 litres to 200 litres. Another very different group of users are entrepreneurs who own cafés or restaurants, selling street foods, or selling staple foods such as bread. In such cases, the stove is likely to be used for several hours each day (Appropedia, 2019). **What makes a good institutional stove?** • *Fuel efficiency:* Where stoves are used in refugee camps, the acute shortage of fuel may be one of the reasons for choosing to cook communally. • *Strength and quality:* Heavy weights, such as a full container of boiling water, will regularly be placed onto the stove. If livelihoods are dependent on cooking food, the stove must be reliable, durable and strong. • *Low emissions.* Good institutional stoves reduce emission. • *Seasonal influences:* If a stove can use a variety of fuels, it may be possible to use lower cost fuels, such as agricultural residues, during some times of the year. However, a stove that relies solely on residues can only be appropriate if these residues are assured. When an organization or individual is considering an institutional stove, other factors need to be considered: In refugee situations, the needs and preferences of those seeking help should be identified before a stove type is selected. A reliable supply chain for fuel should be assured, as the well-being of a lot of people will depend on the outcome. The stove could benefit a whole community or just the person with the stove; how are the benefits going to be distributed? Is the technology under consideration reducing the total emissions to the environment? If so, would it be possible to get carbon finance to support this activity? *Types of institutional stoves include;* Rocket stoves, Nkokonono stove, Libhubesi stove, Bellerive-type stove, Injera stoves, Stoves using peat, Solar-powered cookers and ovens and Gasifier stove **Impacts of institutional stoves:** Institutional stoves have the potential for providing important services at a low cost to large numbers of people. These include: h*ealth* – the new generation of institutional

	stoves provides energy which is cleaner and requires less effort to use, e*nvironment* – stoves with improved combustion require much less wood, thus benefiting the environment. Where residues can be used, two problems are solved at once – more fuel is available and the problem of waste management is resolved, *employment* – Using more efficient stoves can make small enterprises very attractive to the entrepreneur as the profit margins can increase substantially, *where those savings are passed onto the consumer, they pay less for the services*, *additional services*, such as bakeries, can improve the quality of life for communities which are served, *within a refugee situation*, food can be provided quickly and efficiently, reducing the risks associated with fuel collection for traumatized people, institutional stoves have an important socio-economic role to play in society. Well-designed, they provide useful services to the consumer and a good income to the provider. They can also reduce overall fuel use within a community and improve the use of residues which would otherwise be a problem (Appropedia, 2019).
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Uganda has over 30,000 educational institutions and these mostly depend on firewood for cooking. Schools are open for approximately nine (9) months annually. An average school uses 20 tonnes of firewood annually in inefficient cook stoves. Uganda's NAMA "NS-151, The Promotion of the Use of Efficient Institutional Stoves in Institutions" is a good policy indicator that the technology will be promoted. The promotion will be mainly for rocket stoves using 33% less wood. It is assumed that institutional stoves will have efficiency of 40%. The traditional stoves have efficiency of about 10% The improved stoves installation will start with 50 in the first year and will increase gradually to 1000 by the fifth year of the project. The life cycle of the stoves is about 8-10 years. Maintenance is normally carried out at the end of the third year after installation of the stoves. If a strict maintenance is done, it may extend the life cycle of the stoves, the overall cost of emission reduction will be lower. The other option is to decommission the stoves once they reach end of life cycle and install new ones. The cost of emission reduction will be higher.
Implementation barriers	• High initial cost which makes institutions reluctant to take up this technology • Lack of financing mechanisms • Lack of performance assurance or product standards • Lack of adequate local expertise or know-how or skills • Lack of co-ordination among agencies that promote efficient institutional cook stoves.
Reduction in GHG emissions	If implemented the technology will result in annual reduction of 82 ktCO2e/a from 1,000 schools by 2030 (refer to NDC).
Impact Statements: How this option impacts the country development priorities	

Country social development priorities	• Minimized health risks due to reduced indoor air pollution. Health effects of carrying wood long distances by children and other institutional staff are also avoided. • Gender considerations: Both men and women can be engaged in the construction of the institutional stoves. Although currently construction is mainly done by males however the activities can be done by women too. • Better education as students can stay longer in school instead of spending some hours collecting firewood. • Improved skills/capacity due to training opportunities in stoves construction
Country economic development priorities	• Job creation. Where the manufacturing and back-up services are local, there are jobs generated. • Increased establishment of businesses engaged in efficient institutional cook stoves construction
Country environmental development priorities	• Reduced deforestation given that institutions use less firewood for more cooking • Reduced GHG emissions
Other considerations and priorities	**Technology related** • Availability of the market because Uganda has more than 30,000 education institutions • Reliability of the technology • Raw materials required for stove construction are readily available locally **Political benefits** • Alignment to national sector instruments
Costs	
Capital costs	$2,100,000 if the stoves are well maintained and serves for 8 years. If some of the stoves are decommissioned, the cost will be USD 3,361,644
Operational and maintenance costs	If the stoves are well maintained USD 197,250. If additional stoves are installed the cost of maintenance will be USD 1,261,644 (for 1,000 education institutions for the entire lifetime of the stoves)
Cost of GHG reduction	USD /ton CO2eq. 27.29 (strict maintenance of all stoves) USD /ton CO2eq. 42.28 (if some stoves are decommissioned and new ones installed)
Lifetime	8-10 years

TFS 3

Technology name	Bio latrines for Institutions
GHG emission	41,813 -ton CO_2 eq.
Background/Notes, Short description of the technology option	Biogas is one of the oldest technologies which was disseminated in Uganda over the last 40 years. Biogas is a combustible gas produced by the anaerobic fermentation of cellulose containing organic materials. Biogas normally consists of 45% to 75% methane, 25-45% carbon dioxide and 2%-3% moisture and about 1% trace gases. It can be used as fuel for cooking, lighting, and heating. Biogas from fecal matter has been used in many countries. It is suitable for schools, prisons, barracks and other institutions. It can be used to supplement firewood use in institutions. In most cases fecal matter is not enough to provide the necessary amount to meet energy demand in an institution. Most of the schools use three truckloads of firewood per term. The estimated weight per truck is 850 kg. That is 2,550 kg per term. It translates to 7.65 tonnes per year for 1,000 students. The most suitable type is the dome type digester. The performance of the digester can be improved by having a steerer, pH. meter and temperature sensors. The power needed for the operation of the digester can be provided by solar. Such systems are operational in counties like Kenya and Pakistan. Its estimated that additional items will result in about UGX 8- 10 million. (USD 2,110 to 2,600)
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	The use of biogas has been limited to households, but now there are few institutions, which have biogas systems operating for a while, but the performance needs improvement. There is also need to sensitize potential users, on the economic and environmental benefits of biogas technologies and applications, maintenance and general operation procedure. The use of biogas will reduce the use of firewood, charcoal and kerosene at the household and institutional levels. One negative environment impact of biogas is that burning biogas also generates volatile organic compounds and nitrogen oxides, which are air pollutants and an ozone precursor, but the impact is limited[1]. It is assumed that installation of the biogas systems will start in 2020 and by 2025 there will be 32 installations and by 2030 they will reach 100 units. If the school has a population of 1000 students, it is estimated that the feedstock will be enough for cooking for 400-500 students. Biogas will have to be

[1] An Ethnographic Case Study Li Jian, Human Organization, Vol. 68, No. 4, 2009, Society for Applied Anthropology.

	supplemented by other sources of feed stock or fire wood using energy efficient institutional stoves.
Implementation barriers	The upfront cost of building and setting up the system is high
Impact Statements - How this option impacts the country development priorities	
Country social development priorities	• Better education since students are spared the burden of gathering firewood, • Improved sanitation and hygiene conditions which is essential for the overall health and well-being of the students • The technology provides smoke free fuel hence reduces respiratory infections among the students and staff
Country economic development priorities – economic benefits	• Job creation for those involved in construction and maintenance of the systems • Savings on cooking fuel by the school administrations.
Country environmental development priorities	• Reduced deforestation given that institutions will majorly use biogas for cooking • Reduced GHG emissions
Gender	In most of the schools, women do much of the cooking. Biogas is a clean source of energy, with negligible indoor air pollution. The fuel is used by both men and women.
Other considerations and priorities such as market potential	There's a good market potential, Uganda has more than 30,000 schools, the technology is also suitable for other institutions. There is a need for sensitization of the public. It is important to understand the social and cultural pattern of the clients. Use of bio-latrines will reduce the cost of emptying latrines and continuous constructions of pit latrines in the limited space available.
Costs	
Capital costs	US$ 533,333
Operational and Maintenance costs	USD 173,600
Cost of GHG reduction	USD 16.91/ tonnes CO_2eq. This excludes reductions in emission due to degradation of forests. Otherwise it will be lower.
Lifetime	20 years
Other	Biogas plants with improved performance will need additional 10 million for instrumentation, depending on size, location and availability of additional feed stock. It should be noted that the biogas will cater for 400-500 students only. One of the options is to get additional feed stock from cow dung for the remaining students. The school can also have efficient institutional stoves. If controls are included the cost will increase.

TFS 4

Technology Name	**Ethanol for blending with gasoline**
GHG	5,163.16 ktCO2 eq.
Background/Notes, Short description of the technology option	Blending can be done up to 20% without modification of the engine. It is assumed that blending will be done at 5%-10 % by 2035. The use of fossil fuels contributes to increase in GHG emissions. The transport sector is the leading source of emissions. Uganda has potential to reduce the emissions by producing ethanol which can be blended with petrol. The technology is developed in some countries in the world. Some Ugandan sugar factories have the capacity to produce hydrous ethanol /fuel grade. Kakira Sugar Works Limited has invested about USD 36 million in ethanol production. The estimated production is 20 million litres per annum. Government has put in place favourable policies that promote blending.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	There is an additional component of blending equipment that requires about 4 million dollars. The equipment needs to be installed in Kampala where there's the highest concentration of vehicles because the transport sector is the leading emitter of the GHG emissions in Uganda. Use of ethanol is expected to reduce emissions in the transport sector. There is high increase of the import of gasoline over the last decades. There are also issues in marketing of ethanol; detailed costs are not yet determined and the selling price verses production cost is still not clear to the public. The government has not made blending compulsory. It is not clear if the sugar factories will be able to produce enough fuel grade ethanol if the government sets targets for blending. In case blending starts, there is expected to be a reduction in import of gasoline will reduce tax income from selling of gasoline.
Implementation barriers	• The detailed production cost is not well defined. It is not clear on who will set the pump price • It is not clear who will be responsible for construction and management of the blending facilities. • There is delay in making blending mandatory. • The effect of blending in future when Uganda will be producing gasoline is not known.
Impact Statements - How this option impacts the country development priorities	
Country social development priorities	Use of ethanol will contribute to cleaner air hence reducing diseases attributed to air pollution from fossil fuels
Country economic development priorities – economic benefits	• There will be reduction in costs that would be incurred in importing petrol.

	• Job creation for people involved in the production of ethanol • Attracting investments from those who would like to engage in ethanol production and distribution.
Country environmental development priorities	• Reduced deforestation given that institutions will majorly use biogas for cooking • Reduced GHG emissions
Gender	Ethanol may also be used as fuel for domestic and institutional use. Both women and men will benefit from this
Without blending	70,416 kton CO2 eq
With blending	65,253 kton CO2 eq
Reduction in Emissions	5, 136 kton CO2 eq
Other considerations and priorities such as market potential	There is a high rate of urbanization (over 5% per annum) in Uganda hence demand for ethanol will increase in the near future. The number of vehicles is also on the increase. Ethanol fuel is readily available; what is lacking is the implementation of the government policy on blending of fuels.
Costs	
Capital costs	USD 85 million
Operational and maintenance costs	USD 40 million
Cost of GHG reduction	24.21 US$ /Ton CO_2 eq
Lifetime	15years
Other	There's expected to be competition for ethanol for domestic and transport needs if the domestic market for ethanol-based stoves is established. It is necessary to consider the end use technologies, the biomass supply stock and transport of fuel, the ethanol program in relation to the total energy policy.

TFS 5

Technology name	**Non-Carbonized Biomass Briquette Production (Biomass Pellets) for households and institutions**
Subsector GHG emission	33,814 CO_2 eq.
Background/Notes, Short description of the technology option	Firewood and charcoal are the most used fuels in the domestic and commercial sectors. While firewood is most favorable fuel in the rural areas, the use of charcoal is favorable in the urban areas. Wood pellets are solid fuel made from dry sawdust or any other biomass fraction, compressed through a die under high pressure. These can be one of the alternatives to reduce on the woody biomass consumption. In most cased the feed stock needs to be dried so that the moisture is reduced to about 8-10%. Uganda in the NDC proposed to use biomass-based induction cook stoves. Biomass-based pellets are attractive options for such stoves. It can be used easily at households and commercial sectors. It is known that the current use of biomass is not sustainable. Biomass pellets are better because all sorts of biomass fraction can be used to produce pellets. It can promote sustainability of biomass. Wood pellets have high energy density 16-18 MJ/kg which makes them suitable for both commercial and industrial thermal applications.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	The pellets can be produced at commercial level or as a small-scale industry. It is possible to have stand-alone units with low capacity less than 2 tonnes /hour and high capacity from 5 tons /hour. There are various versions of pellet machines. There are several sawmills, furniture plants in Uganda with significant volumes of wood residues for the production of wood pellets. There is already commercial production of pellets in Uganda, however, there are some problems with energy usage in some pellet producing companies. The use of pellets will save on trees. The co-benefits will be improving on water catchment, carbon sequestration, improving on local climate and deforestation.
Implementation barriers	• The cost of machines for pellet production is high. • Electricity consumption for both pelleting and drying is very high. • There is need for technologies which can produce higher volumes of pellets and cheap drying for the raw materials. • More work has to be done to improve on the thermal efficiency of the pellet machines.
Impact Statements - How this option impacts the country development priorities	

Country social development priorities	Better education as the use of non-carbonized briquettes in schools will reduce on the time students spend searching for firewood.
Country economic development priorities – economic benefits	• Job creation for those involved in the production and sale of briquettes • Saw millers and other biomass providers can have additional income through investment in this technology and sale of raw materials.
Country environmental development priorities	• Reduced deforestation since briquettes are alternatives to firewood and charcoal • Reduced air pollution
Gender	The use of biomass pellets in households will reduce the burden of wood collection that is majorly faced by women and girls.
Other considerations and priorities such as market potential	There is market for pellets in Uganda, however, most of the equipment are of low capacities. Large capacity units should be introduced in Uganda. They will be more efficient and production cost will be lower than the present low capacity pellets production units in Uganda.
Costs	
Capital costs	The estimated cost of the machines from China or India is USD 60,000
Operational and Maintenance costs	Cost of feedstock, equipment maintenance and personnel estimated at USD 495,000 over the ten years
Cost of GHG reduction	14.64 USD/ton CO_2 eq.
Lifetime	10 years
Other	India and China are the main source of the pellets machines. At present fuel wood is cheap, but is will not be sustainable in future. Briquettes production will depend on the capacity of machines and cost of raw materials. In Philippines, low capacity (one tonne per hour) will have a production cost of about USD 88-92 per tonne, using woody residues such as sawdust and shavings at a price of USD 30-40. The data from Uganda is from a briquettes manufacturer in Uganda. Since it is one source of biomass (biomass waste fraction) to biomass (compressed), there will not be reduction in emissions. It is a good technology to supplement use of wood fuel and charcoal.

TFS 6

Technology name	**Gasification for electricity generation**
Subsector GHG emission	2,328 Tonnes CO_2 eq.
Background/Notes, Short description of the technology option	Gasification is one of the first-generation technologies that generate gas (producer gas) which can be used to generate electricity and thermal energy from biomass resources. The gas can be used for thermal application such as cooking. It is a clean fuel and burns with clean blue flame. It can also be cleaned and used in a generator for electric energy generation. The raw materials are waste biomass fractions of non woody biomass, wood and agricultural residues.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Gasification is one of the first-generation technologies. The technology is being used at different capacities mostly in China and India and other east Asian countries. In other countries it is used in domestic stoves called *top lit stoves*. It can be used in households, institutions and for commercial purposes. Currently, there are less than five operating gasifiers in Uganda. There is need for dissemination of this technology. Initially, prototypes will be designed and constructed, tested before dissemination to wider applications to the community. It will be useful to the wider population because in many cases biomass wastes fractions are burnt in situ.
Implementation barriers	• The initial cost of the technology is high • The technology is little known in the country. • There is need for ample technical capacity to operate the plants. • The ongoing rural electrification program in most parts of Uganda may affect diffusion of the gasifier technology.
Impact Statements - How this option impacts the country development priorities	
Country social development priorities	• Better health due to reduced indoor air pollution, electricity from gasifiers replaces use of kerosene lamps • Better education because students can read for longer hours • Improved quality of lives due to increased information flow and entertainment in the homes (televisions, radios, phones) • Improved skills/capacity for plant operators
	• Job creation for gasifier operators

Country economic development priorities – economic benefits	• Spin-off businesses are created such as phone charging centres, salons and others which require electricity to run • Increased income by biomass suppliers • Increased agricultural activities due to increased demand for agricultural waste
Country environmental development priorities	• Reduced greenhouse gases emissions • Reduced deforestation
Gender	The technology provides business opportunities that can be taken up by both women and men. Forexample, both women and men can engage in salon businesses, phone charging center, poultry and the like.
Other considerations and priorities such as market potential	• The technology is good but not mature in Uganda • The rural electrification program can make installed gasifier plants economically unviable
Costs	
Capital costs	USD 158,840
Operational and Maintenance costs	USD 210,000
Cost of GHG reduction	158.41 USD /ton CO_2
Lifetime	10 years
Other	Gasification technology is very expensive, there is need for support in areas such as installation and distribution of electricity. Tax waivers should be given for imports of gasifiers and spare parts.

TFS 7

Technology name	**Off-grid solar mini-grids up to 50kW**
Subsector GHG emission	4,139.94 t CO2 eq.
Background/Short description of the technology option	Solar technologies facilitate the extraction of a renewable energy source by harnessing power from the sun. There are two technological principles that can be used to achieve this: (1) Collecting thermal energy from the sun, known as solar thermal; and (2) Converting light into electricity, through the photovoltaic process. Both solar thermal and photovoltaic (PV) can be integrated into buildings. Applications for PV include building integrated photovoltaic (BIPV), solar home systems (non-grid connected) and solar charging stations. Most BIPV applications are grid connected enabling surplus energy produced to be exported to the grid. Solar energy is currently used for on-grid, off-grid electrification for rural communities, solar cooking, providing water heating and power to public buildings. A mini grid, also sometimes referred to as a "micro grid or isolated grid", can be defined as a set of electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a localized group of customers. "They involve small-scale electricity generation which serves a limited number of consumers via a distribution grid that can operate in isolation from national electricity transmission networks. Solar panels capture sunlight, which is converted to electricity. The electricity then goes to an inverter that converts direct current into alternating current, which is then fed directly or indirectly (via the batteries) into the electricity network. The electricity reaches all customers connected to the network. A group of people who live close to each other, in for instance a village, can be easily connected to the grid. A solar mini-grid is the right solution for customers with higher energy requirements like businesses. A solar mini-grid boosts business activity in rural areas, but can only be realized economically if the distance between clients is relatively short. Advantages of a mini-grid include; provision of power to off-grid customers with higher energy needs, little maintenance, no emission of pollutants, no dependence on the import of diesel and fluctuating energy prices
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some	This technology will use energy from the sun. Uganda's location astride the equator makes solar power an increasingly viable potential power supply over much of the country, especially the drier northern parts of the country. The insolation is highest at the Equator, the mean solar radiation is 5.1 kWh/m^2 per day, on a horizontal surface. Mini-grids are a cheaper solution for less populated rural communities, providing sufficient energy for productive use, under faster implementation than grid extension. In 2016, GIZ and the Government of Uganda (GoU) initiated the Pro Mini-Grids project to open up the mini-grid sector by streamlining institutional processes, lobbying for

improvements in the country environment.	political and donor support, identifying viable projects and ultimately implementing a sizeable bundle of mini-grid projects to prove the technical and financial potential on a scale that will convince industry and decision-makers alike. Based on these factors, it is assumed that interest in development of solar-mini-grids is growing in the country. The assumptions are; of the 1000 households to be served by the mini-grid; 250 are high income and 750 low income. High income earners use petrol generators while low income earners use kerosene.
Implementation barriers	• High initial cost of development, installation, maintenance and repairs. • Competition from Grid power which is highly prioritized and subsidized compared to off-grid • Very high tariffs. • Locating solar farms and transmission lines requires negotiations, permits contracts and community approval which increase the cost and duration of the projects. • General information and awareness in relation to new technologies and understanding the practical Problems in implementing and maintaining projects is limited. • Tedious licensing procedures which were designed for large generation and distribution projects. • Difficult in securing financing for small-scale projects. • Lack of Standards and Quality Assurance: • Unpredictable extension of the grid. • Demand for electricity in rural off-grid communities is not for productive use but majorly for home consumption, low industrialization in off-grid areas.
Reduction in GHG emissions	Uptake of this technology replaces kerosene lamps and candles that are majorly used for lighting in rural off-grid communities and fossils fuels used in generators to power electric appliances such as milling machines, refrigerators, hair cutting machines, televisions, radios and telephone charging points. If implemented the technology will result in annual reduction of 4139.94 tons of CO_2 by 2030.
Impact Statements: How this option impacts the country development priorities	
Country social development priorities	• Gender considerations: Both men and women can be engaged in the local businesses powered by the electricity from the mini-grid • Improved health due to the fact the mini-grids can be used to provide light in the rural off-grid health facilities. Also use of solar energy replaces kerosene lamps which in turn reduces indoor air pollution and its related negative health effects • Better education as students can read and learn for longer hours in the evenings

	• Improved skills/capacity due to training opportunities especially for solar technicians who maintain the mini-grids • Improved quality of lives due to increased information flow and entertainment in the homes (televisions, radios, phones)
Country economic development priorities	• Job creation (directly for mini-grid maintenance and indirectly in the local businesses that are powered by the mini-grid • Attracting investments for the development of the mini-grids and spin-off businesses
Country environmental development priorities	• Reduced GHG emissions since the mini-grids have a low carbon foot print • Reduced pollution • Conservation of eco systems
Other considerations and priorities	**Technology related** • Resource availability (sun is abundantly available in Uganda) • Availability of solar equipment on the market • Reliability of the technology • Most people in Uganda are aware of the technology **Political benefits** • Alignment to national sector instruments such as Vision 2040, The Uganda Green Growth Development strategy 2017/18-2030/31. • Solar is one of the energy sources the country plans to develop to generate a considerable capacity of modern energy to drive the industry and services sectors.
Costs	
Capital costs	$300,000 including one-off development costs required in the early stages
Operational and maintenance costs	$250,000 over its lifetime (5% of the capital cost per kW per annum)
Cost of GHG reduction	132.85 USD/ton CO_2 eq.
Lifetime	20-25 years, batteries have to be replaced at least every 5 years

TFS 8

Technology name	Biodiesel production for the transport sector
Subsector GHG emission	1,443 kt CO_2 eq.
Background/Short description of the technology option	Liquid biofuels for transport, including biodiesel, have to a certain extent been in use for a very long time. In recent years however, they are enjoying renewed interest in both developed and developing countries as a result of the need to curb rising emissions from the transport sector, reduce dependence on expensive fossil oil imports and increase farm incomes. An important advantage of biofuels is that they can easily be integrated into the existing transport infrastructure, thus avoiding the often-prohibitive investment costs associated with other renewable options for the transport sector. Conventional, 1st generation biodiesel can be produced from various vegetable oils, such as rapeseed, palm, soybean and jatropha oil and animal fats. Biodiesel can have significant benefits in terms of GHG emissions reduction and socio-economic development. However, biodiesel production has also been criticized for causing deforestation, loss of local livelihood and for having a negative GHG emissions balance (when palm oil is produced on peat land). Depending on the feedstock and conversion route, we can distinguish 1st and 2nd generation biodiesel (lately, even 3rd generation options are starting to emerge, e.g. from algae). 1st generation biodiesel, also known as lipid-derived diesel, can be produced from various vegetable oils, such as rapeseed, palm, soybean and jatropha oil and animal fats. Biodiesel is used as a diesel substitute, and is generally blended with fossil diesel to various degrees. In Europe, the fuel standard permits only up to 5% biodiesel blend, mainly due to limitations imposed by fuel and vehicle specifications. Using blends over 20% may require some modest vehicle adaptations. Higher biodiesel fuel blends are sometimes used in fleet vehicles (e.g. trucks and buses). There are various routes to produce 1st generation diesel-type fuels from biomass. Transesterification, the most common route, is a catalytic process where fat or oil is combined with an alcohol (usually methanol). Two important by-products of this conversion route are glycerin and animal feed in the form of press cakes. The alternative route, hydrogenation, a process resembling oil refining, has so far seen limited deployment, although it produces a renewable diesel of superior quality (with higher blending potential) to that obtained via transesterification (IEA Bioenergy, 2009). Production of biodiesel depends mainly on sufficient provision of economical vegetable oils and animal fats used as feedstock. The production of biomass, both food crops such as rapeseed and oil

	palm but also lignocellulose biomass for 2nd generation biofuels, is limited by the availability of land and crop yields. Transesterification and hydrogenation are technically mature and commercially available 1st generation technologies that produce biodiesel from vegetable oil and animal fats. (IEA Bioenergy, 2009).
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Uganda has the potential to produce substantial amounts of biodiesel from a variety of oil seed crops, which are either already grown for oil extraction or growing wildly. The government's Renewable Energy Policy recommends blending of diesel with 20% biofuel. By specifying the maximum proportion of biodiesel blends the government hopes that investors will be attracted to invest in biodiesel production knowing that there is a market for it. To ensure that this is integrated with the agriculture system, the government is promoting oil seed production to meet the need for feedstock for biodiesel and for edible vegetable oil production. The bio-diesel will be used for the transport sector and farm power production. According to Uganda's Second National Communication, it is assumed that biodiesel blending in the transport sector would start in 2025.
Implementation barriers	• High initial costs required to set up biodiesel plants • Direct and indirect land use change causing deforestation, loss of biodiversity and conflict with food production; • Concentration of production and income by a small number of large farmers and agribusinesses; • Loss of livelihood by poor rural communities; • Increased GHG emissions from land clearing and unsustainable farming practices • Limited technical skills capacity • Inadequate land to cultivate crops from which the oil is to be extracted due to increasing population density and a high demand for land for food crop farming.
Reduction in GHG emissions	If implemented the technology will result total reduction of 1,443,877 tons of CO2 over 10 years.
Impact Statements: How this option impacts the country development priorities	
Country social development priorities	• Improved skills/capacity due to training opportunities for farmers and biodiesel plant workers • Improved quality of lives most especially for farmers • Gender responsive as women can provide agricultural raw materials for producing biodiesel. • Access to efficient local energy

Country economic development priorities	• Increasing energy security by producing and using biodiesel locally, thus reducing the dependence on imported fossil diesel; • Saving foreign currency by reducing fossil diesel imports; • Earning foreign currency by producing biodiesel for export. • Diversifying the industrial sector. • Job creation in the agricultural and industrial sectors • Increasing farm incomes as farmers supply feedstock to industries • Increasing inclusion in the economic system: well-organized farmers unions can gain access to energy markets.
Country environmental development priorities	• GHG savings, unless land area containing high carbon stocks (e.g. rainforest, peatland) is cleared to make way for biofuel feedstock plantations. • Promotes ecosystem restoration by improving soil fertility and water retention.
Other considerations and priorities	**Technology related** • Raw material availability • Promotion of technology transfer **Political benefits** Alignment to national sector instruments of blending
Costs	
Capital costs	40 million USD
Operational and maintenance costs ten years	30 million USD
Cost of GHG reduction	48.48 USD/ ton CO2 eq.
Lifetime	10 years

Annex II: Uganda's installed capacities and the generation companies

GENERATOR	OPERATOR	TECHNOLOGY	INSTALLED CAPACITY	LICENSED CAPACITY (2019)
Large Hydros				
Bujagali Hydro Power Plant	Bujagali Electricity Company Limited (BEL)	Hydro	250.0	250.0
Nalubaale and Kiira HPPs	Eskom (U) Limited	Hydro	380.0	380.0
Isimba HPP	Uganda Electricity Generation Company Limited	Hydro	183.0	183.0
Mini-Hydros				
Mpanga	Africa Energy Management System, Mpanga	Hydro	18.00	18.00
Bugoye(Mobuku II)	Bugoye Hydro Limited[1]	Hydro	13.00	13.00
Kabalega (Buseruka)	Hydromax Limited	Hydro	9.00	9.00
Ishasha	Eco-Power Limited	Hydro	6.60	6.60
Mobuku 1	Tibet Hima Mining Co Ltd[2]	Hydro	5.00	5.00
Mobuku III	Kasese Cobalt Company Limited	Hydro	9.90	9.90
Muvumbe	Muvumbe Hydro (U) Ltd	Hydro	6.50	6.50
Siiti 1	Elgon Hydro Siti (PVT) Limited	Hydro	5.00	5.00
Rwimi	Rwimi EP Company Limited	Hydro	5.54	5.54
Nyamwamba	Africa EMS Nyamwamba Limited	Hydro	9.20	9.20
Lubilia	Lubilia Kawembe Hydro Ltd	Hydro	5.40	5.40
Nkusi	Hydromax (Nkusi) Ltd	Hydro	9.60	9.60
Mahoma	Mahoma Uganda Limited	Hydro	2.70	2.70
Hydromax Nkusi (Waki)	Hydromax Nkusi Ltd	Hydro	4.80	4.80
Sindila (Butama)	Butama Hydro-Electricity Company Ltd	Hydro	5.25	5.25
Thermals				
Namanve[3]	Jacobsen (U) Limited	Thermal	50.0	50.0
Electromaxx[3]	Electro-Maxx (U) Limited	Thermal	86.0	50.0
Co-generation/ Bagasse				
Kakira	Kakira Sugar Limited	Co-generation	51.1	51.1
Kinyara	Kinyara Sugar Works Limited	Co-generation	14.5	14.5
SAIL	Sugar & Allied Uganda Ltd	Co-generation	11.9	11.9
SCOUL	SCOUL	Co-generation	9.5	9.5
Mayuge	Mayuge Sugar Ltd	Co-generation	9.2	9.2
Solar PV				
Access Solar	Access Uganda Solar Ltd	Solar PV	10.0	10.0
Tororo Solar North	Tororo Solar North Ltd	Solar PV	10.0	10.0
Kabulasoke Solar	MSS Xsabo Power Limited	Solar PV	20.0	20.0
Mayuge Solar	Emerging Power U Ltd	Solar PV	10.0	10.0
Off-grids				
Nyagak	West-Nile Rural Electricity Company	Hydro	3.5	3.5
WENRECO - Thermal	West-Nile Rural Electricity Company	Thermal	1.6	1.6
Kalangala Infrastructure Services	Kalangala Infrastructure Services	Hybrid	1.6	1.6
Kisiizi Hospital Power[4]	Kisiizi Hospital Power	Hydro	0.4	0.4
Absolute-Kitobo[4]	Absolute Energy Africa Limited (AEAL)	Solar	0.2	0.2
Bwindi[4]	Bwindi Community Micro Hydro Power Ltd	Small Hydro	0.1	0.1
Pamoja-Tiribogo[4]	Pamoja Energy Ltd	Biomass	0.0	0.0
Pamoja-Ssekanyonyi[4]	Pamoja Energy Ltd	Biomass	0.0	0.0
Swam[4]		Small Hydro	0.0	0.0

Source: ERA ESI database

Notes:

1- Formerly Tronder Power Limited

2- Formerly Kilembe Mines Limited

3 - Plants retained but at a minimum dispatch of 7 MW

4- Certificate of Exemption

Source: Electricity Regulatory Authority (May 2019)

Annex III: List of stakeholders involved and their contacts

NO	NAME	INSTITUTION	CONSULTATION APPROACH
1.	Abdu Kalema, Mr.	Powercon Limited	Technology prioritization workshop
2.	Adam M Sebbit, Prof.	Makerere University	Technology prioritization workshop
3.	Ayub Mukisa, Mr.	Makerere University	Technology prioritization workshop
4.	Brian Semakula, Mr.	Agriculture Technology Centre, MWE	Technology prioritization workshop
5.	Christine Kaaya, Ms.	Parliamentary Forum on Climate Change	Technology prioritization workshop
6.	Claire Kagga, Ms.	Renewable Energy Business Incubator	Technology prioritization workshop
7.	Damalie Akwango, Ms.	National Agricultural Research Organisation - Secretariat	Technology prioritization workshop
8.	Deborah Kasule, Ms.	Uganda National Council for Science and Technology	Technology prioritization workshop
9.	Emmy S. Kimbowa, Mr.	Uganda Solar Energy Association (USEA)	Technology prioritization workshop
10.	Esther Nyanzi, Ms.	UNREEEA	Technology prioritization workshop
11.	Godfrey Nviiri, Mr.	ENRAC	Technology prioritization workshop
12.	John B. Kaddu, Prof.	Makerere University	Technology prioritization workshop
13.	John Tumuhimbise, Mr.	Ministry of Energy and Mineral Development	Technology prioritization workshop
14.	Joshua Zake, Dr.	Environmental Alert	Technology prioritization workshop

15.	Julian Auma, Ms.	Wwater Works	Technology prioritization workshop
16.	Karl Sentongo, Mr.	Uganda National Council for Science and Technology	Technology prioritization workshop
17.	Linda Mwesigwa, Ms.	Step-up Standard Limited	Technology prioritization workshop
18.	Loi Namugenyi, Ms.	Uganda National Council for Science and Technology	Technology prioritization workshop
19.	Michael Wambi, Mr.	Uganda Radio Network	Technology prioritization workshop
20.	Miriam Talwisa, Ms.	CAN- Uganda	Technology prioritization workshop
21.	Peter Ndemere, Dr.	Uganda National Council for Science and Technology	Technology prioritization workshop
22.	Prossy M. Namulindwa, Ms.	Ndejje University	Technology prioritization workshop
23.	Rachael Turyamuhebwa, Ms.	Joint Energy and Environment Project	Technology prioritization workshop
24.	Rita Rukundo, Ms.	UNFCCC Regional Coordination Centre	Technology prioritization workshop
25.	Robert Bakiika, Mr.	Climate Change Department, MWE	Technology prioritization workshop
26.	Royrita Nabasumba, Ms.	Step-up Standard Limited	Technology prioritization workshop
27.	Sam Gwali	NARO – Mukono	Technology prioritization workshop
28.	Sara Namirembe, Dr.	Step-up Standard Limited	Technology prioritization workshop
29.	Susan Nanduddu, Ms.	African Center for Trade and Development (ACTADE)	Technology prioritization workshop

30.	Tsakonus Kiera, Ms.	Joint Energy and Environment Project	Technology prioritization workshop
31.	Walter Cuccu, Mr.	Wwater Works	Technology prioritization workshop
32.	Winnie Grace Onziru, Ms.	Uganda National Bureau of Standards	Technology prioritization workshop
33.	Hatimu Muyanja, Mr.	Ministry of Energy and Mineral Development (MEMD)	Consultations via email