Hydropower Solutions

HYPOSO

Hydropower solutions for developing and emerging countries

Framework analysis and research needs in Uganda
(part of HYPOSO D3.2)

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Uganda

1 Key facts

Population	44.2 million	2018 estimate
Area	241,551 km^2	
Access to electricity	50 %	2019
Installed energy capacity	1,252.4 MW	2019
Installed hydro capacity	1,004.2 MW	2019
Hydro capacity under construction	765 MW	2019
Share of generation from hydropower	80 %	2019
Hydro generation	3,638 GWh	2018
Economically feasible hydro generation potential	12,500 GWh	
Small hydropower potential	400 MW	
Small hydropower installed capacity	145.3 MW	2019

1.1 Climate

Uganda is located south of the Sahara in the central-eastern Africa, the most southern part crossed by the equator line. The climate is tropical and generally rainy with two dry seasons, from December to February and from June to August. In the north-east, Uganda is semi-arid. The average temperature is approximately 26°C (maximum temperature ranging between 18°C and 31°C and minimum temperature between 15°C and 23°C). The average annual precipitation in Uganda is between 1,000 and 1,500 mm, of which the majority is occurring between March and June with rainfall of more than 500 mm. The south is generally wetter than the north with the south-west receiving the heaviest rainfall. The north-east has the driest climate and is prone to droughts.

1.2 Topography

The greater part of Uganda consists of a plateau 800 to 2,000 m a.s.l. in height. Along the western border, in the Ruwenzori Mountains, Margherita Peak reaches a height of 5,109 m, while on the eastern frontier Mount Elgon rises to 4,321 m a.s.l. By contrast, the Western Rift Valley, which runs

from north to south through the western half of the country, is below 910 m a.s.l. on the surface of Lake Edward and Lake George and 621 m a.s.l. on the surface of Lake Albert (also Mwitanzige).

1.3 Water resources

Uganda lies almost completely within the Nile basin. Eight main drainage basins can be distinguished in the country. These include; Lake Victoria, Lake Kyoga, River Kafu, Lake Edward, Lake Albert, River Aswa, Albert Nile and Kidepo Valley. The flow from these catchment basins, though small as compared with the total Nile flow, dominates the water resources potential within Uganda. Major water bodies include lakes Victoria, Kyoga, Albert, George, Edward and another 149 smaller lakes interconnected by a river system. In the north-eastern part of the country, many of the water courses are seasonal. Uganda is home to Lake Victoria, the largest lake in Africa and the second largest freshwater lake in the world with an area of 69,000 km^2. River Nile, is the only outflow from this lake and the country is lying almost entirely within its drainage basin. The discharge of the Nile at the point of outflow is estimated at 31 km^3/year. Lake Victoria and the Nile are the basis of the existing and future major hydro schemes in Uganda (Nsubuga et al. 2014).

The specific hydropower potential (density) of the country can be regarded as quite a moderate potential – approx. 0.05 GWh/year per km^2. To compare, for Austria and Norway this specific indicator is around 0.66, for Cameroon - 0.24 GWh/(year·km^2).

2 Power sector overview

Only about 50 % of the population has access to electricity, and in rural areas access at least 3 times less. Uganda has one of the lowest levels of per capita electricity consumption in the world with 215 kWh per capita per year.

The electricity supply system in Uganda was developed during the 1950s and 1960s with the construction of the Owen Falls Hydropower Station (later renamed Nalubale Power Station) with a total installed capacity of 150 MW. Later the power station was refurbished and upgraded to 180 MW and a new power station, Kiira, was constructed with a capacity of 200 MW.

Uganda is well-endowed with energy resources distributed throughout the country including hydropower, biomass, solar, geothermal, peat and fossil fuels. According to the Uganda Bureau of Statistics (2019), about 50 % of the population has access to electricity. Consumption of electricity is among the lowest in the world at 215 kWh per capita per year, less than half that of the Sub-Saharan African average of 552 kWh. Biomass is the most important source of energy for most of the population, accounting for 90 % (IHA, 2018).

In 2017, electricity generation in Uganda totalled 3,874 GWh with a clear dominance of hydropower share (Figure 1).

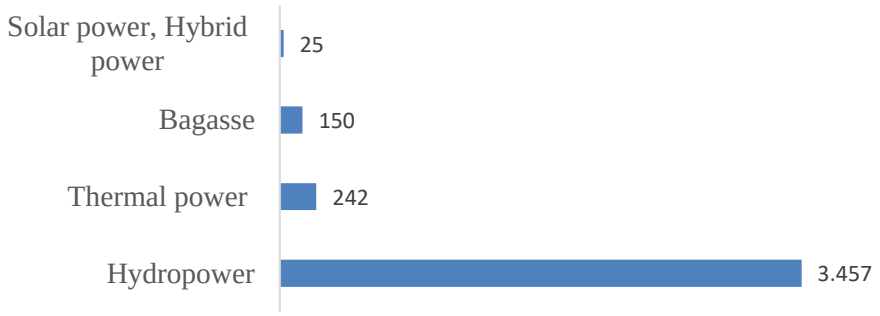

Figure 1: Annual electricity generation by source in Uganda (GWh) in 2017 (ERA, 2018)

As of March 2020, the national electricity sources were as illustrated in the table below (Energy in Uganda, 2020).

Table 1: Sources of electricity in Uganda as at March 2020

Source	Quantity [MW]	Percentage of Total
Hydroelectricity	1,007	80.4
Heavy fuel oil	100	8.0
Solar power	50	4.0
Co-generation	95	7.6

The current contribution of hydropower in Uganda's electricity generation mix is 87 %. This figure will go up to 92 % once large Karuma HPP is commissioned. Hydropower is a key component in electricity generation expansion plan in line with Uganda Vision 2040 strategy (NPA, 2007; IHA,2019).

In the second National Development Plan (NDPII April 2010) the Government invested in the necessary infrastructure to facilitate the exploitation of the abundant renewable energy sources including hydropower, geothermal and nuclear, so as to increase generating capacity to 2,500 MW by 2020 and prepare for achieving the required 41,738 MW by the year 2040.

The Electricity Regulatory Authority (ERA) is endorsed to issue licences, regulate the operations of all electricity operators, including independent power producers (IPPs) and private distribution companies, and establish the tariff structure. Other key players in the energy sector are the Ministry of Energy and Mineral Development (MEMD) and the Rural Electrification Agency (REA). The MEMD provides policy guidance, creates an enabling environment to attract investment in the energy sector, acquires data on the country's resource potential and regulates activities of private companies in the sector. The REA was established in order to facilitate acceleration in rural electrification. One of its key objectives is to promote equitable rural electrification access with

special regard to marginalized communities. Its vision is to achieve a universal electricity access by 2035.

3 Renewable electricity policy

Uganda is a landlocked country with substantial RE potential that is distributed evenly across its territory (Fashina et al., 2017) and involves such energy forms and conversion technologies as wind- and hydropower, solar, peat, geothermal, biomass and biogas based generation, biomass-based cogeneration. However, hydropower remains the national dominant source for electric energy production with a potential of over 4,100 MW (NRFC, 2015). In general, the overall RE power generation potential is estimated to be about 7,200 MW (Karekezi, 2002; NRFC, 2015).

The Renewable Energy Policy, initiated by the Government of Uganda in 2007 (GoU, 2007) stated the goal to increase the use of modern renewable energy as well as the introduction of FiT remuneration mechanism and standardization of Power Purchase Agreements. This has encouraged both individual investors and companies to invest in the generation of RE in Uganda. Furthermore, the scheme has increased the financial support base for RE generation and motivated the rapid sustainable development of renewable energy technologies in the country.

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 (IHA, 2019).

The renewable energy institutional framework of Uganda comprises the following stakeholders (WSHPDR, 2019):

- Ministry of Energy and Mineral Development (MEMD) keeps the overall responsibility for the renewable energy policy (REP) and oversees, and coordinates its implementation with other stakeholders;
- Electricity Regulatory Authority (ERA) sets tariffs, issues generation licences and maintains the renewable energy feed in tariff (REFiT);
- Uganda Electricity Transmission Company Limited (UETCL) is the system operator and single buyer; generation companies agree on a power purchase agreement with UETCL;
- Renewable energy generation companies (subject to fulfilment of relevant conditions);
- Distribution licence holders.

4 Hydropower sector and potential

The gross theoretical hydropower potential of the country has not been fully assessed (H&D, 2019). The technically feasible potential of Uganda is 20,833 GWh/year and the economically feasible one - 12,500 GWh/year (Figure 2). The presented data is an average annual generation estimate for 2018.

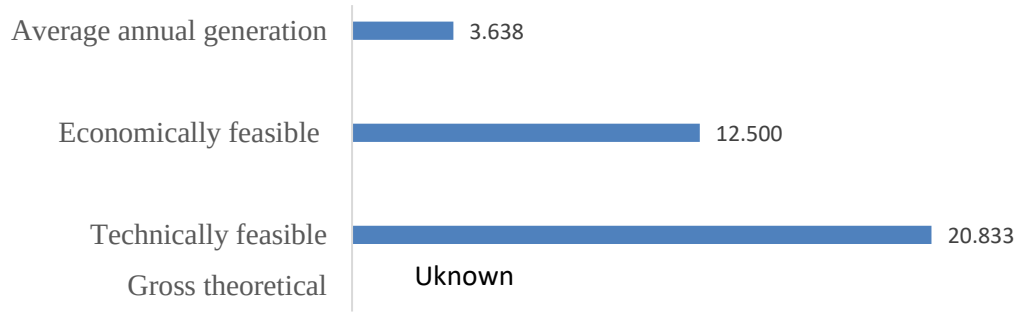

Figure 2: Hydropower potential in GWh/year in Uganda (H&D, 2019)

About 15 % of the technically feasible potential has been developed so far. In 2018, hydro plants generated 3,638 GWh, which was 89 % of the total generation. Generally, the contribution of hydro each year is more than 80 per cent.

A Hydropower Development Master Plan has been developed with support from the Japan International Cooperation Agency (JICA, 2011). According to it Uganda has considerable hydro resource potential estimated to be over 2,000 MW (mainly on the Nile). A more recent study indicates two times bigger potential 4,137 MW (NRFC, 2015).

As of 2019, Uganda had 32 hydropower plants that were in operation, with a total installed capacity of 1,667 MW. (Figure 3). This inventory comprises some 20 micro and small hydropower plants (up to 10 MW).

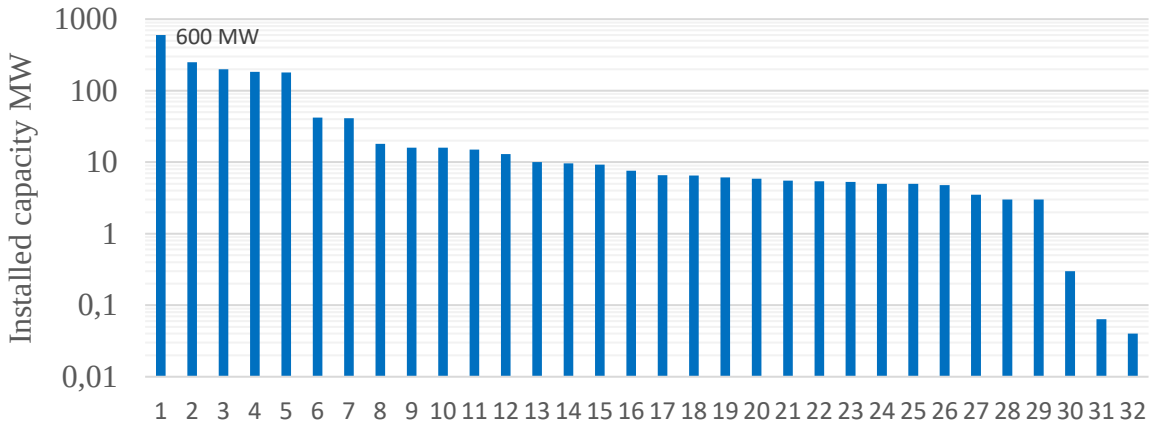

Figure 3: Operational HPPs in Uganda as sorted by installed capacity (project estimation)

There are four large hydropower plants in operation: Nalubaale (180 MW), Kiira (200 MW), Bujagali (250 MW), and Isimba (183 MW) which was commissioned in 2019. In total, 765 MW of hydro is

under construction (2019), according to UEGCL (Uganda Electricity Generation Company Ltd), of which 600 MW is large hydro, 83 MW is medium scale, and 82 MW is small hydro (H&D, 2019).

Based on this project findings, the total hydropower installed capacity has been recently increased from 764 MW to 1,004.2 MW at the end of 2019.

In Uganda, small hydropower (SHP) is generally defined as hydropower plants with installed capacity of up to 20 MW (ERA). Unlike large-scale hydropower, the small- and medium-hydro sites are not located on the Nile, but they also possess potential resources which are yet to be exploited. These sites are located mainly in the Western and the Eastern regions of the country which are hilly and mountainous. About 50 potential small hydropower sites have been identified at the Ugandan rivers.

So far SHP potential has not been fully assessed in the country, only rough estimates can be provided (Table 2).

Table 2:- Small hydro (< 10 MW) characteristics according to different sources

References	Potential, MW		Installed capacity, MW	Number of operating SHP
	MW	GWh		
WSHPDR, 2019	200		52	
H&D, 2019		>400	110	
HYPOSO	~400	~1,250	102	20

As it can be seen from this table, the estimates differ a lot, the given potential (200 MW) is obviously underestimated. The best available technique to conduct a preliminary evaluation of the small hydro potential is to take a portion of 5 to 10 % of the technically or economically feasible potential. The latter approach can be considered as a lower limit that is 12,500 GWh/year in the country. Consequently, it will result to some 1,250 GWh, a rough, but more realistic estimate of SHP potential.

Powerplants which began commercial operation in 2018 included five small hydro stations: Nyamaghasani (9.2 MW); Lubiia (5.4 MW); Nkusi (9.6 MW); Mahoma (2.7 MW); and, Wakio (4.8 MW). Examples of small-scale hydropower schemes currently under development (some are known by the name of the developer) are: Kyambura (7.6 MW); Sindila (5.24 MW); Ndugutu (5.9 MW); Nyamaghasani 1 (6 MW); Nyamaghasani 2(15 MW); Siti 2 (16.5 MW); and Nyagak (5.5 MW). A 1.75 MW hydro scheme is going ahead as part of the Angololo multipurpose scheme, on the border with Kenya. An agreement had been signed for the first cross-border project between Uganda and Tanzania. It will be a 14 MW scheme at Kikagati (H&D, 2019).

The African hydropower database for Uganda provides a list of operational hydropower plants, those under development and only one potential site (Hydro 4 Africa, 2020).

5 SHP policy and market analysis

5.1 SHP policy

Small hydropower is integrated within the whole energy and hydropower sector. Notwithstanding this, mostly small hydro policy is to be highlighted herewith. Key legal documents making up the legal framework to which hydropower must comply are listed in Table 3.

Table 3: Key legal documents regulating RES and hydropower

Name of legal document (not older than 5 last years but those still in force)	Type of activities addressed	Website	Summary and Impact on development of Hydropower (small or large)
Electricity Act, 1999, Cap 145; Laws of Uganda	Power, Energy and Electricity Sector	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/laws/86-the-electricity-act-1999/download	Gives the developer exclusivity to develop the site, the right to do necessary feasibility studies and the knowledge that no conflicting projects are being developed
The National Environment Act, 1995	Environment	www.nema.go.ug	Allows NEMA to ensure that the project and its mitigation plans comply with Ugandan standards for environmental and social impact
The Water Statute, 1995	Water management	www.mwe.go.ug	Allows DWRM control over the use of surface water so that no other parties, for example farmers are negatively affected and so that no other negative effects on the surface water system occur
Energy Policy of Uganda, 2002	Energy	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/policies/83-energy-policy/download	Ensures widespread access to affordable modern energy
Renewable Energy Policy, 2007	Renewable Energy	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/policies/221-the-	Diversifies the energy supply sources and technologies in the country, through enabling negotiations for appropriate

		renewable-energy-policy-for-uganda/download	financing for large projects and feed in tariffs for small projects
Global Energy Transfer Feed-In Tariff (GET-FiT) Program, 2012	Renewable Energy	https://www.era.or.ug/index.php/sector-overview/programmes/getfit	Fast-tracks development of renewable energy generation projects of 1 MW – 20 MW, promoted by private developers, with a total installed capacity of about 170 MW/ 830 GWh per annum.
Electricity (License Exemption) (Isolated Grid Systems) Order 2007	Electricity	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/regulations-codes/93-the-electricity-license-exemption-isolated-grid-systems-order-2007/download	Provides for developers of exempted projects under 2.0 MW to upgrade license if they need to connect to the grid
National Environment Management Policy, 1994	Environment	http://nema.go.ug/sites/all/themes/nema/docs/national_environment_act.pdf	Encourage hydropower development with environmental protection in mind
The Wildlife Policy, 2014	Wildlife	https://www.ugandawildlife.org/news-events/news/wildlife-policy-to-be-revised	Hydropower projects that give priority to the protection of the natural flora and fauna are supported
The National Wetlands Policy, 1995	Wetlands	http://nema.go.ug/sites/all/themes/nema/docs/wetlands_riverbanks.pdf	Encourages development of hydro power resources, especially along the Nile, while recognizing protection and preservation of wetlands

The National Wetland Conservation and Management Policy, 1995	Wetlands	http://nema.go.ug/sites/all/themes/nema/docs/wetlands_riverbanks.pdf	Encourages development of hydro power resources, especially along the Nile, while recognizing protection and preservation of wetlands
Master Plan for Hydropower Development, 2010	Hydropower	https://www.seforall.org/sites/default/files/Uganda_AA_EN_Released.pdf	To maximise Uganda's electric hydro power potential for increased national social-economic development
Power Sector Investment Plan, 2011	Power Sector	www.energyandminerals.go.ug	To maximise Uganda's electric hydro power potential for increased national social-economic development
Occupational Health and Safety (OHS) Policy	Health and Safety	www.mglsd.go.ug	To ensure that all employees work in a healthy and safe environment, are adequately protected and compensated for their labour
Uganda Vision 2040	National Policy	www.npa.go.ug	Uganda to develop and generate modern energy to satisfy demand of 41,738 MW by 2040 and increase electricity per capita consumption to 3,668 kWh and access to the national grid to 80 %
Rural Electrification Strategy and Plan 2013-2022	Energy	www.rea.go.ug	The RESP is aligned towards universal electricity access by 2040, to achieve an accelerated pace of electricity access and service penetration to meet national development goals

Policy and Regulatory Framework			
National Environment Act, Cap 153 and Associated Regulations	Environment	http://nema.go.ug/sites/all/themes/nema/docs/national_environment_act.pdf	Regulating the impact of renewable energy investments on the environment, through award of certificates of environmental clearance
The Water Act, CAP 152	Water management	http://nema.go.ug/sites/all/themes/nema/docs/water_act.pdf	Managing water resources in an integrated and sustainable manner through issuing Surface Water Abstraction and Construction Permits to Project Developers
The Uganda Wildlife Act, 2000	Wildlife	www.ugandawildlife.org	
Land Acquisition Act	Land	www.mlhud.go.ug	Land acquisition and compensation, plus handling way-leaves issues
The Fish Act, Cap 197	Fisheries	www.agriculture.go.ug	Provision for the control of fishing, the conservation of fish during project development
The Rivers Act, Cap 347	Water management	www.mwe.go.ug	Provides for the control of activities like dredging and use of steam vessels by developers

A generation licence may be granted to a developer following the submission of an application to the ERA, which processes the licence application within a maximum of 180 days. These include:

- ERA for the generation licence / license exemption,
- DWRM for water abstraction permit;
- NEMA for environmental permit;
- UETCL for PPA agreement

The process involves publication of notices in the National Gazette and national newspaper to solicit objections to the project, if any.

A brief description of regimes for granting rights (concessions or authorisations) to use hydropower in Uganda is summarized in Table 4.

Table 4: Regimes for granting rights (concessions or authorisations) to use hydropower

Concessions	Small Hydro. New permits (authorizations)	Large hydro. New permits (authorizations)
Type of permits needed & average time	Permit to undertake studies and other activities - not less than 180 days since the day of application	Permit to undertake studies and other activities - not less than 180 days since the day of application

In Uganda SHP lobbying and other activities are implemented by the HPAU (Hydro Power Association of Uganda) - a non-profit organization (HPAU, 2020). It brings together private companies dealing in various aspects with hydropower development. HPAU seeks to contribute to the national, regional and global development and sound management of hydropower resources for sustainable access to energy for improved socio-economic progress.

5.2 Industrial overview

Uganda is a country with abundant potential for small hydropower development. There are many identified sites suitable for small hydropower facilities. Small schemes are generally privately owned and operated by the IPPs. Some of them supply electricity to isolated grids. To date there is 20 SHP under operation, but the access to their data, particularly in terms of economic evaluation is restricted. Currently, on average the investment costs to-date are approx. US$3 to 4 million per MW installed.

Some 40 stakeholders are acting in the hydropower sector, mostly in small-scale hydro. No hydraulic machinery equipment producers were identified (only a few dealers) so far (HYPOSO D3.1, 2019).

5.3 Support schemes and financing opportunities

REFITs were introduced under the Renewable Energy Policy (2007) to promote a greater private sector engagement in power generation from renewable energy sources. The REFIT applies to systems of prescribed priority technologies (SHP and other renewables) of installed capacity in the range of 0.5 to 20 MW, as defined by the Electricity Act, 1999. In addition, to qualify for the REFIT, the projects must be connected to the national grid. Plants including additional capacity resulting from the project modernization, repowering and expansion of existing sites, but excluding existing generation capacity, also qualify for the REFIT. The REFITs are shown in Table 5.

Table 5: Support schemes (REFIT) for hydropower

No	Type	Size	Measurement
	(a). Micro Hydro	Hydro (500 kW >< = 1 MW)	Feed-in Tariff (US$/kWh) = 0.115; repayment period 20 years
	(b). Mini Hydro	Hydro (1 >< = 9 MW)	Linear Feed-in tariff; repayment period 20 years
	(c). Small Hydro	Hydro (9 >< = 20 MW)	Feed-in Tariff (US$/kWh) = 0.085; repayment period 20 years
	(d). Large Hydro	Hydro => 20 MW	No Feed-in Tariff; Required to negotiate a tariff and Power Purchase Agreement with the System Operator, on a case by case basis
	Small Hydro =< 20 MW	Uganda Renewable Energy Feed-in Tariff (REFIT) Guidelines, Phase 4	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/guidelines-and-standards/463-uganda-renewable-energy-feed-in-tariff-refit-guidelines-phase-4/download
	All project sizes	Amended Guidelines for Fixing Quantum of Royalties paid by Hydro Generation Licensees	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/guidelines-and-standards/54-the-amended-guidelines-for-fixing-the-quantum-of-royalties-payable-by-hydro-generation-licensees-in-uganda-2012/download
	All project sizes	Standardized Power Purchase Agreements	https://www.era.or.ug/index.php/resource-centre/regulatory-instruments/forms-templates/97-standardised-power-purchase-

			agreement-ppa-for-the-getfit-program/download

There is a financial gap in the development of renewable energy sources in Uganda, however, as the existing renewable energy developments have been financed through various mechanisms including the Government, IPPs, development partners and public-private partnerships (WSHPDR, 2019).

The key sources of funding among these are the Global Energy Transfer Feed-in-Tariff (GET FIT) Programme and the support from Power Africa (GET FiT Uganda, 2018). The main objective of the GET FiT Program is "to assist East African nations in pursuing a climate resilient low-carbon development path resulting in growth, poverty reduction and climate change mitigation". Roll-out of the program will start in Uganda in Phase 1. Through the roll-out in Uganda in phase 1 of the program, a portfolio of currently 17 small-scale renewable energy generation projects, including SHP promoted by private developers with a total installed capacity of roughly 160 MW will be fast-tracked.

One of the instruments of the GET FIT Programme is the GET FIT Premium Payment Mechanism (GFPPM). Small-scale renewable energy projects selected through a competitive bidding process apply for premium payments. These premium payments constitute an "incentive grant designed to enhance the financial viability of the selected projects and are payable to the project developers in addition to the relevant REFIT tariffs determined by the Electricity Regulatory Authority (ERA)". Through the GET FIT Programme, a total of 158 MW of renewable energy is to be added to the national grid from a total of 17 projects utilizing various renewable energy technologies, including SHP, solar PV and bagasse (GET FIT, 2018).

6 Educational framework

Makerere University in Kampala has about 95 % of the total student population in Uganda's universities. More than 20 private universities and a smaller number of non-university institutions are providing education. Vocational and Technical Education is a necessary aspect of the education system in Uganda. Some programs provide graduate engineering level education to students seeking education at the tertiary or post-secondary level.

There is no hydropower engineering study program in the country education system. Hydropower is usually part of renewable or energy studies (Table 6). Universities such as Kyambogo, Busitema, Ndejje, Nakawa VTI are offering also renewable or energy study programs.

Table 6: Makerere University Renewable Energy program

University	Hydropower as part of renewable or energy studies	Topics included
Makerere	MSc Renewable Energy	Development, design, installation, and operation of small hydropower plants

Uganda currently has a good number of hydro power projects that are being run and implemented by both public and private entities. The challenge however is that the availability of manpower to operate and manage the smooth running of such power stations is still lacking. Therefore, the East African Centre for Renewable Energy and Energy Efficiency (EACREEE) partnered with the Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA) and the Centre for Research in Energy and Energy Conservation (CREEC) and its partners organized East African regional training course on development, design, installation, and operation of small hydropower plants at Makerere University (CREES,2020).

Main weaknesses of the education system and gaps to bridge the knowledge for the hydropower sector are as follows:

1. General level of understanding hydropower is low;
2. No university/technical education programs specifically on hydropower;
3. Technicians get hydropower training only on the job;
4. Technical training generally is too theoretical;
5. O&M personnel lack re-training & expansion of skills;
6. Reliance on outside expertise not only technically but also for studies, design & equipment;
7. Link between classroom and field/industry training missing or inadequate;
8. Capacity building aspect not backed up by energy policies.
9. Limited hydrological data and consequently - a lack of specialists for hydropower assessment.

7 Research situation and needs

Previous section outlines that high education programs for hydropower are inexistent. Renewable energy programs proposed by universities are not offering in-depth or sufficient knowledge on hydropower issues. This suggests that research level in the hydropower are is quite weak. This fact can be confirmed by the HYPOSO project survey on R&D projects conducted recently in Uganda. Neither fundamental nor applied research projects for hydropower were reported. On the contrary, only main features and challenges of hydropower plants projects under developments or already under operation, including a few of them of demonstration type are provided.

To support the above-mentioned statement, a search of the publications in Science Direct database for Uganda was carried out. This database is a website which provides subscription-based access to a large database of scientific and medical research (mainly papers in peer

reviewed journals in English). The search was intended to identify publications with the authors or co-authors from Uganda. During last eight years at least 5 papers related on one or another way with hydropower topic were published and affiliated to Makerere, Mbarara and Kampala International Universities, and Centre for Research in Energy and Energy Conservation (CREEC).

There should be also indicated Ugandans studying abroad, in European universities with specialisation in hydropower. For instance, a master thesis was prepared aiming at evaluating how well GIS tool was able to estimate the hydropower potential from the runoff maps and terrain/elevation (Gimbo, 2015). All above outlined conclude that the research related to the hydropower sector possesses minor potential.

Since hydropower development is starting to progress in this country the basic hydropower knowledge would be advantageous. There is a need to transfer European-top-level experience, knowledge, available state-of-the-art hydro technology to Ugandan researchers.

8 Environment

The Ministry of Water and Environment (MWE), is a cabinet-level government ministry of Uganda. It is responsible for the "sound management and sustainable utilisation of water and environment resources for the betterment of the population of Uganda". The MWE has recently issued a 'Strategic Programme for Climate Change'.

The National Environmental Management Authority (NEMA) is the government body responsible for environmental and social impact assessments for projects being developed.

The Directorate of Water Resources Management (DWRM) is responsible for: developing and maintaining national water laws, policies and regulations; managing, monitoring and regulating water resources through issuing water use, abstraction and wastewater discharge permits; integrating water resources management activities; coordinating Uganda's participation in joint management of transboundary water resources; and peaceful cooperation with the Nile Basin riparian countries.

The Water Sources Protection Guidelines for Hydroelectric power plants describe steps to follow to prepare a Water Source Protection Plan (MWE, 2013). It outlines actions and considerations that are particularly relevant to protecting a water source for a small to medium sized hydroelectric scheme. It is also is a standalone document for ease of its application by those concerned with hydroelectric power plants.

9 Barriers to SHP development

The main challenges to consider for developing small hydropower projects in Uganda are, but not limited to (WSHPDR, 2019):

There is an infrastructure gap in the generation, transmission and distribution of electricity, such that the growing demand is not being met by the existing infrastructure. Distribution losses also remain quite high and there is need for further investment to extend the grid.

There is a gap in financing of the power sector, which will not be bridged by the public sector financing alone, and need for more private sector investment;
High upfront costs and limited access to early-stage support and equity investment present another limitation, as interest rates from commercial lenders are quite high due to the perceived high risks of the investment;
There is a perception of high risk of default on payment by the single off-taker;
The land acquisition process is bureaucratic, complex and slow and affects the overall project costs and the construction of transmission line infrastructure required for the evacuation of power from power plants;
There is a need for capacity building within the government institutions, particularly as relates to planning, design and construction of hydropower plants.

The barriers from a potential investor to SHP:

- Limited local manufacturing capability for equipment related to hydropower technology, which makes it difficult to purchase hydropower related components for replacements, such as bearings, alternators, electronic switch gear
- Political, macro-economic instability and other governance related risks, including taxation regime, mixed signals regarding risks suffered by established developers,
- Project specific characteristics, related to site location, project promoters with their financial and technical strength and experience combined with other external factors related to availability of cost-effective technically competent contractors and consultants, fluctuations of the currency as well as commodity prices.

10 Future prospects

Uganda Vision 2040 identifies electricity generation as one of the key strategic interventions for social-economic transformation of the country. This includes increasing access to 30 % in 2020 and 80 % in 2040 (a 6 % 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 a potential to achieve 100 % access cost-effectively by 2040 with a greater emphasis on small-scale off-grid renewable solutions (IHA, 2019).

There should be also pointed out, that hydropower is sensitive to the climate driven hydrological cycle thus necessitating proper management of the river catchment areas. The prolonged drought experienced in Uganda between 2003 and 2007 led to a decline in hydropower generation of over 60 %, thus necessitating the deployment of expensive thermal power to reduce load shedding which had negatively impacted the economic growth.

The key challenges for hydropower development in Uganda, and most countries in Africa, include the need for substantial up-front investment capital which cannot easily be raised by the sector, as well as environmental and social concerns such as the resettlement and compensations of persons affected mainly by the large hydro projects, and inadequate local implementation experience and technical capacity.

There is a document outlaying steps, actions and considerations that are particularly relevant to protecting a water source for a small to medium sized hydroelectric scheme and aiming to ease hydropower applications (MWE, 2013).

10.1 Large Hydro

To ensure development of hydropower resources in a sustainable manner, in 2010 the government undertook a hydropower development master plan study (JICA, 2011). The study targeted sites above 50 MW mainly along the River Nile. The objective of the study was to prepare a master plan that is in line with the long-term power and transmission development plan. The hydropower master plan prioritised potential hydropower sites based on technical, environmental, economic and financial aspects, to prepare preliminary designs thereof, and to build government capacity in this field.

In line with this hydropower master plan, the government is fast-tracking the development of the identified hydropower sites. It is currently implementing two key flagship hydropower projects namely, Isimba (183.2 MW) and Karuma (600 MW). Other large hydropower plants being packaged for development include Ayago (840 MW), Orianga (392 MW), Uhuru (350 MW) and Kiba (290 MW). (IHA, 2019)

Other hydropower projects currently under development are the 83 MW Achwa project, the 44.7 MW Muzizi project and the 5.4 MW Nyagak project. On top of that, the GET-FiT portfolio is supporting 17 renewable power generation projects to generate about 156.5 MW, where a total of 69.2 MW is expected by 2019 from nine hydropower projects.

To address the challenge of financing, the Government of Uganda put in place the Energy Investment Fund which enabled to commence the construction of Bujagali hydropower plant. The 250 MW Bujagali hydropower plant was developed under a public private partnership arrangement with Bujagali Energy Limited (BEL). Additional investment capital has been attracted through bilateral financing with our development partners. The challenge of inadequate technical capacity has been addressed by putting in place a local content policy to ensure the participation of Ugandans during construction of the projects.

10.2 Small hydro

A total of 59 mini hydropower sites with a potential of about 210 MW have been identified through different studies. This gives a fair picture of the small and mini hydro potential in the country. Some of the sites can be developed for isolated grids and others as energy supply to the grid (Fashina 2019).

Regarding small hydropower projects, the current policy is that their development is undertaken by the private sector. The Renewable Energy Feed-in Tariffs (REFiT) are in place to promote investment in small hydropower and other renewable power projects (IHA, 2019).

There are many unexploited potential SHP sites in Uganda, which could potentially supply electricity to areas not covered by the national grid. Their data are available at ERA and some of these sites are listed in WSHDR (2019).

11 References

1. CREES (Centre for Research in Energy and Energy Conservation Uganda),(2020). https://www.creec.or.ug/?s=hydro (accessed 2 April 2020).
2. ERA (Electricity Regulatory Authority). https://www.era.or.ug/ (accessed 2 April 020).
3. Energy in Uganda (2020) https://en.wikipedia.org/wiki/Energy_in_Uganda#cite_note-16 (accessed 2 April 2020).
4. Fashina, A., Mundu, M., Akiyode, O., Abdullah, L., Sanni, D., Ounyesiga, L. (2019). The drivers and barriers of renewable energy applications and development in Uganda: A review. *Clean Technol*., *1*, 9-39.
5. GET FiT Uganda. Annual Report (2018). https://www.getfit-uganda.org/ (accessed 2 April 2020).
6. Gimbo F. (2015). Verification of a GIS-program for identification of potential hydro power sites in Uganda. MSc Thesis. NTNU,
7. Government of Uganda (GoU).(2007) Renewable Energy Policy for Uganda.
8. H&D (The International Journal on Hydropower & Dams). (2019). World atlas & industry guide. Aqua-Media Int. UK.
9. HPAU (Hydro Power Association of Uganda) https://unreeea.org/members/hpau/ accessed 2 April 2020)
10. Hyposo D3.1. (2019). Contact list of hydropower stakeholders and multipliers in five targets countries.
11. Hydro 4 Africa. http://hydro4africa.net/HP_database/country.php?country=Uganda (accessed 2 April 2020).
12. IHA (The International Hydropower Association). (2018, 2019). Hydropower Status Report.
13. JICA (Japan International Cooperation Agency), Electric Power Development Co., Ltd., Nippon Koei Co., Ltd., (2011). Project for master plan study on hydropower development in the Republic of Uganda. Final report.
14. Karekezi, S. Renewables in Africa—Meeting the energy needs of the poor. (2002). Energy Policy, 30, 1059–1069.
15. MWE (Ministry of Water and Environment). (2013). Framework and Guidelines for Water Source Protection. V.5. Guidelines for Protecting Water Sources for Hydroelectric Power Plants.
16. National Planning Authority (NPA). (2007). Uganda Vision 2040". http://www.npa.go.ug/ (accessed 2 April 2020).

17. NRFC (Norton Rose Fulbright). (2015).Investing in the Electricity Sector in Uganda; Norton Rose Fulbright (NRFC): Hong Kong, China, February.

18. Nsubuga, F., Namutebi, E., Nsubuga-Ssenfuma, M. (2014) Water Resources of Uganda: An Assessment and Review. Journal of Water Resource and Protection, 6, 1297-1315.

19. WSHDR (World Small Hydropower Development Report) (2019). Liu, D., Kiu, H., Wang, X., Kremere, E., eds. UNIDO, ICSHP. www.smallhydroworld.org (accessed 2nd April 2020).