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Kenya Miniwind

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PV mini-grid in Kabunyata village, Ivan Nygaard, 2014

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This report is issued by the Kenya Miniwind project funded by the Ministry of Foreign Affairs of Denmark through the Danida Market Development Partnerships. The project aims to explore and develop the market for a partly locally produced kW wind turbine to be integrated into a PV mini-grid for rural electrification in order to reduce the cost of electricity and support local value creation.

The long-term objectives of the project are accordingly to contribute to poverty reduction, stimulate economic growth and increase the supply of sustainable energy. The short- to medium-term objective is to explore the market potential and learn more about how to design solutions and business models that are suitable for rural electrification. The project will therefore conduct a market study, engage in dialogue with local communities and authorities, and demonstrate the technical, social and economic feasibility of integrating a kW wind turbine into a smart solar-powered mini-grid in Kenya. The project will also describe the assembly and production of a key component of the demonstration wind turbine. Finally, the project will work to improve the mini-grid developer sector in both Kenya and the wider region. The aim is that the knowledge generated through these activities will help develop the concept into a viable business model for the private companies involved, thus paving the way for the large-scale deployment of rural wind.

The project is a partnership between SustainableEnergy, Vestas Wind Systems A/S, the Technical University of Denmark, the Kenya Climate Innovation Center and the Rural Electrification Authority.

MINISTRY OF FOREIGN AFFAIRS OF DENMARK
DANIDA | INTERNATIONAL DEVELOPMENT COOPERATION

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Abbreviations

ABC	Anchor Business Customer
AC	Alternating Current
AE	Absolute Energy
AEA	Absolute Energy Africa
BCtA	Business Call to Action
BECS	Bundibugyo Electricity Cooperative
BMZ	German Federal Ministry for Economic Cooperation and Development
CAPEX	Capital Expenditures
CIRPS	Interuniversity Research Centre on Sustainable Development
REEC	Centre for Research in Energy and Energy Conservation
DFID	Department for International Development (UK)
DWRM	Directorate of Water Resource Management
ERA	Electricity Regulatory Authority
ERT	Energy for Rural Transformation
EU	European Union
FIT	Feed-in tariff
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IREMP	Indicative Rural Electrification Master Plan
KRECS	Kyegegwa Rural Electricity Cooperative Society
kW	Kilowatt
LCOE	Levelized Cost of Electricity
MEMD	Ministry of Energy and Mineral Development
MW	Megawatt
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organization
OPEX	Operating Expenses
PACMECS	Pader Abim Community Multipurpose Electricity Cooperative Society
PV	Photovoltaic
RE	Rural electrification
REA	Rural Electrification Agency

REB	Rural Electrification Board
RESP	Rural Electrification Strategy and Plan
SDGs	Sustainable Development Goals
SHS	Solar Home System
SIDA	Swedish International Development Cooperation Agency
UECCC	Uganda Energy Credit Capitalization Company
UEDCL	Uganda Electricity Distribution Company Limited
USAID	United States Agency for International Development
WENRECO	West Nile Rural Electrification Company

1. Introduction

The world is currently witnessing a large-scale roll-out of new renewable energy capacity that is contributing to growth and prosperity while also reducing the environmental impact of power generation. Recent years have seen a number of projects with record low prices for utility-scale wind and solar projects across both developed and developing countries. This trend is expected to continue over the coming years, thereby making these renewable energy sources ever more cost-competitive with conventional energy sources in various markets.

However, we still face the challenge of providing power to the 1.1 billion people currently living without electricity (IEA, 2017). The vast majority of this group live in Sub-Saharan Africa and India, with current projections indicating that by 2030 there will still be 700 million people without access to electricity, 90% of them residing in Sub-Saharan Africa (IEA, 2017). These groups typically live in scattered settlements in rural areas and have relatively low levels of income and consumption. This makes the conventional approach to supplying power inappropriate here, since extending the national grid is not economically feasible, given the distance from the grid and the consumption profile of the target consumers.

Instead, the focus has centred on mini-grids as a viable solution for providing these communities with access to energy. Mini-grids of various sizes can connect houses and villages through a grid that is supplied by energy generated on a small scale and on site. Mini-grids have traditionally relied on diesel generators, but more recently solar PV systems that store energy in batteries have been successfully implemented and are currently seen as the least cost option in Kenya.

This project aims to investigate the potential for integrating modern, small-scale wind turbines into solar-powered mini-grids as a way of further reducing the price of electricity in mini-grids. The price of the electricity produced from wind turbines ultimately depends on the wind resources that are available locally and the investment and running costs for the turbine. However, solar and wind energies complement each other because of the different production profiles of the two energy sources over the course of the day. Thus, the value of the wind energy produced can be much higher when the sun is not shining. By demonstrating that small-scale wind turbines can be effectively integrated into solar-powered mini-grids, this project will help develop the market for solutions to the goal of providing electricity that rural residents in developing countries can afford. In turn, providing access to sufficient and reliable electricity will help sustain the productive and income-generating activities of local communities in order to spur growth, create jobs and alleviate poverty in the rural areas of developing countries.

1.1 Market segmentation

Wind turbine manufacturers consider several dimensions when they segment the markets for wind turbines:

- Country-level segmentation of markets
- Pad versus MW constraint markets
- Wind-class segmentation

First, the country-level segmentation looks at legislation and how it is defined nationally, as there may be large differences in terms of grid requirements, noise requirements and bird and wildlife preservation that can affect product development and define the License to Operate in and Enter (LtOE) a given market. Subsequently, a regional segmentation is conducted to account for potential regional differences in legislation within a country.

Second, it is important to understand the limits that different countries have set to the maximum size of large wind-power plants. This is an indicator of whether it is the maximum generating capacity per turbine that is important or the maximizing of the wind-power plant's capacity, based on a given capacity constraint per site.

Third, for each regional or national segmentation, it is vital to have a benchmark understanding of the wind conditions. In the wind industry, most profit will be earned from the highest wind classes, since a high wind-class turbine will generate a higher annual yield than a turbine tailored for a lower wind class.

The above segmentation is not fully applicable to small kW turbines, but in order to remain within this framework, in this report we have used it as a guide in assessing market segmentation.

<u>Country-level segmentation of markets</u>
The project has a regional outlook, and market studies similar to the present one have been published for Kenya and Tanzania. The Kenya Miniwind project has a main focus on Kenya because Kenya has a large number of mini-grids already operational, planned or under development. Kenya also has experience with both small- and large-scale wind power, as well as large areas with reasonable wind conditions. It also has an important industrial base and a policy favourable to industrial development. As the production of wind turbines in Kenya would need a regional market to be beneficial, a study of the market for small wind turbines has also been carried out in Tanzania and Uganda.

<u>Pad versus MW constraint markets</u>
This parameter is not directly implementable here, but the size of the turbine to be demonstrated will be decided on the basis of an analysis of the market for different sizes of wind turbines in Kenya and neighbouring countries.

Small wind turbines (10-100 kW) can be connected to the main-grid or to mini-grids. There could be a market for small grid-connected turbines in areas with good wind conditions, but the potential market for them has not been assessed in this report. Any such market will depend strongly on the conditions for net-metering, non-bureaucratic power purchasing agreements and the interest of small investors living close to potential sites for the turbines.

At present, the project's partners are convinced that the market for mini-grids is more viable because mini-grid investors are obliged to invest in production capacity in respect of new or existing grids when demand increases. This means that, if the levelized cost of electricity (LCOE) in the case of wind-produced electricity is competitive with PV-produced electricity in a system using batteries, the mini-grid investor can make the choice to include wind energy in the system. Furthermore, the real value of adding wind may be that additional generating capacity can be added to a system without going to the expense of adding the additional storage capacity necessary if just the solar PV capacity is expanded alone.

The market study has identified all existing and planned mini-grids in Tanzania, including the size of electricity-producing systems, such as PV, diesel, etc., with the objective of providing input into the decision regarding what size of wind turbine to develop in the project.

Wind resource categories
To provide information on this essential parameter, this study divides the planned and existing mini-grids into wind resource categories based on geospatial information regarding the mini-grid locations and on data for annual average wind speeds at 20 m above ground level from the Global Wind Atlas. The sites are divided into 0.5 m/s intervals for wind speeds above 4 m/s.

1.2 Structure of the report

This report has been produced in collaboration with Kenyan and Danish partners in the project, and has benefitted from the various sources of knowledge available to the partners The first section in the report provides an overview of the existing and envisaged policy for rural electrification in Uganda. It continues with an overview of existing and planned mini-grids in the country. Section four describes the public and private market players, while section five provides insights into existing wind-turbine importers, manufacturers and installers. Section six then links the position of planned and existing mini-grids with the expected wind resource potential, and provides a classification of the sites into wind-speed intervals of 0.5 m/s. Finally, section seven provides a conclusion to this study.

2. Policy framework for rural electrification

In Uganda, rural electrification is the mandate of a semi-governmental Rural Electrification Agency (REA), which was set up under the Ministry of Energy and Mineral Development (MEMD) and has been operational since 2003. Rural electrification (RE) forms an integral part of the Uganda government's wider rural transformation and poverty eradication agenda. The primary objective of RE is to reduce inequalities in access to electricity and the associated opportunities for increased social welfare, education, health and income-generating opportunities. As a result, the RE strategy seeks to maximize the economic, social and environmental benefits of rural electrification subsidies by closely coordinating the electrification programme with other government activities in rural areas (MEMD, 2001). In addition, it is also aimed at promoting grid extensions and the development of off-grid electrification. In the following section, we document the policies guiding RE and RE plans and strategy, focusing on the policy framework for mini-grids as part of the rural electrification program.

2.1 A Brief on the Policies and Plans Guiding Rural Electrification

The Electricity Act of 1999 liberalized the power sector in Uganda and created a provision for a Rural Electrification Fund, whose objective was to ensure equal coverage of electrification (The Electricity Act, 1999). The Act also obliges the government "to undertake, support and promote a rural electrification program through public and private sector participation". The RE fund consists of: i) money appropriated by Parliament; ii) any surplus money made from REA operations declared to the Minister of Finance; iii) a levy of 5% on transmission bulk purchases of electricity from generation; and iv) grants and loans from development partners such as GIZ, the World Bank etc. REA acts as a Secretariat for the Rural Electrification Board (REB), which is responsible for overseeing the management the funds, approving reports, contributing to the policy and regulatory framework and recommending subsidy levels for projects etc. (MEMD, 2003). Rural electrification strategies and plans are prepared by the Ministry of Energy and Mineral Development (MEMD) in consultation with other Ministries, and with support from REA.

In 2001 the electrification rate in rural Uganda was 2%, while the percentage of Uganda's rural population was over 85% in the late 1990s.[1] Electrifying most of the country entirely through grid extension did not seem feasible. The scale of the rural electrification challenge was significant, as was the need for a fundamental change of policy and approach. It was in this context that in 2001 a new Rural Electrification Strategy and Plan (RESP) was adopted by the Cabinet with a primary objective of reducing inequalities in access to electricity and to achieve a 10% rural electrification rate by 2010, which meant an addition of 400,000 rural customers (MEMD, 2001). This led to the government focusing on decentralized and distributed forms of generation and deploying locally available renewable-energy sources in the form of small hydro, solar energy, wind and biomass, and with an emphasis on private-sector participation. In this way, the Electricity

[1] https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=UG

Act (1999) laid down the legal framework for the RESP and established the Rural Electrification Fund.

In the RESP (2001-2010), objectives were highlighted, new policy instruments were identified, the institutional framework was laid out, and the barriers to decentralized electrification were acknowledged. The priority projects identified for rural electrification include grid extension, mini-grids and isolated PV systems. It was reckoned that "if the demand is not large and distance to the grid is great, a mini-grid may be more cost effective" (MEMD, 2001). Mini-grids were considered well adapted to "relatively concentrated areas with a potential for productive uses like trading centres and other clusters of businesses and homes". As part of the strategy, it was envisaged that the government would have to develop a long-term Rural Electrification Master Plan covering a twenty-year period with the aim of: i) understanding demand in rural areas; ii) identifying grid and off-grid areas; iii) prioritizing potential projects; iv) carrying out grid-network analysis; v) identifying projects for implementation by the private sector; and vi) forming public–private sector partnerships etc.[2]

The National Energy Policy of 2002 was shaped to promote "increased access to modern affordable energy services as a contribution to poverty eradication". The policy also emphasized the fundamental elements of the RESP 2001, which were: i) development of RE schemes on a demand basis; ii) participation and training of the private sector, including development and operation of isolated power systems (mini-grid and PV); and iii) REA capacity-building . The promotion of renewable energy was another important element of RESP.

Regarding small-scale electricity generation, Article 56 of the Electricity Act 1999 requires the authorities "to publish standardised tariffs based on the avoided cost of the system for sales to the grid of electricity generated by the renewable energy systems of up to a maximum capacity of twenty megawatts" (Electricity Act, 1999). Thus the Electricity Act (1999) set out the regulatory framework for power generation from small renewable energy sources. Furthermore, the RESP identified a need to develop standardized procedures for small power producers, as small systems can play a key role in rural electrification, especially due to the dispersed nature of demand in these areas, suggesting that mini-grids are the least-cost solution. Also, the Energy Policy of 2002 recognized that the country has numerous mini- and micro-hydropower sites, which should be developed to supply isolated areas or feed into the national grid. In that period, a study was carried out identifying nine potential sites, some of which might be taken up for further development (EP, 2002).

The Renewable Energy Policy (2007) provided incentives for investments in grid-connected generating plants and generation for independent grids. Under the Renewable Energy Policy, the government instituted regulatory support in the form of standardized

2 Rural Electrification Strategy and Plan Covering the Period 2001 to 2010. Ministry of Energy and Mineral Development. February 2001. Kampala, Uganda

power purchasing agreements (SPPAs) to streamline and standardize independent power production for single off-takers, as well as feed-in tariffs (FIT) to guarantee a buyer and a price for independently supplied grid power (RE Policy, 2007). Around that time, Uganda was experiencing an unprecedented electricity deficit of about 165MW, resulting in massive load-shedding. This was due to prolonged drought, inadequate investment in least-cost generating capacity and a relatively high load growth. In this context, MEMD decided to accelerate the development of small grid-connected renewable energy projects to reinforce the grid, which also led to the introduction of PPA and FIT to expedite transactions. For mini-grids, the policy identified the need to support micro- and pico-hydro and biomass gasifiers, though it did not provide any regulatory framework for them (RE Policy, 2007).

The Electricity Regulatory Authority (ERA), Uganda's independent energy regulatory authority, is the primary regulator for mini-grid projects, including license approval, retail tariff-setting and the enforcement of technical standards. Although REA has a broad mandate regarding rural electrification, it does not have regulatory authority over mini-grid projects. However, ERA does consult with REA when reviewing and approving projects to ensure that developers are already in discussion with the latter regarding issues such as the intended project site, funding assistance etc.

However, the institutional framework around mini-grids in Uganda is not very clear. Project developers have reported difficulties in navigating the mini-grid development process in Uganda.[3] Although all developers understand that ERA is the regulatory authority in charge of approving projects, many have noted that it was not always clear when it was necessary to engage ERA or REA or both during the various stages of mini-grid development (USAID, 2017).

2.2 Existing policy framework

Historically, the focus of the Government of Uganda and its development partners has been on grid extensions, that is, the development of large hydro-projects, and on back-up thermal power. This has resulted in the lack of instruments oriented towards the private financing of technologies for mini-grid solutions that would have an impact on the rural population. Few private companies have invested in mini-grids, as the costs of providing access are high due to the remoteness of the sites, the dispersal of settlements and the difficulties of the terrain. Furthermore, debates around tariff rates have also caused delays in project development.

In the Ugandan context, mini-grids have not been clearly defined, classified or assessed, though they have been called isolated grid systems. In accordance with the ERA guidelines from 2013, three categories of isolated grid systems combining generation, distribution and sales licenses were identified (ERA, 2012):

Category I – medium generators of 10 MW and above but less than 50 MW
Category II – small generators of 2 MW and above but less than 10 MW

[3] https://www.esi-africa.com/exclusive-interview-riccardo-ridolfi/

Category III – very small generators of up to 2 MW; a) 0.5MW but less than 2MW; b) less than 0.5 MW

The current regulatory framework followed for mini-grids is described below.

2.2.1 Approvals

All mini-grid projects are subject to a range of approvals. Within the electricity sector, ERA approves the applications for licenses and exemptions, and REA is also involved in the review process. In addition, the National Environmental Management Authority (NEMA) must approve the environmental impact report or assessment before ERA can issue a license. In the case of mini-hydropower projects, additional approval by the Directorate of Water Resource Management (DWRM) is also required. However, there is no clear order of approvals, and there is a lack of systematic coordination among the different authorities.

2.2.2 Licensing

Uganda takes a divided approach to licensing based on the categories of isolated grid systems. For projects greater than 2 MW, the Electricity Act of 1999, Chapter 45, outlines the licensing process, including the timeline, requirements and rules for obtaining a license. The ERA website and ERA's Renewable Energy Investment Guide provide further details (ERA, 2012).

Projects of less than 2 MW do not require a license, and instead go through a license exemption procedure, after which they are issued with a certificate of exemption. Part XIV, Section 114 of the Electricity Act 1999 grants ERA the authority to issue a certificate of exemption, thus allowing projects whose capacity does not exceed 2 MW to generate, distribute and sell electricity (USAID, 2017). Further rules issued under Electricity Order 2007 address license exemptions for isolated grid systems (Electricity [License Exemption] [Isolated Grid System] Order 2007). Electricity Order 2007 requires a certificate of exemption and outlines high-level rules for tariff approval, technical standards, reporting, connection to the main grid, customer service, dispute settlement and upgrading capacity above 2 MW. It also covers applications for certificates of exemption.[4]

License Exemptions for Projects (Less Than 2 MW) – Exemptions involve a two-stage process. The developer must first complete a feasibility study and acquire the necessary approvals from NEMA (and DRWM for hydro-projects) for a given site. As part of that process, the developer has to submit an environmental report to NEMA, which ERA reviews. ERA does not coordinate the various approvals for the developer. A developer whose feasibility study has been approved by NEMA, DWRM and ERA may apply for a license exemption. When the exemption is granted, the developer has exclusive rights to generate, distribute, and sell electricity in a given area.

- License exemptions have no predetermined length; applicants specify their preferred length, which is approved or adjusted by ERA.

[4] Statutory Instruments 2007 No. 39, The Electricity (License Exemption) (Isolated Grid Systems) Order 2007. 17th August 2007.

- The license exemption fee is US$3,500 (USAID, 2017).

The licensing process in Uganda has been the subject of considerable attention. Although the licensing process for IPPs has been streamlined and simplified, challenges remain with the license exemption process. Some mini-grid developers identified the following issues (USAID, 2017):

- Lack of clarity regarding the order of approvals, the requisite documents and the procedure for submitting information
- The long time needed to obtain a certificate of exemption (some waited a year or longer for approval)
- The lack of provisional rights to a site during the feasibility stage
- Difficulty in finding the necessary expertise to cover the cost of feasibility studies
- The license exemption fee is burdensome for smaller projects.

2.2.3 Connection to the main grid

Uganda has not yet developed a process for managing project ownership after connection. While licenses and concession agreements provide mini-grid developers with exclusive rights to a site for a defined period, in-country stakeholders expressed conflicting perspectives on whether those rights would continue after grid connection. The planning process is not very well coordinated among the different stakeholders, including ERA, REA, the main distribution utility UMEME, the transmission company UETCL, MEMD etc. ERA staff acknowledged the need to compensate developers in the event that mini-grid operations are ended prematurely due to grid extension. The mini-grid industry in Uganda is still in its infancy, as is the policy and regulatory framework.

2.2.4 Tariffs for mini-grids

ERA is responsible for determining and regulating the tariffs for mini-grids. For this, each electricity service provider must submit a proposed tariff to ERA, which is reviewed by the regulatory staff and subsequently amended or approved. The current review process is reported to be quite lengthy and unattractive to private-sector investments (USAID, 2017). ERA is in the process of streamlining the process, and it currently works with developers to determine individual tariffs for each project. Although in theory the tariffs are supposed to reflects costs, in practice they are close to the national grid tariff. The maximum tariff levied on mini-grids thus far is 26 cents/kWh, the main grid tariff being 19 cents/kWh. Some mini-grid projects have slightly higher tariffs than the grid tariff. However, it can be politically challenging to charge poor rural customers higher rates than the national tariff and to charge customers who live in close proximity different rates.[5] In Uganda, it is feasible to keep the mini-grid tariff close to the national grid tariff because of the financial support provided by REA for distribution infrastructure, which may or may not be financially sustainable in the long term. Most developers note that the tariffs charged were insufficient for them to recover their costs fully at current levels of demand.[6]

[5] Personal communication with ERA.
[6] Personal communication with a few developers (Absolute Energy and Kalangala Services) and ERA.

Currently, each mini-grid project is initially proposed by a developer and obtains approval from ERA, REA and other agencies to move forward with project construction. Even as Uganda develops a master-planning process for rural electrification, the government plans to continue working with mini-grid developers to approve private sector-identified projects in specific cases (USAID, 2017). A new mini-grid working group has been set up consisting of officials from ERA and REA, development partners such as GIZ and USAID, and the National Association of Regulatory Utility Commissioners (U.S.), which has entered into a formal partnership with ERA to support streamlining of the mini-grid policy and regulations. The target is to engage with stakeholders and complete the process in a year.

3. Existing mini-grids, including projects under construction

The Government of Uganda has shifted its focus to mini-grids, especially off-grid systems, because, like many sub-Saharan Africa countries, it has scattered settlements, limiting the number of people who can effectively be reached by the national grid by, for example, grid expansion. Furthermore, many people are migrating to trading centres, which provide opportunities to install decentralized mini-grids.

3.1 Existing mini-grids

In Uganda, there are currently thirteen registered mini-grids producing electricity to the rural population with a total installed capacity of 3,211 kWh. They are mainly either community or privately owned. Hydro-stations are mainly community-operated, while the two biomass plants are run by both the community and Pamoja Energy Ltd. (Pamoja Cleantech Uganda Ltd.). Solar plants are operated mainly by the private companies. No information regarding the isolation or connection to the national grid has been found. The installed capacity and number of connections within the different energy sources are given in Table 1 below. Any additional information on, for example, specific plants, coordinates, external support and ownership can be found in Annex 1.

Energy Source	Number of Plants	Installed Capacity [kWp]		Number of Customers		Primary Ownership
		Mean	Total	Mean	Total	
Hydro	5	260.2	1,301	700	700	Community / Hospital
Biomass	2	13	26	-	-	Pamoja Energy Ltd & Community
Solar	6	314	1,884	486	2,918	Private company / community

Table 1. Installed capacity, in kW, and number of connections to Uganda's thirteen mini-grids by energy source, 2017.

Six of the registered mini-grids are solar plants, five are hydro and only two are biomass plants. The six solar-based mini-grids have an average installed capacity of 314 kWp and provide electricity to approximately five hundred connections. The five hydropower plants have an average installed capacity of 260 kWp, though there is very limited information regarding the number of connections (customers/households) to the mini-grids. There is also limited information available on the biomass or the five registered hydro-plants, the only information available coming from the 255 kWp Kisiizi plant, which serves seven hundred connections.

In Figure 1 below, the approximate locations of all thirteen registered mini-grids in Uganda are displayed on a map scaled by their installed capacity and energy source. A select sample of the projects is illustrated in the section below.

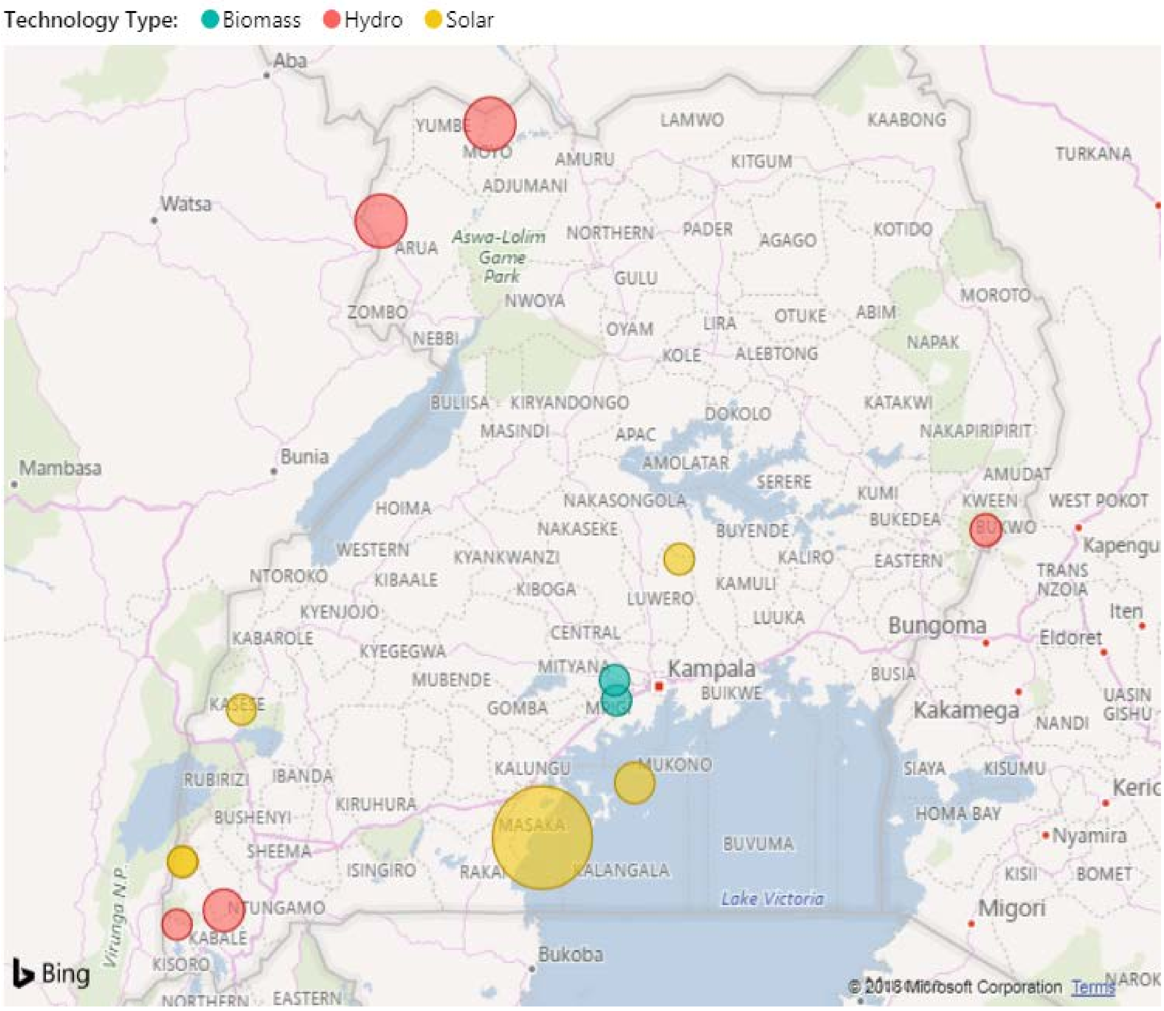

Figure 1. Approximate location of thirteen registered mini-grids in Uganda scaled by installed capacity [kWp] and coloured by energy source. The two solar mini-grids in Kanyegaramire and Kyenjojoare are illustrated by the same bubble.

Kisiizi Hydro

Among the first mini-grid projects undertaken in western Uganda was the Kisiizi mini-hydro plant, with an installed capacity of 255 kWp and with over three hundred connections. This mini-grid is owned and operated by Kisiizi Hospital Power Ltd., an independent company and uses a hybrid operator model. The project is a joint venture between Kisiizi Hospital and the Church of Uganda. It was built in 1984 with a 60 kVA Gilkes Turgo hydro-turbine that generated just enough power for the hospital. In 2009 a 294 kVA Ossberger crossflow turbine was commissioned, raising the power output significantly. There is also an 80 kVA standby generator, which is only utilized as backup to the hospital during the dry season, when there is a reduced flow from the river and no turbines are running.[7]

The total project cost was approximately USD 900,000, of which 75% went on the power generation system and 25% on the distribution system. It was funded using 30% equity

[7] Mini-Grid Policy Toolkit – Case Study: Kisiizi Hydroelectric Mini-Grid. Hybrid Operator Model, 2014.

and a 70% grant from the World Bank through the Energy for Rural Transformation (ERT) programme.

Kyamugarura Solar

In Kyamugarura, the solar mini-grid project benefits up to five hundred local people in the community, the ultimate aim being to create a cluster of mini-grid projects in the local area. This 13.5 kWp solar array has 38.4 kWh of battery storage and provides electricity to the school, health centre and sixty businesses.[8]

Figure 2. The 13.5 kWp installed solar mini-grid project in Kyamugarura, west of Uganda in Kyenjojo District, providing electricity to sixty local connections. The solar panels are mounted on top of two containers, which serve as an office for the cooperative.

Kanyegaramire Solar Project

Along with the Kyamugarura project, this project is also jointly funded by Energy for Development (e4D), which provided the generating costs, and REA, which funded the civil work and distribution grid. These projects were led and coordinated by the Sustainable Energy Research Group of the University of Southampton (UK). The design features include a 13.5kWp solar array, 38.4kWh of battery storage, two kW invertors and local low voltage AC, with an off-grid distribution network providing electricity to a hundred users. The plants are operated and maintained by a registered local co-operative.

Bwindi Hydro

This micro-hydro project is located in south-western Uganda, near the Bwindi Impenetrable National Park, and has an installed capacity of 64 kW. It is a community project supported by GIZ that provides power to a local hospital and neighbouring community. The project is operated by the Bwindi Community Micro Hydro-Power, a form of electricity cooperative.

[8] http://www.energyfordevelopment.net/current-projects/kyamugarura-uganda/

Kitobo Solar

Another successful solar PV mini-grid system, shown in Figure 3 below, is located on Kitobo Island, where a 228.8 kWp PV installation using batteries with a total capacity of 520 kWh and a gasoline generator of 60 kW provides electricity to more than 520 domestic and business users. The project has been commissioned by Sustainable Energy Services for Kitobo Island, a project co-funded by the Energy & Environment Partnership and led by the investment platform Absolute Energy Capital, in partnership with technicians from the Interuniversity Research Centre on Sustainable Development (CIRPS) and the international NGO AVSI Foundation. The three-phase, low-voltage distribution grid was built by the Rural Electrification Agency, which has supported the project.[9]

Figure 3. The 228 kWp installed solar mini-grid project on Kitobo Island, Lake Victoria, providing electricity to 520 domestic and business users.

3.2 Mini-grids under development

Besides the thirteen registered and operational mini-grids in Uganda described in the section above, a few additional mini-grids under development have been found.

1. Located on Bukasa island, in Kalangala District, a 100 kW Bukasa solar P.V. system is to be developed by Absolute Energy Africa Limited.
2. Located in Bukurungo Trading Center, in Kamwenge District, a 50kW biomass plant is proposed, to be developed by Pamoja Energy Africa Ltd.
3. Within the "Decentralized Renewable Development Program" being carried out by AfDB and REA, about ten decentralized mini-grids are envisaged for the islands on Lake Victoria.
4. The Uganda Energy Credit Capitalization Company (UECCC) is working with the ORIO Infrastructure Fund of the Government of the Netherlands to support the development of ten mini-hydro projects ranging from 50 to 500 kW.

[9] http://www.worksystem.us/index.php?option=com_k2&view=item&id=58:kitobo-island-uganda-off-grid-photovoltaic-power-system-with-vanadium-storage-completed&Itemid=146&lang=en#

5. Konserve Consult Ltd. is in the process of developing a 300 kW solar photovoltaic project on Kimi Island, in Lake Victoria. Konserve is in the process of obtaining the necessary approvals and expects that the project will yield a ten-year pay back.
6. Rwenzori Mountaineering Services is piloting a 3 kW pico-hydro project to power electricity for tourism sites and agro-processing, with support from Private Sector Foundation Uganda and CREEC.[10]
7. The Pro Mini-Grids project, co-financed by the EU and the German government, is being implemented by GIZ. This is the first bundled off-grid project to use mini-grids, which in the past have been implemented as unsolicited single-village projects. This is being initiated through bundled tenders, which are hosted by REA. During the pilot phase, the tender mechanism will be used to select a private company for the electrification of up to fifteen villages in Rakai and Isingiro Districts in southern Uganda and up to 25 villages in Lamwo District in northern Uganda (GIZ, 2017).[11] The mini-grids will be located more than three kilometres from the main grid. The peak power for individual mini-grids will be in the range of 30 to 80 kW, as the villages are relatively small, with an average of two hundred connections per mini-grid.

[10] http://creec.or.ug/services/pico-hydro/

[11] Personal Communication with Pro Mini-Grids Manager at GIZ.

4. Plans for rural electrification

The Government of Uganda has a vision of achieving universal access to electricity by 2040. Rural electrification is indeed a high policy priority in Uganda and is coordinated primarily through REA. From 2001 to 2012, the rural electrification program was based on the first RESP, which aimed to increase access to electricity in rural areas from 1% in 2001 to 10% by 2010. The first RESP took a decentralized approach and relied heavily on the private sector. For various reasons the RESP did not achieve its intended results, as by the end of 2010 access to electricity in rural areas was less than 4% (REA, 2013).

In response, REA developed the second RESP covering the period 2013-2022 with the aim of increasing the rural electrification rate to 26% by 2022. The 2013 RESP is modified according to lessons learned from the weaknesses and bottlenecks identified in the previous program framework. The updated plan called for a more centralized approach and is being led by REA in partnership with the private sector. Rural electrification is an integral component of the government's overall policy and program to promote national economic and social development and integration (REA, 2013).

4.1 Rural Electrification Strategy and Plan (RESP) 2013-2022

Achieving the proposed 26% rural electrification rate by 2022 will rely on specific electricity service expansion goals in (1) on-grid services and (2) off-grid services. This means that approximately 1.42 million new rural consumers will have access to electricity by 2022 (REA, 2013). The strategy in RESP 2013-2022 focuses on mobilizing resources and stakeholders to operate in thirteen defined scaled-up service territories for which long-term electrification service business plans, or "master plans", will be developed, implemented and monitored against annually determined rural electrification investment and service connection targets (REA, 2013).

The government is beginning to take a more active role in the planning for mini-grid development. RESP envisions that the selected provider or other private-sector developers will provide services through renewable energy-based mini-grids, with an estimated 8500 new service connections from mini-grids being implemented by 2022 (REA, 2013). PV-powered mini-grids have been suggested for villages between a hundred and a thousand households, the smaller ones preferably being located in the neighbourhood of mobile communication stations (5).

REA is undertaking a master planning process to identify sites as good strategic locations for mini-grid development, with support from USAID and GIZ. However, at this stage only limited village-level electrification data are available. Recently, the first of the service territory business plans were drafted, though the data have not as yet been made officially available.[12] REA anticipates running a competitive tender and provisioning concessions of the identified sites to selected developers, potentially as part of broader concessions to provide a distribution service to a region. The Electricity Regulatory Authority (ERA) would oversee the tender and concession process. The process is designed to ensure that mini-grid development is included in a comprehensive national plan, as

[12] Personal communication with REA.

well as to address a major barrier identified by developers in Uganda, namely the difficulties in and expense of locating and conducting early-stage feasibility studies of potential sites.

Reportedly, the estimated cost of the second RESP is just over US$950 million. Of this, over 90% is projected to be spent on on-grid electrification, with the remainder split between off-grid electrification, customer financing, technical assistance and other areas (REA, 2013). REA is in the early stages of amending the second RESP to better clarify the role of mini-grids in rural electrification.

However, much of the mini-grid regulatory regime is still under development. Presently, mini-grid projects are regulated based on their capacity. Mini-grids greater than 2 MW in capacity are subject to the same regulations as national-grid independent power projects (IPPs), including licensing, tariff approval, technical standards and general oversight. Mini-grids of less than 2 MW in capacity are regulated through a license exemption procedure that outlines the rules for tariff approval, technical standards, reporting, customer service and dispute settlement. Autonomous mini-grids are regulated under Electricity Order 2007 No. 39 (Electricity [License Exemption] [Isolated Grid System] Order 2008). ERA is engaged in an ongoing process to update the regulations to make them more suitable for the small-scale applications (USAID, 2017).

4.1.1 Rural electric service territories

In order to expand access to electricity, REA has implemented a reconfiguration of the rural electrification sector into thirteen commercially scaled service territories, as shown in Figure 4 below. Establishing these territories with permanent service providers was seen as an important early milestone in the rural electrification strategy plan and a prerequisite for attracting capital investments for system construction.

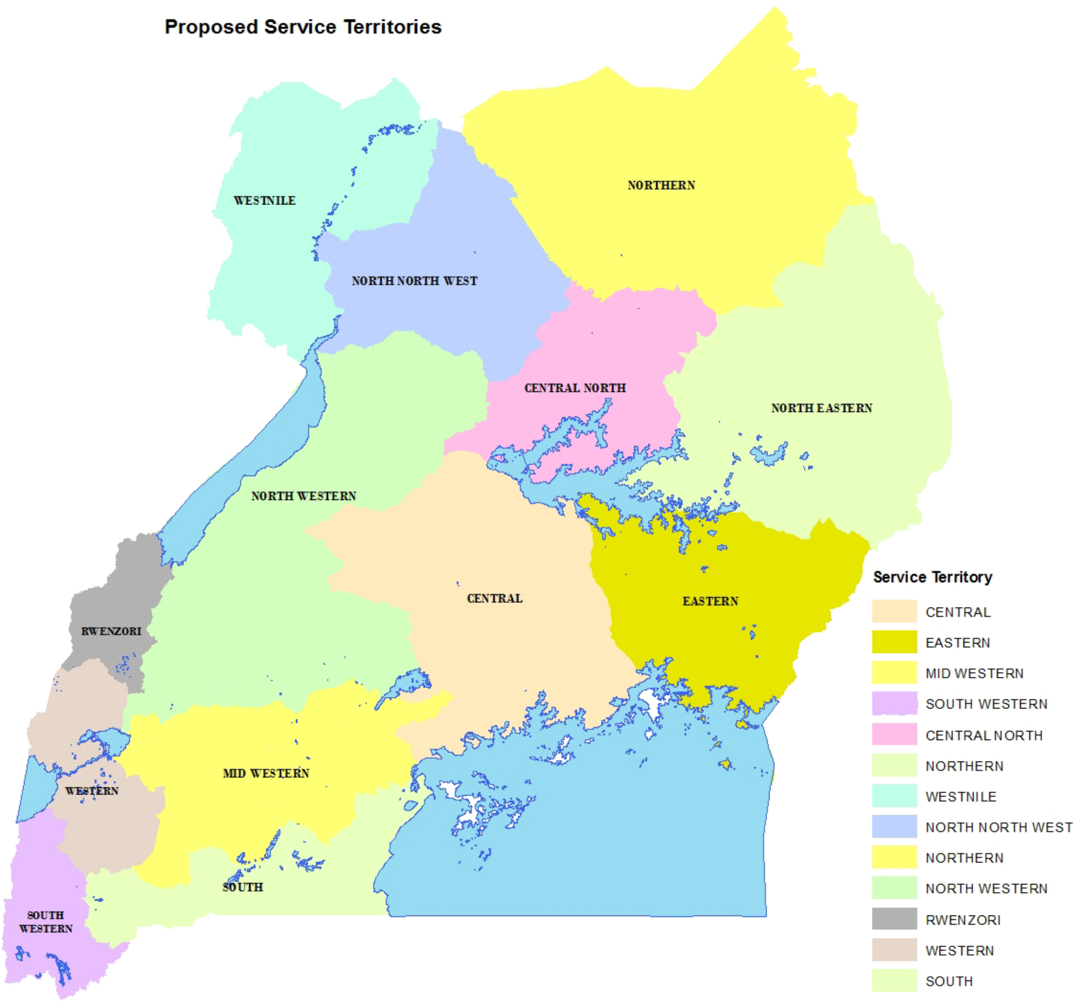

Figure 4. The thirteen proposed service territories

REA designed this policy to determine the commercial viability of investments into rural electrification, thereby paving the way for an accelerated in-flow of renewable-energy capital investments. Related elements of the new strategy are designed to reduce households' financial barriers to obtaining service connections and to link the marketing of on-grid services directly to off-grid electrification services such as solar PV.

Since the service territory electrification programs will be carried out simultaneously, the growth in electrification will occur evenly throughout the country in the form of a robust, national program.

The thirteen territories were divided between the following five private distribution companies: Bundibugyo Electricity Cooperative (BECS), West Nile Rural Electrification Company (WENRECO), Pader Abim Community Multipurpose Electricity Cooperative Society (PACMECS), Uganda Electricity Distribution Company Limited (UEDCL) and Kyegegwa Rural Electricity Cooperative Society (KRECS).

Distribution Company	UEDCL	PACMECS	BECS	WENRECO	KRECS
Service Territories	1. North Western 2. Mid-Western 3. Southern 4. Eastern 5. Central North 6. North East 7. North North Western 8. Western 9. South Western	10. Northern	11. Rwenzori	12. West Nile	13. Central

Table 2. The thirteen service territories and their small distribution companies.

Each of these distribution companies is responsible for the master plan in each of the thirteen service territories. However, these master plans are still not ready for publication, and we therefore do not have access to them.

3.1.1.1 On-grid services

On-grid services will be expanded to provide approximately 1.28 million new service connections.

3.1.1.2 Off-grid services

Off-grid connections are to be increased by approximately 140,000 additional installations of solar PV home systems (SHS) and mini-grid distribution service connections, but no details are available on the distribution between SHS and mini-grids (REA, 2013).

The off-grid electricity services, comprising energy service technologies not dependent on the national grid, are primarily solar photo-voltaic systems, with investments in island mini-distribution systems drawing electricity supply from decentralized power generation facilities.

4.2 Indicative Rural Electrification Master Plan (IREMP)

Back in 2008, REA presented an Indicative Rural Electrification Master Plan (IREMP) as a working stage between the first and second RESPs. The objective of the IREMP was to enable the government to promote the rural electrification programme through public- and private-sector participation in a coordinated manner, with a clear idea of the future options available for accessing electricity services to different areas, regions, communities and economic activities.[13]

Based on certain criteria and prioritization regarding the maps in the two subchapters below, Figures 5 and 6 show the suggested roll-out plans. The tariff-based prioritization was designed to suggest projects indicative of “value for money” for a given budget.

4.2.1 Identified Trading Centres reached by grid extensions

If this tariff-based prioritization were still within the “affordability” limit, grid expansion plans were suggested. IREMP identified a total of 644 MV (33KV) lines (regional

[13] http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1264695610003/6743444-1268073536147/7.1Uganda_IREMP.pdf

distribution lines and spurs) for construction during the ten-year planning period. As seen in Figure 5 below, the identified Trading Centres, scaled with household size displayed in the red bubbles, were to be reached within one to eleven years of the grid extension.

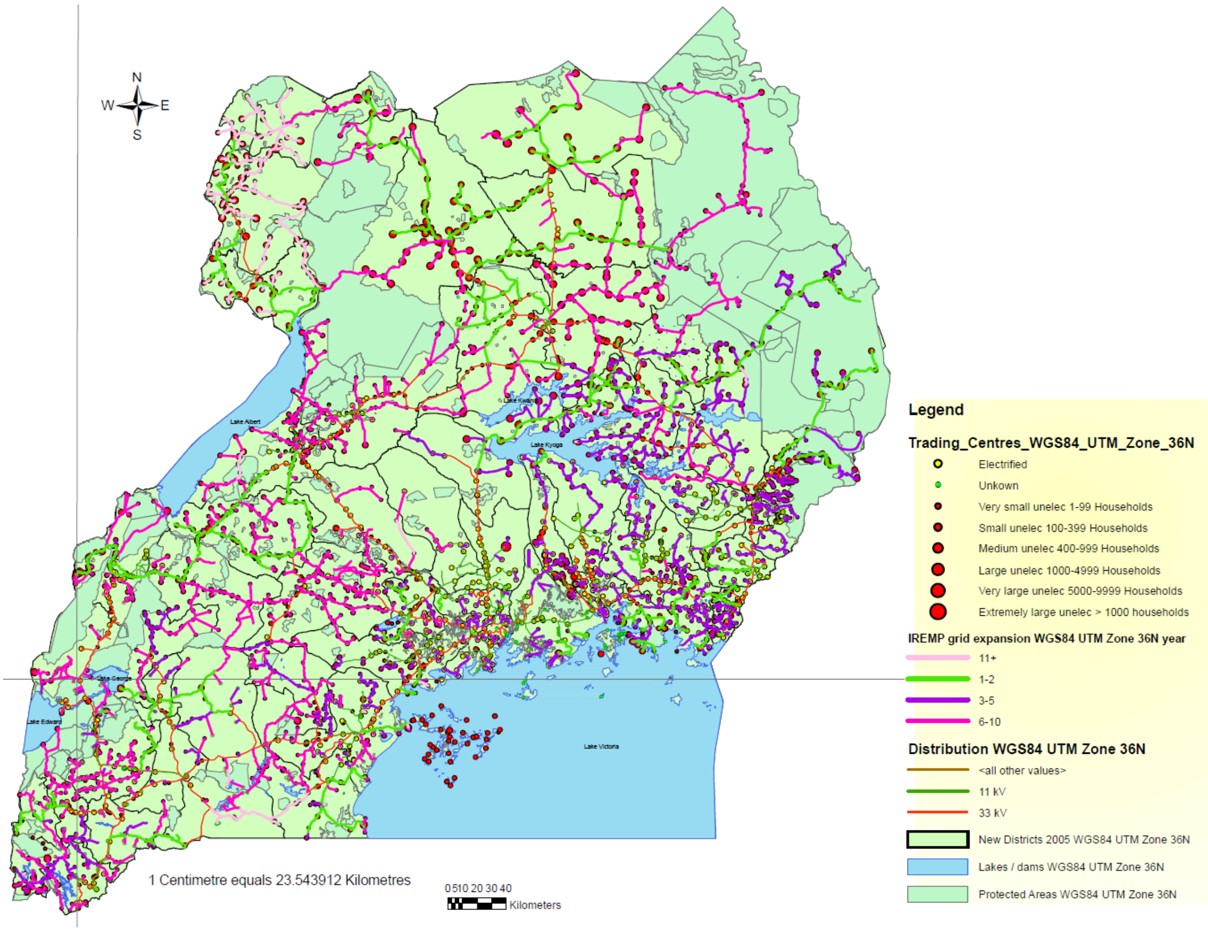

Figure 5. IREMP line prioritization on lowest tariff with Trading Centres. Source (REA, 2008)

4.2.2 Identified off-grid sites

The grid extensions were limited to where the average cost rises to a point exceeding the "affordability" limit, which becomes the cut-off point. Other loads beyond this point were to be connected more cheaply via an off-grid solution. These situations would involve first, islands which are physically unreachable, and secondly, loads where the capital cost per connection or least-cost energy-supply option is much higher when supplied by grid connection than another option. Almost fifty diesel-based mini-grids were considered, serving a total of 8,500 customers. For smaller communities, stand-alone solutions (PV, Pico hydros, small diesel/petrol gensets) were considered instead for these loads outside denser settlements (that is, those outside the main grid and the identified mini-grids). It was expected that 50% of these customers would have a PV system below 15 Wp.

In Figure 6 below, the off-grid sites are shown together with education facilities as a proxy for identifying off-grid population-dense areas.

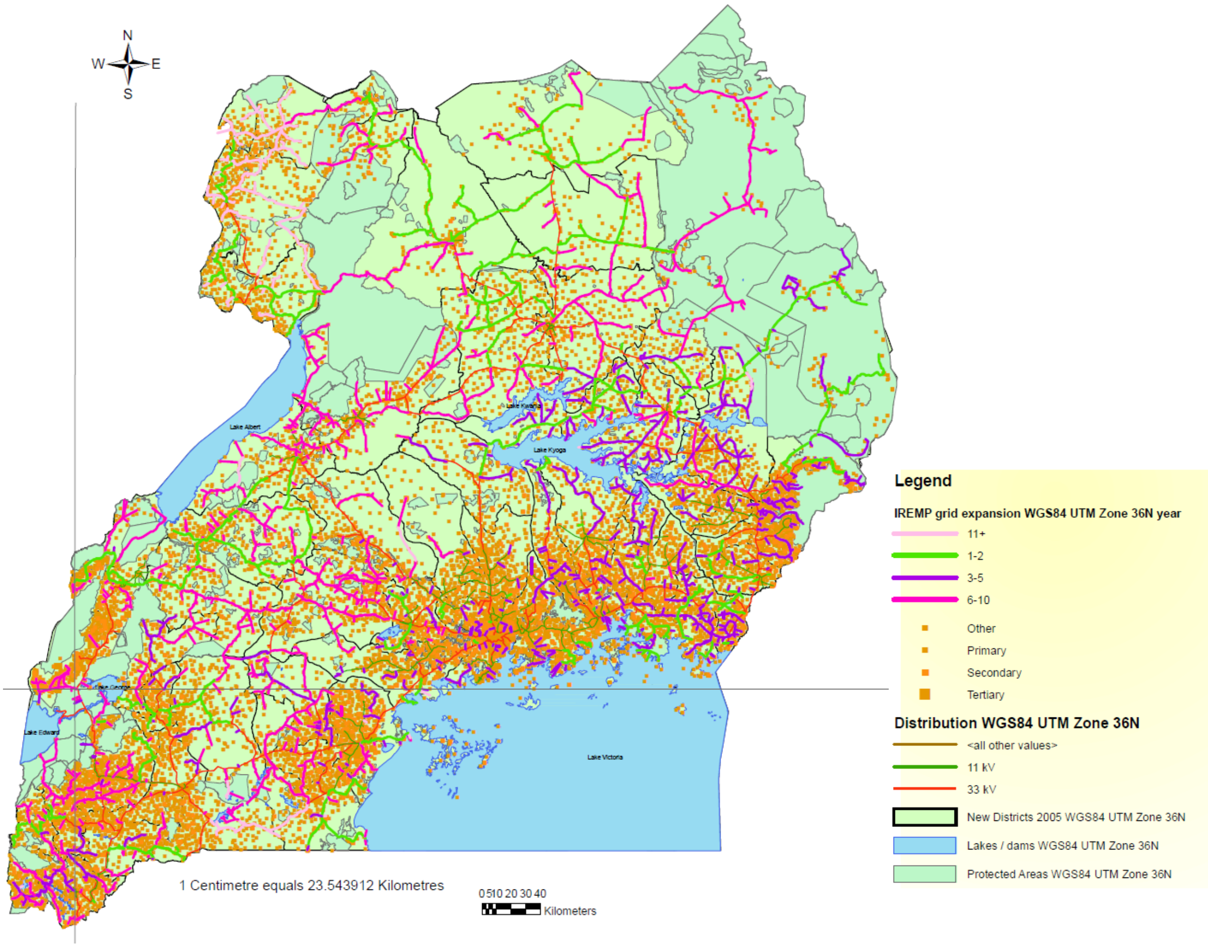

Figure 6. IREMP line prioritization on lowest tariff with Education Facilities as a proxy for off-grid population-dense areas. Source: (REA, 2008)

5. Public and private market players

Mini-grid projects in Uganda are owned and operated by a range of stakeholders. A majority of them have been developed and are operated by private-sector developers but are effectively organized as public-private partnerships. Generally, the generating equipment is owned by the private developers, which are also responsible for the construction costs. However, REA typically funds the mini-grid distribution infrastructure, including the connection costs and the house wiring costs, through the REF. REA maintains ownership of the mini-grid distribution networks, which are leased to developers. Some of the projects are also jointly owned by the community or university or an NGO. This section focuses on the public and private market players involved with renewable mini-grid projects in Uganda.

5.1 Description of each of the private market players

As mentioned previously, Uganda is in the initial phase of market development of the mini-grid segment, especially for projects of less than 2 MW. There are many projects in the range of 1 MW-10 MW. Nearly ten micro-hydro sites in Uganda have an installed capacity of less than 10 MW. However, most of these sites fall out of the scope of this study.

At present, only a few market players are active in providing electricity from hybrid renewable energy sources with a capacity of less than 1 MW. These include Kirchner Solar Group, Kalangala Infrastructure Services, Absolute Energy, Pamoja Energy Ltd., Remergy and Konserve Ltd. Of the six companies, one has a mini-grid project above 1 MW, and another has a pilot project under development, both of which are excluded here. Table 3 below shows the list of private companies identified:

Private Company	No. of active mini-grids	Size of mini-grids (kWp)	Customers	Contributi on to SDGs
Kirchner Solar	1 pilot project	22.5	Community, telecoms	7, 13
Pamoja Cleantech	2 (others in pipeline)	13	Community and SMEs	7, 13
Remergy	1 pilot project	5	Community	7, 13
Absolute Energy	1 project (others in pipeline)	230	Community and SMEs	7, 13

Table 3. Private companies and their characteristics

5.1.1 Kirchner Solar

Kircher Solar is a German solar company which has created more than 16,000 solar parks and rooftop installations worldwide since 1996. In 2009 it started a subsidiary in Uganda called Kirchner Solar Uganda Ltd.

Kirchner Solar Uganda, in cooperation with the communications company Airtel and GIZ, are cooperating as part of a public-private partnership. This cooperation is part of the develoPPP.de programme, run by GIZ on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

Through this it supports Kabunyata village in installing a solar PV mini-grid in 2014 as a low-cost, reliable alternative for integrated electricity supply to different consumer categories in the area. It is powered by a 22.5 kW solar facility. The solar set is equipped with 48 monocrystalline high-performance PV modules and produces up to 22 MWh of electricity per year. On the one hand, the solar system provides the local population with electricity, while on the other hand, it feeds the energy needs of the mobile masts of the leading Ugandan mobile phone company, Airtel, thus creating a reliable mobile phone network in a rural area.[14] Furthermore, its customers purchase electricity through a prepaid meter system calculated in kilowatt hours and processed by mobile phone.

Typically, Kirchner Solar provides the entire technology through turnkey mobile "energy containers" on site. Kirchner acts as an energy provider and also provides the operational management. To this end, it has provided training to local specialists to ensure that the system can be maintained and serviced by people from the village.[15] The project has cost about €422,000, of which nearly €200,000 is the subsidy or grant amount provided by GIZ.

5.1.2 Pamoja Cleantech

Pamoja Cleantech AB (henceforth, Pamoja) is a Swedish energy service company with its head office located in Stockholm and business operations taking place in rural Uganda.

The company has installed a small-scale biomass gasification power plant that runs on agricultural biomass residues such as maize cobs and coffee husks provided by the local farmers. The attached generator produces a power output of 32 kW, which is distributed to households in the village of Tiribogo, Mpigi District, via a mini-grid.

Pamoja started off with two important local partners: a local business man, who organized the workforce, sourced the raw materials and served as the key channel for communication with the villagers; and the Centre for Research in Energy and Energy Conservation (CREEC) of Makerere University, which helped to approach the village and provided technical expertise (Eder, J. et al., 2015).

In this project, the grid network finance was not provided by REA. To connect households to the mini-grid, Pamoja charged an initial connection fee of 100,000 UGX. In addition, each household had to pay for the wiring inside the house, which cost between 100,000 UGX and 200,000 UGX depending on the individual agreement. Thus, the households incurred an investment cost of at least 200,000 UGX, which many people in Tiribogo village could not afford (Eder, J. et al., 2015). This project, along with another biomass-based mini-grid project of Pamoja's, was supported by the Royal Institute of Technology, Stockholm, in the form of both grant assistance and technical assistance.

5.1.3 Absolute Energy

Absolute Energy Africa (AEA) is an Italian private company established in 2009. It has operated in Uganda since 2015-16 through a stand-alone solar mini-grid project on Kitobo Island in Lake Victoria. The installed capacity includes 228.8 kWp solar PV with 70 kW diesel back-up. The energy generated is 394.7 MWh per year.[16] Work System s.r.l., an

[14] https://www.giz.de/expertise/html/12403.html
[15] https://www.devex.com/impact/partnerships/solar-power-to-light-up-rural-uganda-340
[16] http://eepafrica.org/wp-content/uploads/AbsoluteEnergy_Infographic_A4.pdf

Italian company, was the EPC contractor for the Kitobo site, was responsible for the construction and assembly of the components, and employed some local workers from the community.

The project is made up of 880 polycrystalline PV panels, innovative redox flux Vanadium batteries with a total capacity of 520 kWh, and a gasoline generator of 60kW. The three-phase low-voltage distribution grid has been built by REA. Access to the electrical service is managed by means of a pre-paid mobile system and is monitored through individual smart meters connecting them to the remote management system.[17]

Later, furthermore, AEA also introduced a business incubation component into the project, as the demand for electricity remained lower than the supply. The local economy is mainly fishing-based and therefore lacks a steady stable income. With support from the Shell Foundation Incubator Program, AE has been tasked with training and imparting skills to fifteen local entrepreneurs to encourage them to start or expand their businesses.

AEA operates the mini-grid with the help of a local NGO based on Kitobo Island. In addition, AEA plans to expand mini-grid projects on a further twenty islands on Lake Victoria, for which they have already secured licenses from ERA.[18]

5.1.4 Remergy Energy

Remergy Eneryg A/S, a Denmark-based company established in 2014, has installed a pilot solar PV mini-grid project in Kayanza village, Kasese District. The mini-grid is a 5 kW system that provides electrical power to 120 households and businesses, mainly for lighting (Pedersen, 2016).

Remergy worked in collaboration with System Teknik A/S Denmark and received support from WWF-Uganda and Access 2 Innovation in conception, project design and implementation. A Ugandan NGO Joint Energy and Environment Project (JEEP) undertook all the power distribution and household installations.[19]

However, in 2015, after the project, Remergy became insolvent, and the management of the project shifted to WWF-Uganda and the local community.

5.2 Business models used and impact on SDGs

Typically, Uganda operates through a concession model: the government has leased operation of the generating and distribution assets to the private sector under long-term concession agreements ranging from 20 to 25 years. The same model has been replicated for rural electricity providers as well. Furthermore, a variety of private ownership models and system configurations can be observed among Uganda's mini-grid projects, including utility operator, private operator, and community or hybrid operator. The majority of mini-grid projects have been developed and are operated by private-sector developers but are effectively organized as public-private partnerships. Usually the generating equipment is owned by the private developer, which is also responsible for the

[17] http://www.worksystem.us/index.php?option=com_k2&view=item&id=58:kitobo-island-uganda-off-grid-photovoltaic-power-system-with-vanadium-storage-completed&Itemid=146&lang=en
[18] Personal communication with Riccardo Ridolfi, Business Development Manager, AEA
[19] http://jeepfolkecenter.org/2014/05/26/solar-micro-grid-in-kasese/

construction costs. However, REA typically funds mini-grid distribution infrastructure through the Rural Electrification Fund. REA maintains ownership of the mini-grid distribution networks, which are leased to the developers. Thus, the government has no direct role in the operation of mini-grids but provides important financial support to mini-grid projects and ensures that the distribution infrastructure is built to national grid standards.

However, this section will discuss the business models of the private market players, which have a private company managing all aspects in both regulated and unregulated environments. These include the private ABC mini-grids (e.g. Kirchner Solar), private AC village mini-grids (e.g. Remergy) and also private large mini-grids (e.g. Kalangala Infrastructure). The investments in mini-grid projects are typically in the form of donor grants and government support. Most of the projects have some form of donor or external support and therefore are not entirely commercially viable.

In case of the Kirchner Solar operator model, Airtel benefits from lower-priced solar electricity and is no longer dependent on fluctuating oil prices on the global market. The investment risk for Kirchner Solar Group stays within calculable limits because Airtel (the anchor load) guarantees the purchase of large quantities of electricity, and German development cooperation acquires a new means of promoting development in remote rural areas with relatively small amounts of its own funding.

According to Pamoja's business model, private households and entrepreneurs that use machines and devices should be connected to electricity. Pamoja's primary aim was not only to earn revenues from the project, but also to support local development in the community and provide electricity to low-income households. The original concept of Pamoja's pilot project in Mityana District involved using a telecom tower as an anchor load or a business operating a diesel generator. This was mainly done to ensure a stable source of income and to make the system economically beneficial.

Absolute Energy (AE) adopts a holistic approach based on the inclusion of the local community, the productive use of electricity and long-term sustainability. In partnership with the Shell Foundation, AEA is developing its rural multi-utility facility, starting from the delivery of electricity for productive use to communities beyond the reach of the national grid. AE suffered from low demand for the installed mini-grid, and hence incorporated a business incubation component to encourage local fishermen to engage with more productive activities and thus increase electricity loads.

5.3 Major donor-funding activities

At present the mini-grid segment in Uganda is dependent on external grants and funding support from a number of financial institutions, social enterprises, development aid agencies and international governments.

Business Call to Action (BCtA) is a global initiative that encourages companies to fight poverty through inclusive business models. Pamoja Cleantech, a micro-grid developer specializing in waste-to-energy projects, joined as a member in 2016.[20] BCtA was launched

[20] https://waste-management-world.com/a/ambitious-plans-for-waste-fuelled-micro-grids-in-uganda-firm

in 2008, a unique multilateral alliance between key donor governments, including the Dutch Ministry of Foreign Affairs, the Swedish International Development Cooperation Agency (SIDA), the UK Department for International Development (DFID), the US Agency for International Development (USAID), the Ministry of Foreign Affairs of the Government of Finland and the United Nations Development Program.[21]

Energising Development (EnDev) Uganda is currently implementing several micro-hydro power (MHP) and pico-hydro sites. The EnDeV program is a global partnership supported by six donors: BMZ, The Ministry of Foreign Affairs of the Netherlands (DGIS), The Norwegian Ministry of Foreign Affairs (MFA), the UK Department for International Development (DFID), the Swiss Agency for Development and Cooperation (SDC) and the Swedish International Development Cooperation Agency (SIDA).[22]

Kircher Solar has been supported by the develoPPP.de programme, run by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Agency for International Cooperation) on behalf of the German Ministry for Economic Cooperation and Development.[23]

Absolute Energy was supported by the Energy and Environment Partnership Trust Fund as part of the Southern & East African program, funded by the Government of Finland, the Austrian Development Cooperation and UK Aid.[24]

GIZ is developing a procedure that enables public agencies to invite private companies to tender for clusters of mini-grid projects. The tender scheme will help to ensure more effective subsidy disbursement and economies of scale during project development and execution. GIZ has also supported ERA in developing a set of simplified and standardized license application templates for mini-grids. In partnership with the EU, the German Climate Technology Initiative (DKTI) and the German Government, GIZ is implementing the project between 2016 and 2020.

[21] https://www.businesscalltoaction.org/member/pamoja-cleantech
[22] https://www.giz.de/en/worldwide/40417.html
[23] https://www.altenergymag.com/news/2012/10/23/kirchner-solar-group-and-developppde-launch-large-electrification-project-in-uganda/11418/
[24] http://eepafrica.org/?option=com_docman&task=cat_view&gid=34&limit=10&limitstart=0&order=hits&dir=ASC&Itemid64

6. Assessing wind potential at mini-grid sites

The aim of this chapter is to provide an assessment of the proportion of mini-grid sites in Uganda that may be suitable for the integration of small wind turbines, based on estimates of wind resources in the area immediately surrounding a mini-grid.

It should be emphasized that this assessment is not based on wind measurements at each site and thus suffers from a degree of uncertainty. However, the analysis is based on the very latest scientific wind resource data from the Global Wind Atlas, and as such it constitutes a very appropriate study when looking at a number of geographically dispersed sites throughout the country.

6.1 Methods for assessments of wind resources

The basis for estimating wind potential consists of two sets of data: a) wind resource information from the Global Wind Atlas; and b) mini-grid site locations and mini-grid electrical capacities. The methodologies for using these two data sets are described respectively in the two sections below.

6.1.1 Extracting wind resource information from the Global Wind Atlas

The Global Wind Atlas uses large-scale wind-climate data and mesoscale modelling to obtain a set of generalized wind-climate data that cover the globe at a grid spacing of 9 km. These data are then used with microscale modelling techniques, which, together with topographical and land roughness data, produce a series of local wind climates for every 1 km of the globe at heights of 50, 100 and 200 m. More detailed information on this can be found on the Global Wind Atlas website (https://globalwindatlas.info/).

The Kenya Miniwind project has put together an analysis tool that can help analyse wind-climate data so that it can be related to specific mini-grid sites. The analysis is conducted within a radius of 2.5 km around each mini-grid site location. The reason for taking an area, rather than an exact location, is three-fold: 1) as the production of a small wind turbine is very sensitive to location, it should be located in the optimum position within a reasonable distance of the mini-grid, and not necessarily at the exact mini-grid location. 2) it is unlikely that the position of the local wind climate data and the mini-grid location will coincide. 3) the wind-climate and topographical data are associated with a degree of uncertainty that is more evenly distributed if more locations are included in the analysis.

For each circle's area around a specific mini-grid location, the Global Wind Atlas data within the area are extrapolated to a height of 20 m above ground so that it is more representative of the resource a small wind turbine would experience. These are then analysed, and the wind speeds of the top 10% of the locations with the highest wind speeds are collected and averaged.

Thus, the wind resource information that is extracted is the average of the top 10% annual mean wind speeds from within the 2.5 km radius circle.

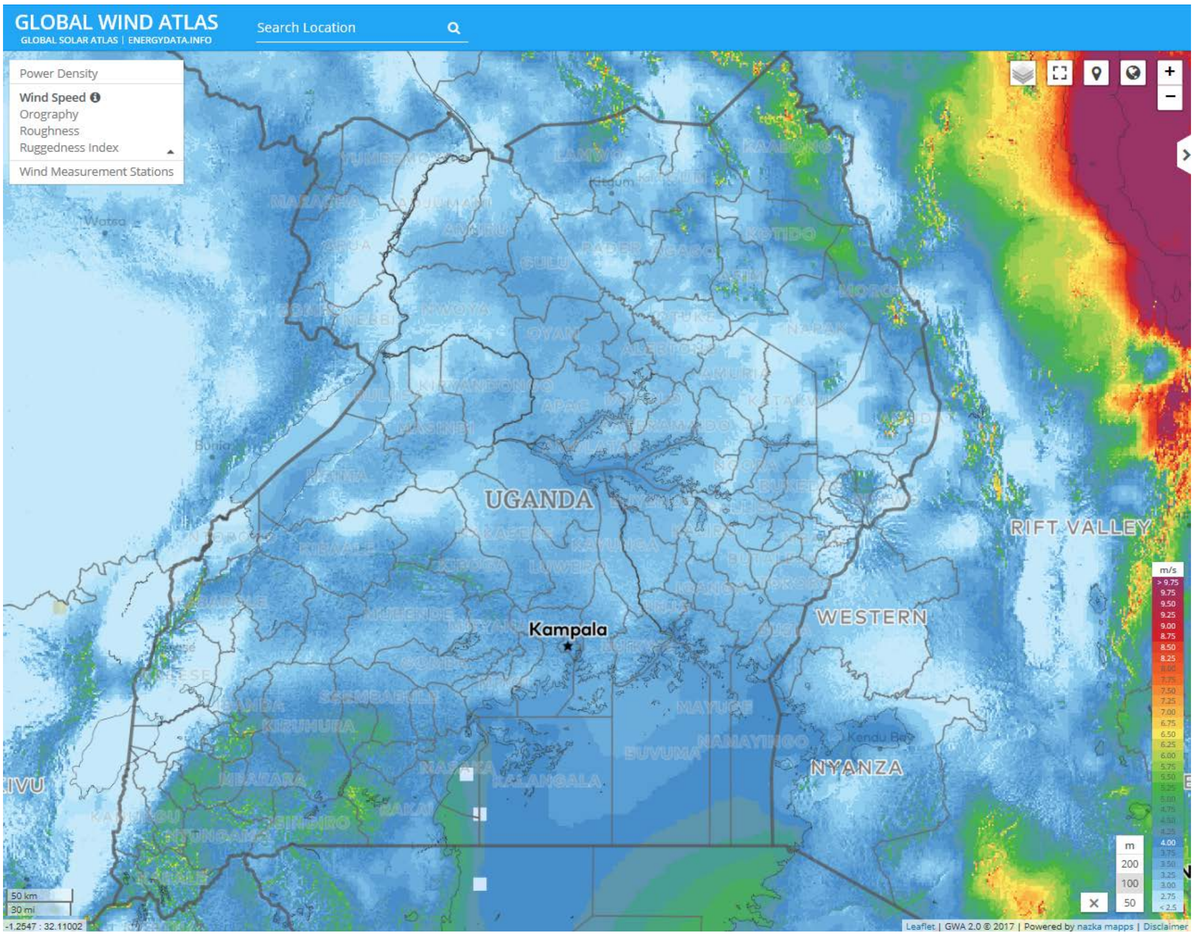

Figure 7. Screen shot from the Global Wind Atlas web browser interface

6.1.2 Mini-grid site locations and mini-grid electrical capacities

The locations of the mini-grid sites are taken from the mini-grid site information, as shown in Annex 1 of this report. All the sites have an electrical capacity of 150 kW or less, and these have been analysed with the exception of two sites that do not have location information. The 150kW cut-off was chosen to ensure that there is a reasonable power-to-capacity ratio between the project's demonstration turbine and the mini-grid's capacity, given that the envisaged turbine will have a rated capacity of between 5 and 20 kW.

In all, there are six sites under 150 kW, the geographical positions of them all being shown in Figure 8. The operational statuses of these mini-grids RE listed in Annex 1.

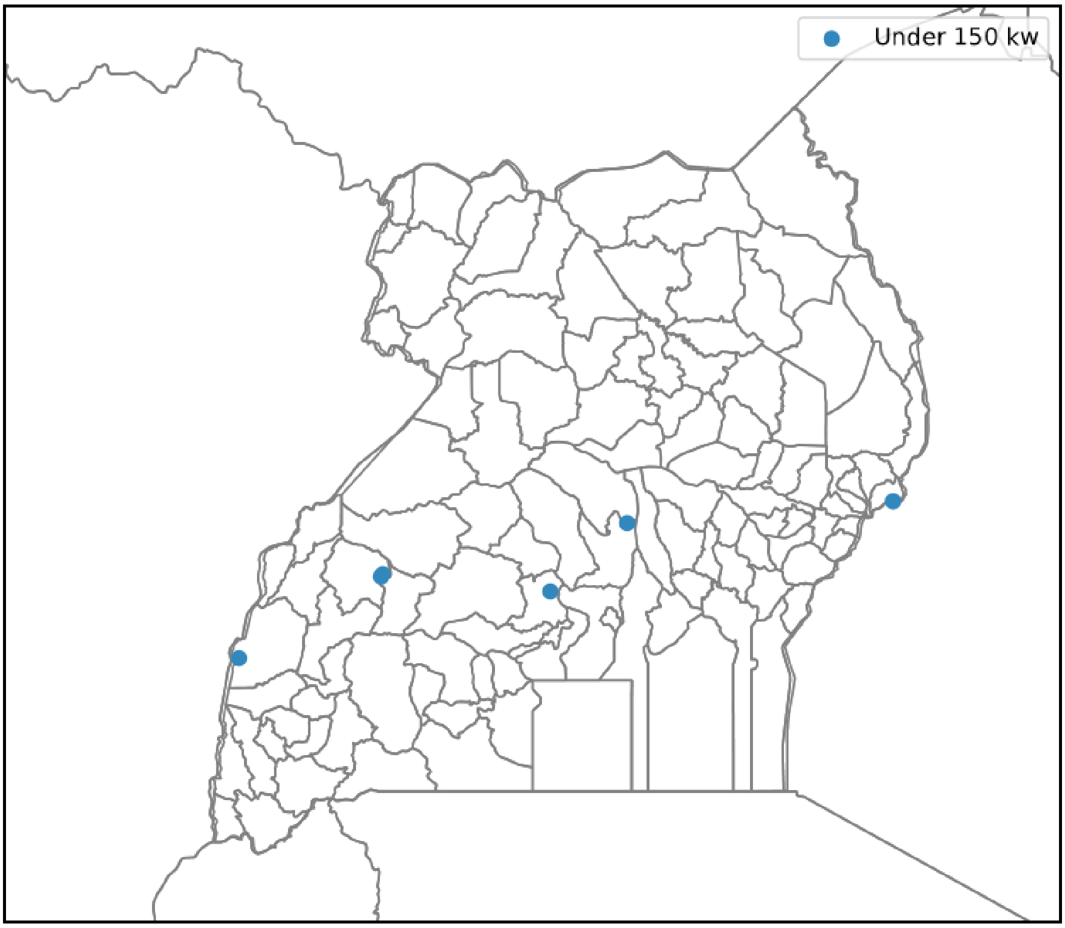

Figure 8. Location of all sites under 150 kW

6.2 Classification of mini-grids according to wind potential

The following maps give the locations of the mini-grid sites according to the wind potential found in the analysis. An annual average wind speed of 4m/s or above has been chosen as the wind speed that represents a site having feasible potential. This, of course, is a very coarse delineator because feasibility depends on a huge range of other factors, including specific wind-turbine performance, exact siting, mini-grid system design, consumption patterns, the economic context, and institutional and community factors, to name just a few. An outline of how the Kenya Miniwind project intends to make a more accurate analysis of feasibility, which includes the value of wind energy produced and not just the amount, is provided in Section 6.4.

It should be noted that the following maps all give indications of the wind potential in m/s, with the numerical value representing the ***average of the top 10% mean annual wind speeds.***

6.2.1 All sites under 150kW

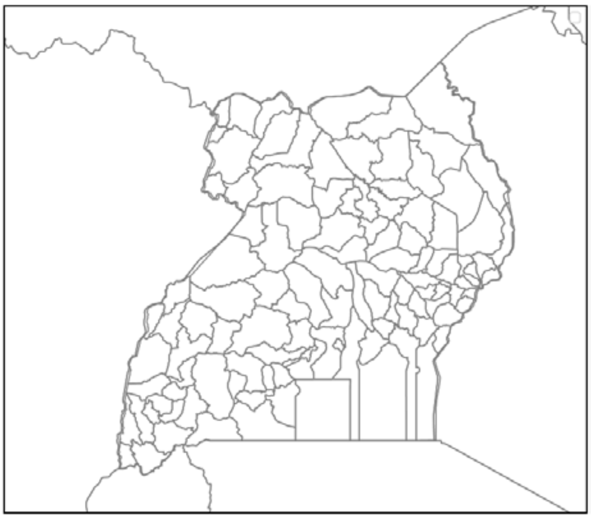

Figure 9: Sites with a wind speed above 4m/s

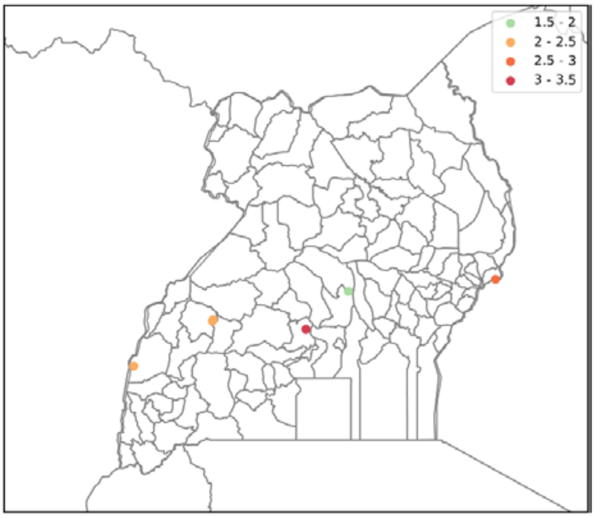

Figure 10: Sites with a wind speed under 4m/s

Summary: of the six sites, none have a wind potential over 4 m/s.

6.3 Estimate of proportion of potentially suitable mini-grids

Thus, from the data set of available mini-grids, there are no sites that are potentially suitable for the integration of wind power when the wind resource alone is taken into account.

6.3.1 Further investigation of the feasibility of wind power

As part of Activity 2.1 (Feasibility Studies), a more detailed assessment of the feasibility of the integration of wind power will be made by carrying out preliminary feasibility studies on five mini-grid sites. These studies will include an assessment of the wind resource, but will also cover the range of other aspects to be taken into account when considering introducing a wind turbine into a community with an existing mini-grid.

In combination with this, Activities 4.2 (Demonstration of integration) and 4.6 (Performance of hybrid mini-grid operation) will investigate the **value** of the wind energy produced, rather than the straightforward price of each kWh generated. Much of the economic feasibility of integrating wind power into a mini-grid will depend on the correlation between the temporal profile of wind-power production, solar-power production and consumer consumption.

6.3.2 Outline of methodology for investigating the value of wind power

Conventional mini-grids based on solar PV for generation require a certain amount of battery storage capacity first, to handle fluctuating loads, and secondly, to be able to provide consumers with energy when the sun is no longer shining. It is frequently during the hours of darkness that much of the load on such mini-grids is present, as the power is used for electric lighting.

The drawback of battery storage (most commonly still using lead-acid technology, as is well known) is that it is costly to purchase and will need regular replacement throughout the life of the mini-grid. However, if a community being served by an existing mini-grid requires more electrical energy than it currently receives, there is little choice but to expand the solar PV capacity and, along with it, the battery storage capacity, incurring the extra costs involved.

If wind energy is now added by integrating a wind turbine into the mini-grid system, then the value of the energy produced will depend on the daily profile of the wind resource. If the energy produced from wind has a similar profile to that from solar PV, then the competitiveness of the wind energy will be purely on a cost of energy produced basis because a similar amount of battery storage will still need to be added.

However, if the wind frequently blows during the hours of dusk and overnight, which is a common phenomenon, then it is the opinion of this project that it can be introduced into the system *without* having to expand the battery capacity. This represents a significant saving in capital expenditure and running expenses and thus an increase in the *value* of wind energy.

To assess the economic benefits of integrating wind power as opposed adding solar power, this project will carry out a number of simulations of mini-grid scenarios, as outlined above. In the first instance these will use generic data, but the simulations will be refined as data is collected from the demonstration turbine and its associated mini-grid.

7. Conclusion

Although rural electrification forms part of the broader national development agenda, and despite a rural electrification agency having been established around the turn of the millennium, only limited progress has been witnessed so far in Uganda. Some steps have been taken to encourage private investment in the development of renewable energy-based mini-grids, but the continued difficulties in navigating the institutional framework surrounding mini-grids means that only a very few private companies (six) are active in developing mini-grids in Uganda, often with the aid of various donors.

Currently, there are only thirteen mini-grids in operation in Uganda, with only a limited number of additional projects on the horizon. However, given the ambition to achieve a 26% rate of rural electrification by 2022 and universal access by 2040, the pace of rural electrification is likely to pick up in the years to come. In 2013 it was envisaged that private developers would be able to provide 8,500 new service connections by 2022 through renewable energy-base mini-grids. A Rural Electrification Master Plan is expected to be finalized within the near future, and given the recent reduction in the cost of PV mini-grids, it is likely that the master plan will propose a distinction between grid connection and mini-grids that is more favourable to mini-grids than in the 2013 plan.

7.1 Policy framework for rural electrification

Rural electrification is part of the Government of Uganda's wider rural transformation and poverty eradication agenda. The Electricity Act of 1999 liberalized the country's power sector and made provision for a Renewable Energy Fund. In 2003, the Rural Electrification Agency (REA) was established with a mandate to promote rural electrification. With over 85% of the population living in rural areas, the rural electrification rate of only 2% recorded in 2001 indicated a vast potential for off-grid solutions since grid extension did not seem feasible. Therefore, the Rural Electrification Strategy and Plan (RESP) adopted in 2001 represented a first attempt to address this issue. The plan had an emphasis on decentralized and distributed forms of generation through locally available resources such as solar and wind. Furthermore, engaging the private sector was encouraged. While standardized tariffs for renewable energy systems of up to 20 MW had been included in the Electricity Act, the RESP also developed standardized procedures for small-scale power producers as a way of facilitating rural electrification. Under the Renewable Energy Policy of 2007, Standardized Power Purchase Agreements and feed-in-tariffs were instigated. The Electricity Regulatory Authority (ERA) has the mandate to regulate mini-grids by approving licenses, setting retail tariffs, enforcing technical standards etc. Nevertheless, project developers have reported difficulties in navigating the institutional framework surrounding mini-grids.

Historically, little emphasis has been placed on supporting the private financing of mini-grids, with the result that few private companies have invested in them, mainly due to the high costs of providing connections. Mini-grids are subject to a range of approvals by ERA, while obtaining a license is only required for projects larger than 2 MW. Thus, projects below 2 MW are issued with a certificate of exemption, which is granted upon approval of a feasibility study and an environmental report to be conducted by the developer. Once granted, the certificate of exemption assigns exclusive rights to generate, distribute and sell electricity in a given area. However, several challenges surrounding the licensing process for IPPs have been highlighted, including a lack of clarity regarding the process and the length of time before the certificate is granted. Moreover, there is no clarity regarding what happens to mini-grids if the grid reaches the site. Tariffs are to be proposed by electricity service providers themselves and will be reviewed by ERA, which approves or adjusts them following a lengthy process. Individual tariffs are determined for each project, and although they are supposed to reflect costs, in practice they are close to the national grid tariff of 19 cents/kWh. Although REA provides support for distribution infrastructure, most developers report that the tariffs charged are insufficient for them to recover their costs at current demand levels.

7.2 Existing and planned mini-grids

There are currently only thirteen mini-grids in operation in Uganda, both privately owned and owned by local communities. Six of these mini-grids are solar-based, with an average installed capacity of 314 kWp and roughly five hundred connections. Two of the remaining mini-grids are based on biomass, while five are hydro-based. Additional mini-grid projects have been identified that are either under construction or in the planning phase. The most notable is the Pro Mini-Grids project co-financed by the EU and the German government and implemented by GIZ. This is the first project to bundle several mini-grids together, which it will put out to tender by private companies.

Given the Government of Uganda's ambition to achieve a rural electrification rate of 26% by 2022 and universal access by 2040, rural electrification solutions will be in high demand. The government has been assuming a more active role in planning for the expansion of mini-grids and has divided the country into thirteen scaled-up service territories where long-term electrification service business plans are to be developed. As part of this, it is envisaged that private developers will provide 8,500 new service connections by 2022 through renewable energy-based mini-grids. More specifically, solar-based mini-grids have been suggested for villages of a hundred to a thousand households. The process of expanding the use of mini-grids is designed to address one of the major barriers mentioned by developers, namely the difficulties in and expense of locating and conducting early-stage feasibility studies of potential sites. While rural electrification has gained more attention in recent policy initiatives, 90% of spending associated with the second RESP is nevertheless going towards on-grid electrification.

7.3 Private and public market players and wind resources

Currently, the number of private companies actively involved with hybrid and renewable energy mini-grids is very limited. Only six companies have been identified: Kirchner Solar Group, Kalangala Infrastructure Services, Absolute Energy, Pamoja Energy Ltd., Remergy and Konserve Ltd. Of the six companies, Kirchner Solar Group is the most notable, being a German solar company with a subsidiary in Uganda since 2009. Its 2014 solar mini-grid was installed in a village with the support of the German government and in cooperation with the leading national mobile phone company, Airtel. Denmark-based Remergy and its pilot solar mini-grid providing electricity to 120 households is also worth mentioning, although the company became insolvent in 2015. Mini-grid projects in Uganda are typically supported by various kinds of donors in the form of financial institutions, development aid agencies or national governments. This is partly a result of the legislative framework, which does not yet allow for a significant increase in private investments in renewable energy-based mini-grids.

For the purposes of assessing the wind resources in the vicinity of relevant mini-grid sites, it was decided to focus mainly on sites with a capacity below 150 kW because this the appropriate capacity range for a the turbine the size of 5-20 kW to be developed for this project. Furthermore, an annual average wind speed of 4 m/s was set as the limit above which sites would be included as having a feasible potential. There are only six mini-grid sites in Uganda with a capacity below 150 kW, none of which have a wind resource above 4 m/s. Thus, judging by the wind resource alone, none of the sites is suitable for the integration of wind power.

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Annex 1. Details of mini-grids

Project name	Year commiss-ioned	Installed capacity (kWp)	Coordinates*	Location – village, district, region	Ownership	Customers connected	External support	Type of support	Remarks	Annual average wind speed (m/s)**
Micro-Hydro										
Bwindi	2014	64	3M 791547, 9891981 (UTM ARC 1960)	Kanungu District	Bwindi Community Micro-Hydropower Ltd. (community ownership)	62	EnDEV GIZ	Technical assistance, grant		-
Suam	2013	40	00◦13’02” N, 34◦43’56” E	Suam village, Bukwa District	Community		EnDEV GIZ	Technical assistance, grant		2.8
Solar										
Kanyegaramire	2015	13.5	0◦38’28.09” N 30◦51’04.93” E	Kyenjojo District	Community cooperative	100	University of Southampton	Technical assistance, grant	High demand, needs expanding	2.5
Kyamugarura	2015	13.5	0◦39’35.81” N 30◦51’51.82” E	Kyenjojo District	Community cooperative	60	Uni. of Southampton	Technical assistance, grant	Appropriately sized	2.2
Kabunyata	2013	22	1◦03’00.09” N 32◦43’00.62” E	Kabunyata village, Luwero District	Kirchner Solar	120	GIZ	Technical assistance, grant	High demand, needs expanding	2.0
Kasese	2015	5	0◦01’04.70” N 29◦46’30. 31” E	Kayanja village, Kasese	Remergy	88	WWF	Grant	On the ground operations by WWF	2.4
Biomass/biogassifiers										
Mpigi	2012	32		Tiribogo village, Muduuma Sub-county, Mpigi District	Pamoja Energy Ltd.	120	RIT Stockholm, Millennium Science Initiative-World Bank	Technical assistance, grant		-
Mityana	2013	32	.52803 N 32.13436 E	Magala village, Sekanyonyi sub-county, Mityana District	Pamoja Energy Ltd.		RIT Stockholm, Millennium Science Initiative-World Bank	Technical assistance, grant		3.3

* Within a radius of 500 m to 1 km from the actual project site.
** Annual average wind speed = the average of the top 10% annual mean wind speeds at 20 m height from within a 2.5 km radius of the mini-grid location.