Technical Notes on Energy-Digital Nexus for Minigrids

Technical Note 1: Digitally enabled minigrids

Energy and digitalisation act as accelerators and enablers of many, perhaps all of the SDGs, playing an important role in **improving access to public services, protecting the environment, addressing climate change, promoting agriculture, contributing to an inclusive, sustainable development and to job creation**. In order to empower development you need to:

- **Increase access to affordable, reliable, sustainable and modern energy**
- **Increase renewable energy generation and energy efficiency**
- **Contribute to the fight against climate change**

In this new era of energy transition and digital transformation, the idea of a nexus between digital solutions and the energy sector emerges. Digitalisation proves to have a potential in boosting results of the work in the energy sector by building energy systems, which are now more **intelligent, efficient, reliable, safe, sustainable and cost-effective**.

At the same time, **more than 1 billion people still do not have access to electricity** with most of them living in rural areas of developing countries. In Sub-Saharan Africa alone, off-grid systems are projected to provide access to nearly 65% of the newly electrified population[1].

Autonomous minigrids are able to provide power for residential loads, as well as effectively power a vast array of apparatuses and equipment, directly associated with economic development. These productive uses of energy emerge as a development driver in rural areas of the developing world. This, in turn, **leads to job creation and poverty alleviation**.

The financing of minigrids still poses considerable difficulties, leading to a slow increase in the number of new installed systems. Digitalisation on the other hand provides novel solutions that decrease costs and improve service for rural electrification minigrids. Different digital technologies combinations could be applied to all stages of a minigrid project development, implementation and operation including the actual financing. A combination of digital technologies paradigms presents the potential to make minigrid investments in the developing world viable in economic terms even in the short term.

[1] Dagnachew, A.G.; Lucas, P.L.; Hof, A.F.; Gernaat, D.E.H.J.; de Boer, H.-S.; van Vuuren, D.P. The role of decentralised systems in providing universal electricity access in sub-saharan Africa—A model-based approach. Energy 2017, 139, 184–195.

Stage	Sub-stage	Digital Technologies	1	2	3	Notes
PROJECT DEVELOPMENT AND PRE-INSTALLATION	Site selection	Artificial Intelligence	•	•		While collecting data for the installation, artificial intelligence based decision support systems are able to compare and propose the best among possible locations. Cloud computing allows the easy and low cost collection of data (e.g. climatic conditions, anthropogeography) from publicly available databases and easy running of any software that has been developed from any location with access to the internet.
		Cloud computing	•			
	Feasibility studies and surveys	Artificial Intelligence	•	•		All these technologies facilitate the assessment of demand, the energy resource assessment as well as provide an initial design of the minigrid. Collection of data through field surveys with appropriate questionnaires using applications like Google Forms. Drones for example could be used to collect at low cost data, which is then fed in to geographical information systems to provide meaningful conclusions, such as the setting of the grid poles, location of the various subsystems, etc.
		Cloud computing	•	•		
		Big Data	•	•		
		Unmanned Vehicles	•			
	Project development activities	Big Data	•		•	Using data available on the internet, the minigrid developer can easily access availability and cost of different technologies. Moreover local contracts creation process can also be facilitated.
		Cloud Computing	•		•	
	Establishing the institutional setup	Ubiquitous computing	•			Multiple digital technologies are able to be utilised for this step. Serious games and e-learning are used for capacity building, eSignatures and blockchain can be used as a backbone of the governance structure. While civic technology might be very advanced as implemented for example in Estonia, some aspects could be useful to be implemented in the community.
		eSignatures	•	•	•	
		Blockchain	•	•	•	
		Civic technology		•	•	
DESIGN, PROCUREMENT, INSTALLATION AND COMMISSIONING	Project Design	Artificial Intelligence	•	•		Multiple digital technologies are used for decreasing the costs associated for the implementation of this step, but also for the actual system operation, since in this step the final design and sizing of subsystems is performed. Finally, most technologies have the potential to decrease costs directly (e.g. printed photovoltaics present lower cost, internet of things decreases the cost of a control and monitoring system etc.)
		Cloud computing	•	•		
		Big Data	•	•		
		Internet of Things	•	•		
		Blockchain	•	•	•	
		Wireless Networks	•	•		
		Alternative Finance			•	
		Printed Electronics	•			
		3D printing	•			
	Procurement	Big Data			•	This step includes the procurement of equipment. Access to multiple providers globally creates competition leading to decreasing costs. Moreover as far as financing is concerned finetch and alternative finance help tap capital providers in a non-traditional manner as for example in crowdfunding.
		Internet			•	
		Fintech			•	
		Alternative Finance			•	
	Installation and commissioning	Virtual and Augmented Reality	•			These technologies aid indirectly and decrease costs. The training of installers can take place in a virtual environment, while augmented reality could improve the quality of installation and commissioning as well as decrease the required time. Duration of work benefits are translated to cost savings.
POST COMMISSIONING AND SUSTAINING OF THE PROJECT	Operation, maintenance and monitoring	Big Data	•	•	•	Since this step includes the actual day to day operation of the minigrid, it includes all the technologies needed for the technical operation (e.g. artificial intelligence, big data, internet of things, remote monitoring and control, etc.).
		Internet of Things	•	•		
		Wireless Networks	•	•	•	
		Internet	•	•	•	
		Blockchain	•	•	•	
		Artificial Intelligence	•	•		
		Mobile Computing		•	•	
		Edge Computing		•	•	
		eSignatures		•	•	
	Business development	Blockchain	•	•	•	All the technologies related to the payments and business operation are applied here. This includes technologies for implementing pay as you go models (wireless networks, mobile computing, eSignature etc.) as well as technologies for minimizing operational cost of the minigrid and decreased cost operation.
		Alternative Finance		•	•	
		Fintech		•	•	
		eSignature		•	•	
		Civic Technology		•	•	
		Mobile Computing	•	•	•	

Minigrids

Minigrids are small-scale power supply networks, which can work either autonomously or interconnected with a larger grid. In minigrids, different energy sources and energy storage devices are able to be distributed at any location covered by the grid. At the same time advanced control algorithms are used in order to ensure optimal utilisation of the available energy production and storage. Currently there are minigrid offerings from a few kWs up to MWs of installed power. A minigrid can be defined as a grid that can operate autonomously or interconnected to a larger grid and allows distributed generation[2]. Distributed generation includes both renewable energy technologies (e.g. photovoltaics, wind turbines, micro hydro, etc.) but also fossil fuel generators. Current minigrids are single phase, three-phase or split-phase. Most of the times they are AC based, since DC current is usually used in very low capacity micro-grids – often called nano- or pico-grids – where they power LED lamps and charge mobile phones[3].

What are productive uses of electricity ?

Productive uses of electricity are agricultural, commercial and industrial activities involving electricity services as a direct input to the production of goods or provision of services. Productive uses include water pumping, refrigeration, operation of hullers, polishers, threshers, graters, grain mills, oil presses and workshop machinery.

What is digital technology?

Digital technology is an umbrella term for computer-based products and solutions. Considering that nearly everything designed and developed these days uses computers, it is a rather generic term. Digital technology may refer to using new algorithms or applications to solve a problem even if computers were used to develop solutions in the past.

What is a digital-energy nexus solution?

A Digital-Energy Nexus Solution is a basic device or service that features a digital technology application in the energy field. Some examples include a smart-meter, a software for the design and sizing of a minigrid, a printed photovoltaic or an inverter that allows bidirectional energy transfer in a prosumer scenario.

What is a Digital-Energy business model offered by a company commercially?

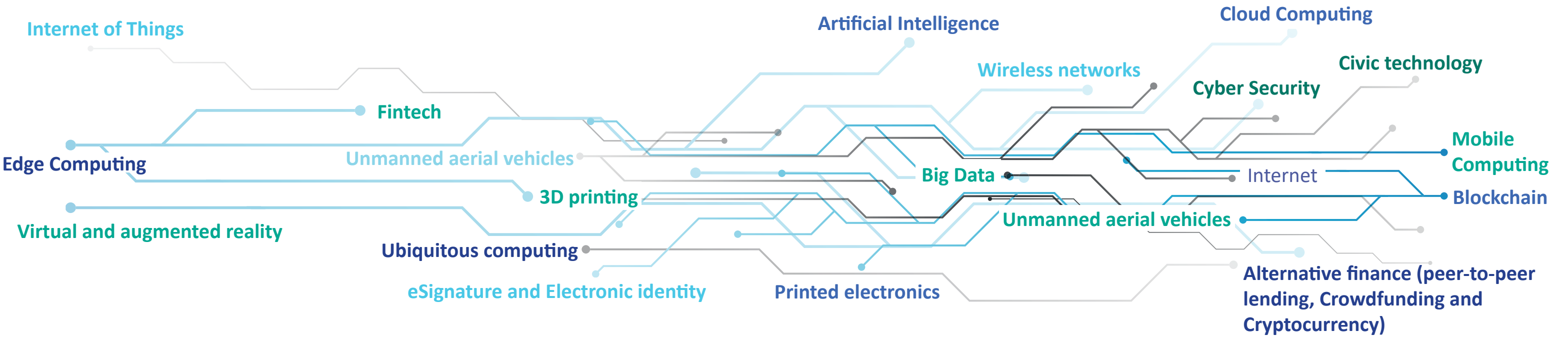
A Digital-Energy business model offered by a company commercially is the combination of basic devices or services in order to create a marketable device and/or service. An example of this would be the combination of a smart meter along with a mobile phone application and a web-based server, which allows the implementation of a pay as you go model.

What is a Digital Enabled Minigrid?

A digital minigrid is the integration of digital technological services and technologies in the process of mini-grid development and operation with the objective to:

- **reduce the cost of electricity supply (1)**
- **promote the productive use of electricity to create revenue sources than also contribute to overall affordability (2)**
- **facilitate the financing of the investment** (3)

The following Table presents the impact the various digital technologies have in the various steps of a minigrid project implementation. The above impacts are identified by the respective numbers in the table.



[2] The distinction between microgrids and minigrids has become fuzzy and it usually has more to do with definitions given in legal documents and less with actual technical differences, since in most occasions the main perquisite (ability to operate both islanded and interconnected with a main grid) as well as the ability to include distributed generation applies to both.
[3] Butare A., Kyriakarakos G., Guidelines for institutional and policy model for micro-/minigrids, 2018, EU TAF SE4All E-S

Technical Recommendations for Digital Enabled Minigrids

There are many different digital-energy nexus solutions, as well as digital-energy business models that are offered commercially. The ultimate target, though, is how to combine these most effectively in order to create a viable Digital-enabled Minigrid.

Minigrid developers have to make certain choices while designing the minigrid. Each minigrid is different and unfortunately, there is no one size fits all solution. Each developer has to investigate which product/service is more cost effective and compliant with the minigrid under design.

Some digital applications like the ones presented below are recommended to be applied to most – if not to all - minigrids

SITE DATA COLLECTION

This includes climate data, socio-economic data, local economy data and spatial planning data. Digital applications can facilitate and provide some of this data through the internet at no cost, or other software could be used to facilitate the data collection and analysis and further building of productive use activities around them.

SMART METERS INSTALLATION

This is a starting point for any type of digital applications and will need to be a prerequisite for a microgrid support applicants for the planned scheme.

DESIGN AND SIZING OF THE MINIGRID

Software for techno-economic optimization in order to properly match the demand with the design system.

INTELLIGENT ENERGY MANAGEMENT SYSTEM

Such a system will further decrease the installation cost since the production of electricity is optimised and allows more productive uses of electricity to be powered since the energy flows in the system are optimized.

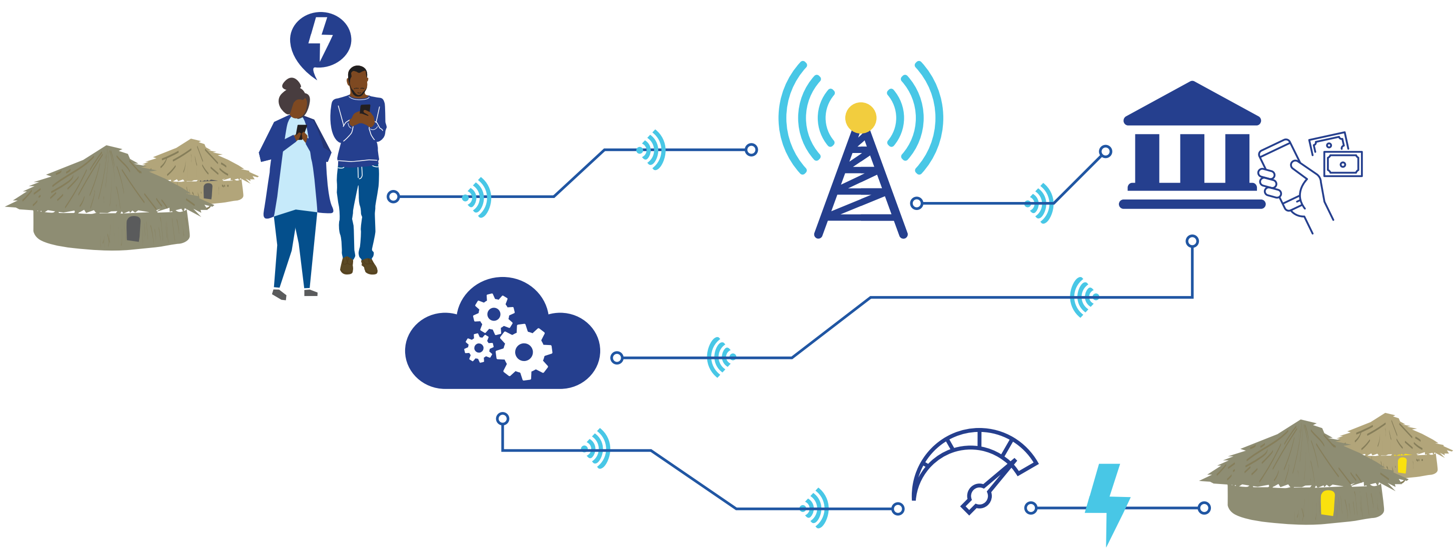
REVENUE COLLECTION SYSTEM

Depending on the model chosen, hardware and software combinations have to be chosen in order to allow pay as you go schemes, mobile payments, and setting pricing strategies commonly for all produced product/services in order to ensure economic viability, etc.

OPERATION MONITORING SYSTEM

A proper design data acquisition system facilitates proper maintenance increasing the operational lifetime of equipment, decreasing excessive wear and ensuring that no considerably high drops in efficiency are observed.

Moreover, a Pay-As-You-Go model using mobile money for minigrids is presented in the following figure.



EU Technical Assistance Facility – Sustainable Energy Initiative
Project funded by the European Union
EuropeAid/Development Cooperation Instrument
DCI-ENV/2013/335-152