Sustainable Energy Handbook

Module 5.1
Rural Electrification

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1 General Introduction

According to the International Energy Agency's Africa Energy Outlook 2014, 620 million people in Sub-Saharan Africa do not have access to electricity or remain un-electrified due to poor quality of the grid. This is nearly half of the 1.3 billion un-electrified people in the World. Overall, the electricity access rate for sub-Saharan Africa has improved from 23% in 2000 to 32% in 2012.

Nearly 80% of those lacking access to electricity across sub-Saharan Africa are in rural areas, an important distinction when considering appropriate energy access strategies and technical solutions.

In April 2012, President Barroso took the commitment in the framework of the Sustainable energy initiative (SE4ALL) to provide access to sustainable energy for an additional 500 million people in developing countries by 2030. Rural electrification is therefore a key sector of intervention for DEVCO in the energy area. The Operational handbook has been prepared to help EU staff, based in delegations or at headquarters, to follow up new sustainable energy projects as well as policies.

2 General principles

Rural electrification is the process of bringing electrical power to rural and remote areas. Electricity is used not only for lighting and household purposes, but it also allows for mechanization of farming operations, such as threshing, milking, and hoisting grain for storage. In areas facing labour shortages, this allows for greater productivity at reduced cost.

A **rural area** is a geographic area that is located outside cities and towns. The word "rural" encompasses all population, housing, and territory not included within an urban area. Whatever is not urban is considered rural. Rural areas are characterised by their remoteness and low population density as well as a high level poverty. This implies that most of the time the demand for electricity is low and the financial profitability of electricity supply services is not ensured. (Key average numbers for rural households in Sub Saharan Africa (SSA): 150-250W/household; 50-70kWh/month; 150-300$ income/month).

Rural electrification can be implemented through the 3 following options as shown in the next figure:

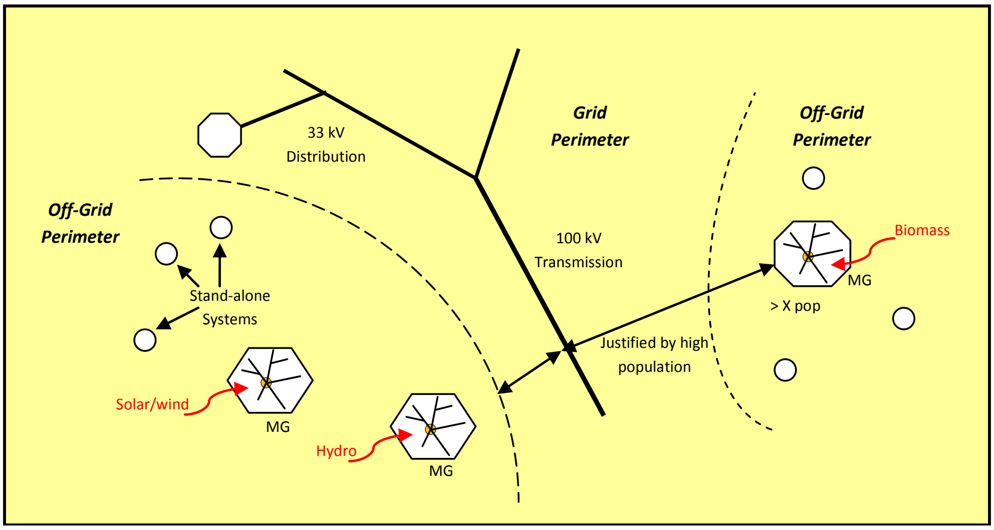

Figure 1 : Illustrative view of On-Grid and Off-Grid perimeters (DFID-IED, 2013)

On-Grid rural electrification: refers to the extension of electricity distribution to rural areas through an electricity grid. Grid connexion is the most expected solution as it is supposed to provide more power and energy to the customers at a lower price. But rural electricity connections are more costly to construct than urban connections because the customers are scattered over a wide area, access is more difficult and the consumption usually is much lower – less than 1000 kWh per year. (cf. Handbook module on-grid rural electrification).

Off-grid mini-grid: Mini-grid refers to a system where all or a portion of the produced electricity is fed into a small isolated distribution grid (LV/MV; single-/tri-phases) which provides several end-users with electricity. The off-grid[1] attribute indicates that the mini-grid is isolated from the main grid (typically more than 5-20km), supplied by independent source(s) of power (fuel- or renewables-based), and operated by national utility or any other operator. The power range for a mini-grid is from 10 kW to several MW. Off-grid interventions help population in remote areas to get on the energy ladder on a time scale that accelerates impact. (cf. Handbook module on rural electrification with mini-grid).

Off-grid isolated individual systems: A standalone individual power system is an off-grid system that supplies a single rural customer with one or several generator sources (hybrid system) and various electrical appliances. According to the power dimension, they can be grouped into four categories: portable lights (i.e. rechargeable & solar lanterns), mini kits (i.e. pico hydro & pico solar systems), Home Systems (supplied by solar SHS or pico-hydro) and Residential Systems (generally supplied by hydro, wind or solar –with diesel backup or not). Off-grid isolated individual systems are usually implemented for pre-electrification purpose (ahead of deployment of on-grid or off-grid mini-grid systems). Most individual systems in Africa are still supplied by diesel/fuel gensets. (cf. Handbook module on rural electrification with standalone systems).

[1] Off-grid mini-grid are in contrast of on-grid mini-grid where the mini-grid is connected to the main grid and is operated by a separate institution than the country's public or private utility.

3 Technology overview

The electrification strategy of a central decision maker is driven by:

- priority loads such as public institutions (schools, health centre, administrative centre, trade centre) and large population clusters outside the main cities
- least cost approach for each electrification scheme among a range of solutions including on-grid and off-grid technologies (mini-grid and solar home systems)

As a result of this strategy:

- Off-grid solutions are proposed by central planners to priority loads and neighbouring dense population clusters that are distant from the main grid (e.g. over 5-20 km)
- The electrification of populations by central planners in isolated areas that are not close to a priority load may be delayed by many years and even decades.

For those populations and communities, the only way to get access to modern energy on a reasonable time scale is to implement off-grid solutions from the market adapted to the range of affordability. Individual off-grid solutions can empower the most remote communities to get a critical first step onto the **energy ladder** with basic energy services such as lighting, mobile phone charging, fans, TV, etc. Lighting and phone charging are the beginning not the end of energy access. Once these basic needs are met, many populations are capable of expanding their energy consumption to include higher level needs like refrigeration or even agro-processing. This will bear the desired development impact considered by the sustainable energy for all initiative and permits to realistically envisage the universal access objective for 2030 that would be impossible to reach with only on-grid solutions.

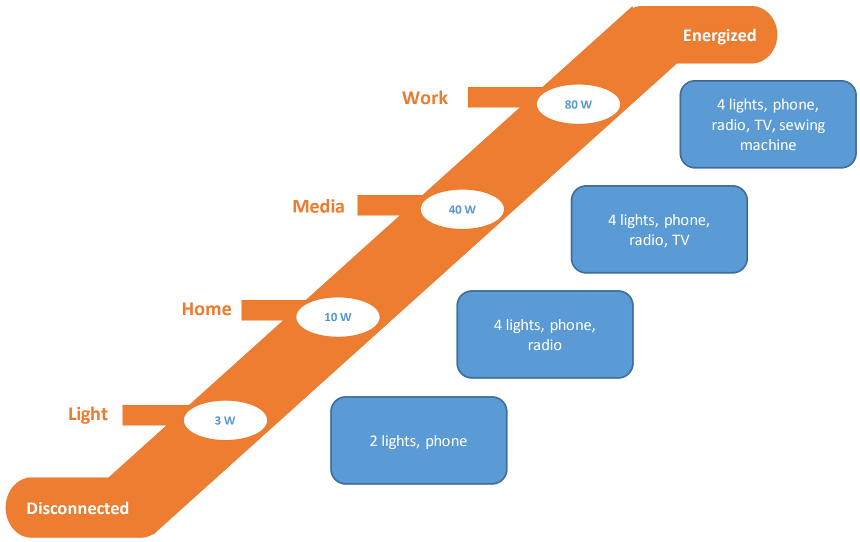

Figure 2: The energy ladder (source: Azuri Technologies)

In **non-isolated** areas (e.g. that are close to the main grid – e.g. less than 5 km) consumers with sufficient loads (above 100-300 kWh per household per year) and sufficient revenues (above 2000-3000 $ per year) can be supplied through **the extension of the grid**. Several small load centres located within the same area or along the same road shall be combined into a cluster. The cost per kWh transported and distributed, excluding generation, has to be reasonable (not exceeding 0.15USD/kWh).

In case the loads are only basic uses (lighting, mobile phone charging) with annual consumption of less than 10 kWh usually associated to low revenue (less than 100 $ per year), even with the grid being nearby, **solar lanterns** are the least cost option.

Isolated service areas (e.g. that are distant from the main grid – e.g. over 20 km) where loads are in sufficient number (over 50 customers) and are fairly close to each other (less than 100 meters) require local generation and local distribution network to avoid the high costs of extending the main grid to these areas. **Local mini-grids** supplied by hybrid power systems are the most economical solution.

In isolated services areas where loads are fairly distant of each other (e.g. over 500 meters) or are in limited number (less than 20 customers), **individual off grid** solutions avoid the high cost of deploying a local distribution network that would connect all these distant loads to a single local generator or would mutualise the use of individual generators.

The graphic below summarises the decision-making process:

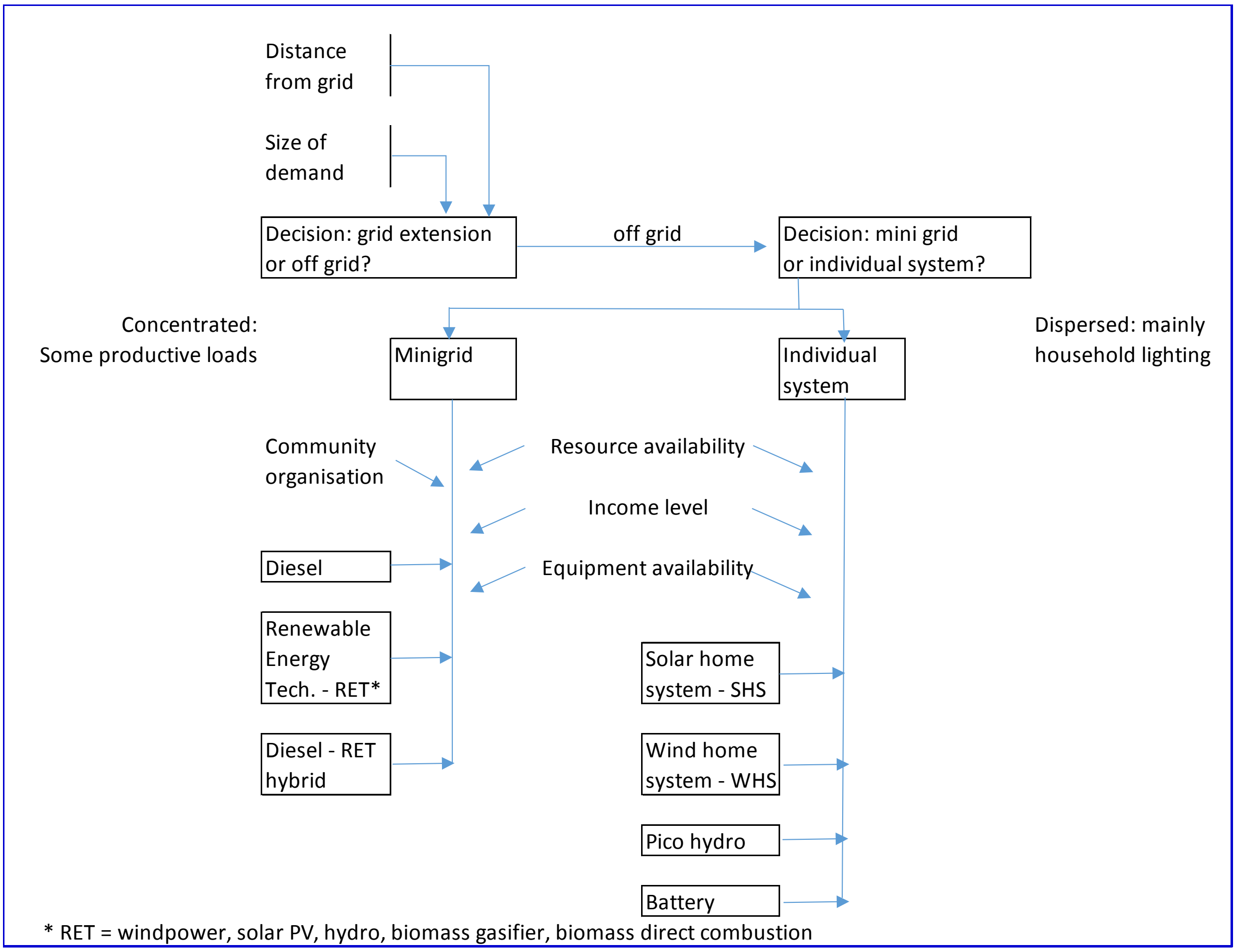

Figure 3: The decision making process (source: WB guide 2008)

4 Benchmarks

Binary definition of energy access – 'having access or 'not having access' – fails to capture important differences in quality and quantity of energy supply technologies. Moreover, it does not recognize the energy supply ladder, whereby a user's improved energy access leads to more demand for greater quantity and quality of energy. Intermediate technologies are critical steps on the pathway to reliable, available, adequate, and high-quality supply.

The SE4ALL initiative is proposing use of **multi-tier framework**, as opposed to binary definition, to track progress towards Universal Energy Access by 2030.This is grounded in the ways poor people actually experience energy access. Tiers are based on the attributes of people's energy supply, and the services they use based on that supply. Indicative frameworks for household electricity are proposed in the SE4ALL Global Tracking Framework report.

The indicative household electricity framework has six tiers: each defined by electricity supply attributes such as quantity, duration, evening availability, affordability, quality of supply, and legality of connection. A higher tier represents an electricity supply with better attributes and the possibility of access to more modern energy services, which can translate to improved well-being for users. The technologies likely to deliver these attributes range from kerosene/candles (Tier 0), through to intermediate electricity technologies such as solar lanterns that enable lighting, radio and mobile phone charging, to reliable grid supply that allows all electric applications.

The typical benchmark for rural electrification consists to compare each rural electrification approaches, i.e. on-grid connection, off grid mini grid, off grid stand alone for the broad range of uses on the energy ladder.

The table below displays the average connection cost per customer according to the broad range of use on the energy ladder.

Continuous Spectrum of improving Electricity supply Attributes

Attributes	Tier 0	Tier 1	Tier 1	Tier 1.5	Tier 2	Tier 2.5	Tier 3	Tier 3	Tier 4	Tier 5
Service Description	Kerosene lighting	Task lighting and phone charging (or radio)	Task lighting and phone charging (or radio)	4 lights, phone charging and radio	General lighting and TV or fan (if needed)	General lighting and TV and fan (if needed)	Tier 2 and any low power applicances	Tier 2 and any low power applicances	Tier 3 and any medium power applicance	Tier 3 and any high power applicances
Peak available capacity (W)	-	1	5	10	20	50	200	500	2000	2000
Duration (hours/day)	-	4	4	4	4	4	8	8	16	22
Evening supply (hours/day)	-	2	2	2	2	2	2	2	4	4
Average annual consumption per household										
Load factor		17%	17%	17%	17%	17%	18%	20%	20%	25%
annual consumption (kWh/year)		1,5	7,3	14,6	29,2	73	315	876	3504	4380
Price of electricity (US$/kWh)		5,0	4,8	4,0	4,0	3,0	1,0	0,50	0,30	0,25
annual cost (US$/year)		7,3	35	58	117	219	315	438	1051	1095
Average costs (US$/household)										
Least cost		70	110	166	288	500	1800	3200	1600	1600
Likely electricity supply technology	**None**		**Solar lanterns**		**Stand-alone home systems**			**Mini grid**	**on grid**	

Table 1: Benchmark of Electricity access solutions up the energy ladder (Source: ESMAP and TAF)

The level of revenue per customer on the energy ladder starts at round 10 US$ per year for Tier 1, increases to 100-500 $ per year for tier 2 and 3 and exceeds 1000 $ per year for tier 4 and 5.

The level of investment ranges from 70 US$ for tier 1, increases to 300-1000 US$ for tier 2, and peaks at 3000$ for Tier 3, 4 and 5.

5 Useful references

Basics on Rural Electrification and RETs

- Finance Structure and its Management for a Rural Electrification NAMA, UNDP, 2014 http://www.undp.org/content/undp/en/home/librarypage/environment-energy/mdg-carbon/finance-structure-and-its-management-for-a-rural-electrification/
- DESCO: How a New Breed of Distributed Energy Services Businesses can reach 500mm energy-poor customers within a decade, Bardouille, Persistent energy partners, 2014
- META Model for Electricity Technology Assessment, ESMAP, March 2014
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- Renewable Power Generation Costs in 2012: An Overview, IRENA, 2013 http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=277
- Sustainable energy planning: Leapfrogging the energy poverty gap in Africa, Szabó, JRC, 2013
- Lighting Africa: Market trends report, IFC-WB, 2013
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- From Gap to Opportunity: Business Models for Scaling Up Energy Access, IFC 2011
- PRODUSE - Productive use of Energy: Manual for Electrification Practitioners, EUEI-GIZ, 2011
- Maximizing the productive uses of electricity to increase the impact of rural electrification, ESMAP, 2008

Multi-tier approach for Measuring Access to energy

- A new multi-tier approach for measuring energy access, ESMAP, February 2014 http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Multi-tier%20BBL_Feb19_Final_no%20annex.pdf
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- SE4ALL knowledge hub, DrVenkatta Putti, ESMAP https://www.esmap.org/sites/esmap.org/files/06-KEF2013-SE4ALL_Putti-KnowledgeHub_ESMAP.pdf
- The 2013 Global tracking framework report, World Bank ESMAP / IEA, Chapter 2 Universal Access to Modern Energy services http://www.se4all.org/wp-content/uploads/2013/09/7-gtf_ch2.pdf