Supportive framework conditions for mini-grids employing renewable and hybrid generation in the SADC Region

Guidelines on Market Needs and Demand

December 2013

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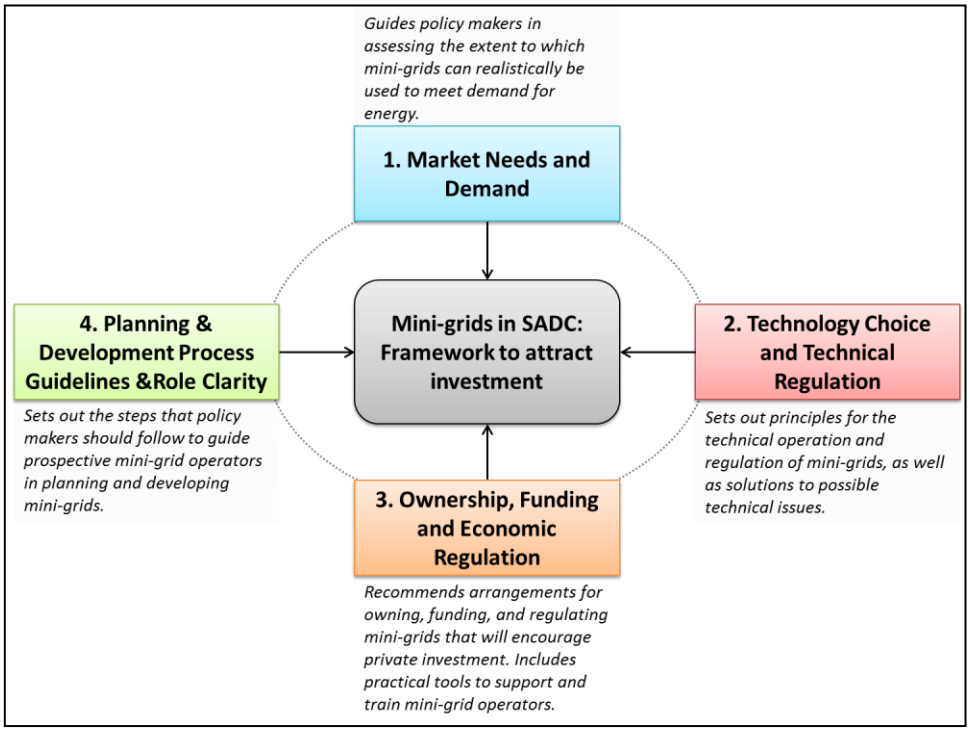
Acronyms and abbreviations

CFL	compact florescent lamp
COA	Comprehensive Options Assessment
ECA	Economic Consulting Associates
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility
EUR	Euro (currency)
EWURA	Energy & Water Utilities Regulatory Authority of Tanzania
GHG	Green House Gas
GVEP	Global Village Energy Partnership
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRSE	Institute for Electricity Sector Regulation of Angola
kVA	kilo volt-amperes
kWh	kilo watt-hour
LCOE	Levelised cost of energy
LEA	Lesotho Electricity Authority
LPG	liquefied petroleum gas
MAED	Model for Analysis of Energy Demand
MERA	Malawi Energy Regulatory Authority
MPCA	Mini-grid Project Coordinating Agency
MW	Megawatt
NGO	Non-governmental organisation
NRECA	National Rural Electric Cooperative Association, USA
O&M	operations and maintenance
PA	Practical Action
PPP	Public Private Partnership
PRODUSE	Productive Use of Energy
PV	photovoltaic
REASAP	Regional Energy Access Strategy and Action Plan
REF	Rural Electrification or Energy Funds
RERA	Regional Electricity Regulators Association of Southern Africa
SADC	Southern Africa Development Community
SE4ALL	Sustainable Energy for All
SHP	small hydro power
SPP	small power project
SPPA	Standardised PPA
SWH	Solar Water Heater
UAF	Universal Access Fund

Executive Summary

The supportive framework conditions for mini-grids employing renewable and hybrid generation in the SADC region address four focus areas as summarised in the figure below:



The instruments in this volume address the first focus area – Market Needs and Demand – which is the foundation for planning and developing mini-grids. Energy needs are universal but the ability and willingness to pay (demand) is limited, especially in remote and low income communities which constitute the bulk of the population without access to modern energy services.

Research to establish a thorough understanding of market needs and demand is done at national and project level.

The key actions at national level are:

- National energy surveys to create databases of energy services for different end uses, customer categories, income and geographical locations – households, social & administrative institutions and business instituions.
- Definition of criteria for determining affordability and locations that are zoned for grid and off-grid solutions. Criteria include income (existing or potential), grid proximity, population and geographical equity.

- Prioritisation of rural locations for phased development towards universal access. This prioritisation helps to target subsidies and income generating projects which can create the anchor loads for energy service providers.

- Development of grid and off-grid electrification masterplans

The development of a universal access strategy and masterplans helps to create stakeholder consensus on:

- Definition of energy access and access targets, that is the time horizon for achieving universal access for different end uses.

- The role of the three basic energy supply options in fulfilling market needs and demand, namely standalone devices, main-grids and mini-grids. A comprehensive assessment of options ensures that only those mini-grids that are the optimum solution for market needs are implemented.

- The selection and ranking of locations for use of the different options. For remote and low income communities mini-grids are best used where there are existing or potential prospects for productive use of electricity.

These national level actions help project developers to identify the best locations where detailed needs and demand assessments can be made for mini-grid development. The project level assessments are focussed on guiding the sizing and design of the energy source and distribution network.

1 Introduction

The purpose of this volume is to provide guidelines for the assessment of energy needs and demand that can be fulfilled using mini-grids. ***An understanding of the energy market is the key determinant of success for mini-grid projects.*** This guide will help policy makers to decide the principles for access to mini-grids and criteria for prioritisation of grid and off-grid options in SADC member countries. The guide will also help regulators in assessing the quality of the market studies in feasibility studies presented for registration, licensing or other regulatory compliance requirements.

1.1 Electrification strategies

There are three basic strategies for electrification:

- ***Main Grid extension***: centralised power stations with a transmission and distribution network to deliver electricity to end users
- ***Mini-grids***: small scale distribution networks supplied by small power projects or purchasing power in bulk from the main grid
- ***Standalone devices***: for provision of light, thermal energy or power for individual tasks or end users. Solar home systems, solar lanterns and kits are examples of such devices.

The main grid is most suitable for financially viable productive end uses and for densely populated urban and rural centres. For remote and low income communities isolated mini-grids or standalone devices offer a more competitive alternative to main- grid extension.

The objective of undertaking research to establish market needs and demand is to identify the most appropriate option for electrification. Based on an assessment of the amount of money spent by poor households earning less than US$2 per day, a study undertaken for the International Finance Corporation (IFC)[1] estimated that standalone devices would constitute the bulk of the market (84%) for electricity and other modern energy services if policies and regulations are put in place to re-direct the money currently spent on traditional energy services for lighting and cooking. Mini-grids would be able to supply 11% of the market while grid extension would only be viable for 5% of the market. The percentages are relatively low because only households and institutions with above average incomes can afford mini-grid and main grid electricity. Although there are many simplifying assumptions behind these estimates they illustrate the importance of a thorough understanding of market needs and demand in guiding policy makers to determine the extent to which mini-grids can realistically be used to fulfil demand.

[1] IFC (2012), *From Gap to opportunity: Business Models for Scaling Up Energy Access*

2 Regional principles for access to mini-grids

The regional principles are the key success factors for mini-grids as determined from international best practice and these are:

- Ensuring that mini-grids are used within the context of a vision for universal access and are used where they provide a more competitive solution to meet market needs and demand than main-grid and standalone devices
- Using the least cost technology for the energy source and this includes the use of the main-grid as an energy source or sink rather than as a competitor
- Establishing a sustainable funding and operational model that is based on customer empowerment and smart non-recurring subsidies and continuous capacity building for the technical and administrative skills needed

2.1 Alignment of national electrification targets to regional and international access targets

As a general principle access to mini-grids using renewable and hybrid generation is designed to contribute towards the region's strategy to increase access in an environmentally and economically sustainable way. The role of mini-grids is much more easily appreciated within the context of a program for achieving universal access. The first step is for countries to align their national goals to the regional and international goals that most of them have formally adopted.

2.1.1 Regional goals

The Regional Energy Access Strategy and Action Plan (REASAP) adopted by the SADC Energy Ministers in 2010 specify the following goals:

- The **strategic goal** of the SADC Regional Energy Access Strategy and Action Plan is to *'harness regional energy resources to ensure, through national and regional action, that all people of the SADC Region have access to adequate, reliable, least-cost, environmentally sustainable energy services'.*
- The **operational goal** is to **'***endeavour to halve the proportion of people without such access within 10 years for each end use and halve again in successive 5 year periods until there is universal access for all end uses'.*

2.1.2 International goals

In May 2013 the SADC Energy Ministers directed the SADC Secretariat to ensure that the REASAP is aligned to the United Nations Sustainable Energy for All (SE4ALL) initiative that aims to achieve the following objectives by 2030:

- **Universal access to modern energy services.**
- **Doubling the rate of improvement in energy efficiency.**
- **Doubling the share of renewable energy in the global energy mix.**

2.2 Public private partnership

Mini-grids shall be financed, developed, operated and maintained by public, private and community owned enterprises or a hybrid or combination of such enterprises. The bulk of project funding is expected to be provided by communities and the private sector. **The focus of public sector funding shall be to create the enabling environment that attracts private sector funding**.

2.3 Role clarity

The public sector shall provide guidelines to facilitate a transparent and efficient regulatory process involving both electricity and non-electricity sector agencies. The objective is to provide quality products and services while minimising project development time and costs.

2.4 Market needs and demand

An understanding of the energy needs of target beneficiaries and their ability and willingness to pay is the basis for the design of sustainable projects. Needs are universal, but demand (ability and willingness to pay) is limited. Productive uses of electricity and appropriately targeted subsidies are the principal options for enhancing demand. Tariffs shall be designed to match the ability and willingness to pay of different tariff categories and can incorporate cross-subsidisation as necessary to achieve market competitiveness.

2.5 Technology choice must be driven by the market

Technology choice is determined by investors responding to market needs and demand as well as government incentives and support for selected technologies such as renewable energy. The use of the main grid to support mini-grid development is particularly important as it is likely to create the most viable mini-grids in SADC. Main-grid utilities and rural electrification agencies should provide

sufficient main-grid capacity on transmission and medium voltage systems to support bulk-supply sales to mini-grids. The localisation of technology within the project area, country and region is critical for project life cycle sustainability. Technology comprises equipment, expertise and experts.

2.6 Funding

Project cashflows are the key determinant of funding success. Sustainable cashflows require clear accountability for adequate and optimum financing, design, construction, operation and maintenance of the projects. **Cost-reflective but competitive pricing** can be achieved if developers are empowered to charge tariffs that cover all reasonably incurred investment, operation and maintenance costs including depreciation and a return on capital. The return is defined from time to time by the regulator and reflects the risks. Subsidies, where necessary, will be provided for those projects where people can afford to pay for the on-going costs.

3 Establishing market needs and demand for mini-grids

The principles outlined above provide the basis for establishing market need and demand for mini-grids in accordance with the following steps:

3.1 National energy surveys

The Ministry responsible for energy, in partnership with the national electrification and census agencies, needs to carry out and publish periodic energy surveys that collect the following information:

1) Number, size, incomes and geographic location of households, administrative and social institutions (principally educational and health centres) and businesses.

2) The sources and capital cost of acquiring energy services e.g. electricity connection charges and wiring costs, appliances used and costs, etc. Appendix A1 provides a checklist for typical energy services. This checklist can be used to design survey forms.

3) The operational (monthly or annual) cost of energy paid by the consumer for different end uses. This is important information for determining the ability and willingness to pay.

4) The percentage of income spent on energy services classified by geographic location (rural and urban) as well as proximity to the national grid.

3.2 Policy options for influencing mini-grid demand

The Ministry responsible for energy must make a policy decision on the definition of affordability, for example as a percentage of income spent on an on-going basis. The Ministry can then adopt the following options depending on affordability and desired rate of access to modern energy services:

1) Subsidies are provided only for capital costs for electricity where the people are able to pay for the on-going costs including depreciation or there is potential for income generating activities that will empower the target beneficiaries to pay[2]. This will allow replacement of the system to avoid perpetual subsidy trap which is unsustainable.

2) For geographic locations within a defined distance from the main-grid, the capital cost subsidy is that required for grid extension and connection.

[2] EUEI PDF (2011), *Productive Use of Energy – PRODUSE, A Manual for Electrification Practitioners*. www.euei-pdf.org

3) For geographic locations beyond the defined distance the capital cost subsidy is that required for initial investment of off-grid mini-grids (including the power supply) and customer connection charges.

3.3 Classification of rural locations for grid and off-grid options

Appendix A2 provides details of a selection and ranking system.

3.4 Development of the rural energy and electrification masterplans

Mini-grid developers need to know the planned development of the main-grid in order to decide on the technology for energy supply for their selected project location. The Ministry of Energy assisted by the national electrification agency needs to develop an indicative grid and off-grid rural electrification masterplan. Appendix A3 describes how the masterplans are developed.

3.5 Project level needs and demand assessment

Project developers can undertake or fund energy surveys within the project area. A good guide for assessment of electrification needs at project level is the US National Rural Electric Cooperative Association (NRECA) ***Guides for Electric Cooperative Development and Rural Electrification***[3] (see Box 1).

Box 1 NRECA Guidelines for Assessment of needs and demand

The demographic study establishes the market conditions for the project, defines the number and type of beneficiaries and identifies uses of the to-be-constructed electric system. The analyst carries out field surveys to compile the necessary information. Among the most significant information obtained is data regarding the project beneficiaries' capacity and willingness to pay. This information determines the project beneficiaries' relative economic activities and levels, which indicates whether or not they can afford the tariffs set by the electric service company. In addition the data enable the analyst to calculate the quantity and percentage of consumers who may connect to the electric distribution system in the first year of operation and in subsequent years thereafter.

Source: Module 5 of NRECA's Technical Assistance Guides: www.nrecainternational.coop

The regulator must check to ensure that the survey has been done and the information used to determine the following parameters:

[3] NRECA International: www.nrecainternational.coop

3.5.1 Demand forecast for determining energy supply size

The baseline assessment of energy demand provides an indication of the first year demand or penetration rate (percentage of customers connected to total potential connections). The baseline must also establish the share of electricity in the energy mix. The assessment of demand for subsequent years will depend on:

- ❑ Projected increase in number of customers due to population growth,
- ❑ Increase in per capita consumption (as electricity increases share in the energy mix), and
- ❑ Impact of subsidies and productive use applications.

Distribution loss reduction and other energy efficiency measures are also taken into account in determining forecasts.

Similar areas that are already electrified provide historical growth data that is useful for making projections on a new area. For this reason it is important for policy makers and regulators to develop and maintain a database on consumption patterns from all registered and licensed suppliers.

3.5.2 Demand forecast for determining network size

The aggregated demand is useful for sizing the energy source and the type of energy technology to match the demand. The sizing of the network requires the demand to be disaggregated according to the spatial distribution of the customers. The following parameters computed from existing electrified areas with similar demographics are important for the disaggregation:

1) **Diversity factor (ratio of the sum of individual maximum demands (measured in kW) to the simultaneous maximum demand):** Due to diversity in time of peak use, the diversity factor is equal to or greater than 1 because the sum of the individual maximum demands for the different customers is invariably equal to or higher than the simultaneous maximum demand that a generator or transformer will need to carry. Knowledge of the diversity factors for different customer categories helps to avoid over investment.

2) **Demand factor (ratio of peak demand to the total connected load):** this factor helps to estimate the load that a feeder with known connected loads will carry.

3) **Load factor (ratio of the average demand over a period of time to peak demand over the same period):** knowledge of the average load and peak load helps to introduce appropriate measures to save costs by reducing the peak demand in order to improve load factor.

A1 Checklist for energy services

The most basic energy services are for lighting, thermal and power applications. The following table helps to illustrate these different energy services and the needs they fulfil in households, social and administrative institutions (such as schools, clinics and government offices) and business institutions (that produce and trade goods and services).

Table 1 Checklist for Assessment of Energy Needs

Basic Energy Service		Household	Social and Administrative Services	Economic Production
Light		Task and Internal lighting	Internal lighting	Internal lighting
		Security lighting	Security lighting	Security lighting
			Public lighting	Public lighting
Thermal Applications		Cooking	Cooking	Cooking
		Water heating	Water heating	Water heating
		Space heating	Space heating	Space heating
		Drying	Drying	Drying
		Refrigeration	Refrigeration	Refrigeration
		Air-conditioning	Air-conditioning	Air-conditioning
				Smelting
Power	**Static**	Media access & entertainment	Media access & entertainment	Media access & entertainment
		Communication	Communication	Communication
			Information processing	Information processing
			Electric & electronic equipment	Electric and electronic equipment
			Electric processes e.g. electrolysis	Electric processes
	Motive	Transport	Transport	Transport
		Machinery drives	Machinery drives	Machinery drives

The above classification is similar to that used in the popularly used International Atomic Energy Agency (IAEA) Model for Analysis of Energy Demand (MAED)[4]

[4] IAEA, 2006: Model for Analysis of Energy Demand (MAED-2) (www-pub.iaea.org/MTCD/publications/PDF/CMS-18_web.pdf).

which defines four energy consumption sectors – Industry, Transportation, Services and Households. Industry is a term used to include all economic productive activities such as agriculture, mining, manufacturing and construction. For mini-grids, the small scale distribution networks used are not likely to have transportation as a major consumption category.

Pre-electrification traditional energy services for lighting will include candles, kerosene lamps, and batteries. Batteries, and to a lesser extent, small diesel and petrol generators are also the main source of power for media access and entertainment. Firewood, kerosene and charcoal are the predominant traditional energy source for cooking, water and space heating. Natural sunshine is used for drying. Rural businesses use kerosene, petrol and diesel engines for limited lighting, refrigeration, pumping and grinding operations. Motive power is also provided by animal and human labour.

It is necessary to quantify and publicise the costs for the traditional services in order to raise awareness of the value of converting to modern energy services. This provides the correct reference for determining the reasonableness of mini-grid tariffs instead of the national uniform tariffs charged by the national utilities. It should be noted that mini-grids do not replace all these services and therefore only the cost of services displaced by mini-grids are relevant for comparison.

A2 Criteria for selection and prioritisation of rural and off-grid locations

The prioritisation of off-grid options depends on the selection and ranking criteria for rural locations. Selection should principally be determined by the following parameters, in order of importance:

A2.1 Existing or potential income generating capacity

Highest priority is given to those locations where the majority of the people are already able and willing to pay for modern energy services based on the proportion of income being spent on existing energy services. This applies to locations where people have significant incomes such as social (schools and hospitals) and administrative centres, rural service centres and irrigation schemes.

The next priority is for locations with potential for increased economic productivity as soon as electricity is made available. These are locations where integrated energy and economic planning is required so that there is concurrent development of the energy services and the productive applications.

Promotion of productive uses: Mini-grid viability can be enhanced significantly through anchor customers engaged in production of goods and services. For rural areas the most common productive uses of electricity are telecommunication base stations, lighting for extended operating hours, refrigeration, water pumping, corn grinding, welding and other workshop machinery and tools. It should be noted that productive uses do not arise spontaneously but need active promotion[5]. It is necessary to have integrated economic and energy planning, which can be undertaken by the electrification agency in consultation with the target beneficiaries and relevant stakeholders such as ministries of agriculture, industry and commerce, small and medium enterprises and community based non-governmental organisations.

A2.2 Distance from the main grid

The basic decision regarding main-grid extension or off-grid solutions is determined by distance from existing and proposed main-grid and level of demand. Four scenarios arise from these considerations:

- **Scenario 1 - High income near main grid**: this group is able to pay full-cost recovery tariffs that cover main-grid extension costs as well as operation and maintenance and may also be able to cross-subsidise lifeline tariffs for low income customers.

[5] EUEI-PDF, 2011: *Productive Use of Energy – PRODUSE – A Manual for Electrification Practitioners (www.euei-pdf.org)* provides useful recommendations for promotion of productive uses of mini-grids.

- **Scenario 2 - High income far from main grid**: subject to subsidies for access using main-grid extension or off-grid options based on least-cost analysis, this group can pay for operation and maintenance as well as asset replacement. This group may be able to cross-subsidise lifeline tariffs for low income customers.

- **Scenario 3 - Low income near main grid**: subject to subsidies for main-grid extension and connection costs to increase economic productivity, this group can pay lifeline tariffs cross-subsidised by high income customers. Grid-connected mini-grids can be used to increase access.

- **Scenario 4 - Low income far from main grid**: subject to subsidies for off-grid energy services designed to increase economic productivity, these are able to pay lifeline tariffs cross-subsidised by high income customers

The exact distances that constitute "far" or "near" and the income levels that are "high" or "low" are established on a country to country basis. Mini-grids are primarily focussed on the high and low income communities that are located at distances where it is not financially viable to extend the main grid (Scenarios 2 and 4). Grid-connected mini-grids can be used for scenarios 1 and 3 to improve utilisation of the existing grid. The design of mini-grids must allow the possibility of both island and parallel operation with the main grid and this means incorporating storage to provide supply to essential services when the main grid is disconnected.

A2.3 Population density

Priority is given to locations with high population density where the number of customers served per kilometre of line is relatively high and therefore the cost per customer is lower. These locations can then generate the income through taxes and levies that can be used to subsidise access for more sparsely populated areas.

A2.4 Geographic equity

Due to the fact that the locations that satisfy the above criteria are not necessarily evenly distributed in a given country, province or district it is necessary to adjust the order of development to ensure that at least one project per geographic region is selected for implementation during a defined project implementation cycle. Geographic equity is necessary for balanced national development where the richer areas of the country subsidise the poorer.

A2.5 Examples of application of ranking system

The Namibia off-grid masterplan provides an example of how the prioritisation system for selecting grid and off-grid options is applied in practice.

The ranking system used generally reflects the above criteria. Predictably the highest scores are for administrative, health and education centres where there are employees who receive regular salaries and where there are government subsidies or

fee based services that generate the cash for payment of electricity bills. Grid connections are recommended for centres within 5 km and off-grid solutions apply for areas beyond. Centres with more people score higher. Although not shown in the table the report highlights geographic equity by ensuring that there is at least one project in each administrative region.

Table 2 Namibia: Grid and Off-grid locality ranking scores

Facility/Point score		Grid	Off-Grid
Constituency capital		80	80
Health Facilities	Hospital	80	80
	Health Centre	60	60
	Clinic	40	40
	Outreach point	20	20
Schools	Senior secondary school: Year (11-12)	60	60
	Junior secondary school: Year (8-10)	55	55
	Combined school (prim & sec)	50	50
	Senior primary school: Year (5-7)	40	40
	Junior primary school: Year (1-4)	30	30
	Hostel	60	60
Other Infrastructures	Agricultural development centres	60	60
	Agricultural extension office	20	20
	Per borehole	5	5
	NamPost	15	15
	Per household to be connected	1	1
	Informal settlements	10	10
Proximity to existing power lines	Village to power line (0 to <=1km)	30	0
	Village to power line (>1 to <=5km)	20	10
	Village to power line (>5 to <=10km)	10	20
	Village to power line (>10km)	0	30

Source: Namibia January 2007: Off-grid Energisation Masterplan

A3 Rural energy and electrification masterplans

Electrification of a country involves a combination of grid-extension and off-grid options which can be coordinated through Rural Energy and Electrification Masterplans. The masterplans are best developed on the basis of the planning horizon required to achieve universal access. Several countries including Namibia, Tanzania and Zambia have rural electrification masterplans but which are not focussed on achieving universal access.

The basic principle behind development of a masterplan is the recognition that the electrification of a country requires phased development which integrates economic and energy planning. Grid and off-grid solutions are also complimentary. As the number of off-grid consumers and their per capita consumption increases it becomes cost-effective to integrate the off-grid communities into a regional and then national grid. Extremely isolated communities will continue to depend on mini-grids. Such communities need to have mini-grids that provide the same quality of service as the main-grid.

A3.1 Grid masterplan

Consistent with the REASAP strategic and operational goals, and the SE4ALL objectives, the national grid masterplan is a vision of the network required to achieve universal access by 2030. The order of development towards this target network is dictated by the selection and ranking of rural locations described in Appendix A2. The terms of reference for the grid masterplan must include the following:

- Market study to establish current and projected demand and prioritisation of rural locations, validated through a stakeholder workshop
- Development of a medium and high voltage level grid network to interconnect the rural locations in accordance with the order of prioritisation
- Least-cost analysis is used to identify an indicative preferred development plan. However in an environment in which there are multiple project developers the actual order of development will be dictated by market forces.

A3.2 Off-grid masterplan

Once the grid masterplan has been developed a policy decision has to be made regarding the time horizon that demarcates grid and off-grid. Time is a better factor than grid proximity because it is not unusual for potential customers to remain unserved for decades while located under a power line. Planning cycles differ between countries and therefore it is sufficient to indicate that there should be three time horizons covering the short, medium and long term according to the number of years assigned to these terms by the country:

- Areas that will have the grid extended in the short term will be electrified through main-grid extension and grid-connected mini-grids.
- Areas that will have the grid extended in the long-term will be electrified through off-grid mini-grids employing renewable and hybrid generation. These are the areas where mini-grid developers will expect to have no competition from the main grid for a long time.
- Areas that will have the grid extended in the medium term will have the option of grid or off-grid solutions depending on the proximity of the time planned to either the short term or long term respectively.

The grid and off-grid master plans need to be reviewed periodically to take account of unforeseen changes in circumstances. For example the grid may be extended to an off-grid area earlier than anticipated if a major investment takes place that can justify grid extension. It is therefore necessary that the agency responsible for planning should have the necessary skills to review and update the master plans. If the skills are not there then the terms of reference of the first masterplan must incorporate the necessary capacity building.

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