Regional Electricity Regulators Association of Southern Africa

euei pdf
energy for development

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

Guidelines on Technology Choice and Technical Regulation

December 2013

RECP
Africa-EU Renewable Energy Cooperation Programme

This study has been elaborated on behalf of the Regional Electricity Regulators' Association of Southern Africa (RERA) to establish a framework for attracting increased investment in mini-grids employing renewable and hybrid generation in the countries of the Southern African Development Community (SADC). This project has been financed under the Africa-EU Renewable Energy Cooperation Programme (RECP, www.africa-eu-renewables.org), an integral part of the Africa-EU Energy Partnership (AEEP).

Supported by:
European Union Energy Initiative
Partnership Dialogue Facility (EUEI PDF)
c/o Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ)
P.O. Box 5180
65726 Eschborn, Germany
E info@euei-pdf.org
I www.euei-pdf.org

Authors:
Economic Consulting Associates www.eca-uk.com
and Practical Action (Southern Africa) http://practicalaction.org/southern-africa

With comments and contributions by:
RERA Secretariat, RERA Workshop Participants, EUEI PDF

Date of Publication:
31 December 2013

Contents

Tables and boxes

Tables

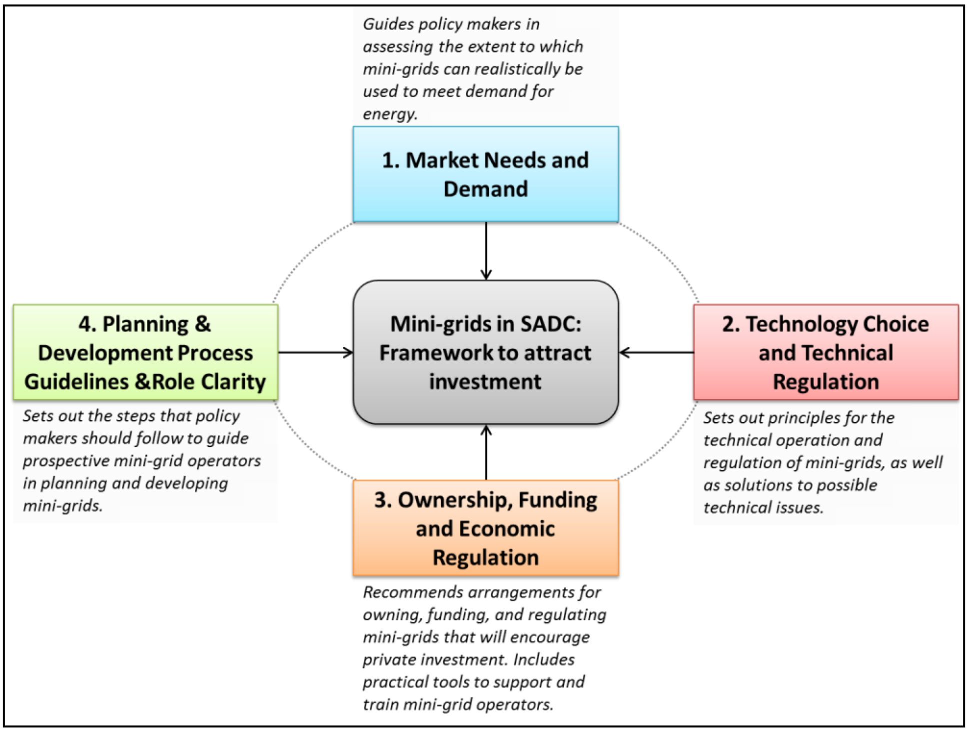
Boxes

Acronyms and abbreviations

BOT	Build Operate and Transfer
COA	Comprehensive Options Assessment
CSP	Concentrating Solar Power
EU	European Union
EUEI PDF	European Union Energy Initiative Partnership Dialogue Facility
IRENA	International Renewable Energy Agency
LCOE	Levelised cost of energy
NRECA	National Rural Electric Cooperative Association, USA
O&M	operations and maintenance
PA	Practical Action
PV	photovoltaic
PVPS	Photovoltaic Power Systems
REASAP	Regional Energy Access Strategy and Action Plan
RECP	Africa-EU Renewable Energy Cooperation Programme
RERA	Regional Electricity Regulators Association of Southern Africa
RRA	Renewable Readiness Assessment
SADC	Southern Africa Development Community
SAPP	Southern African Power Pool
SCADA	Supervisory Control and Data Acquisition
SHP	small hydro power
SPP	small power project
SWH	Solar Water Heater

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:



Guides policy makers in assessing the extent to which mini-grids can realistically be used to meet demand for energy.

1. Market Needs and Demand

Mini-grids in SADC: Framework to attract investment

2. Technology Choice and Technical Regulation

Sets out principles for the technical operation and regulation of mini-grids, as well as solutions to possible technical issues.

3. Ownership, Funding and Economic Regulation

Recommends arrangements for owning, funding, and regulating mini-grids that will encourage private investment. Includes practical tools to support and train mini-grid operators.

4. Planning & Development Process Guidelines &Role Clarity

Sets out the steps that policy makers should follow to guide prospective mini-grid operators in planning and developing mini-grids.

The instruments in this volume address the second focus area – Technology Choice and Technical Regulation. This sets out the principles for the technical design, operation and regulation which mini-grids must comply with. The guidelines outline national and project level actions that need to be undertaken.

The overriding principle for technology choice and technical regulation for sustainable mini-grids is fulfilment of market needs and demand. That is why the establishment of market needs and demand takes precedence. It is also the reason why it is necessary to undertake a comprehensive assessment of technology options including demand side and energy efficiency. A case study on comprehensive assessment of technologies is presented for guidance.

The objective of national level actions is to influence technology choice towards renewable energy and safe, reliable, secure and efficient supply and utilisation of energy. This is an exercise in removal of barriers to renewable energy development through such measures as

- ❑ Renewable energy policy, targets and incentives
- ❑ Renewable energy resource assessments

- Localisation of technology - local manufacture of equipment, local development and adaptation of expertise and retention of experts – at regional, country and project levels as appropriate

At project level technical regulations must focus on development of safety and appropriate product and service quality standards to ensure value for money for mini-grid customers. They should also provide for operational flexibility to allow parallel and island operation between the mini-grid and main-grid.

Key technical issues and possible solutions that can be adopted:

- **Variability and uncertainty of output of renewable energy technologies**: requires energy storage, back up from fossil fuel generators, main-grid connection or demand response using smart grid technologies. Comprehensive assessment of technologies is required to arrive at the least cost option.

- **Distribution network limitations against low customer density and incomes**: voltage constraints limits the distance of the distribution network from the energy source which requires the mini-grid to focus on densely populated part of the community influence the settlement pattern by having a designated growth centre with planned residential and business stands. Costs can also be reduced through phased development (for example starting with a single phase network that is upgraded to a three phase as load grows), use of simplified wiring techniques, and using standard equipment.

- **Balancing supply and demand reflected by stable voltages and frequency and low harmonics:** mini-grid should be designed for flexible operation in island or parallel mode; control can be automated through smart grid technologies; main-grid operator can assist with grid interface issues and the training and certification of skilled operation and maintenance personnel.

- **Efficiency of customer management system:** metering, billing and revenue collection are critical but can now be facilitated through smart and prepayment meters, mobile banking, and smart-grid technologies for automated compilation and analysis of customer service statistics.

- **Proactive preparation for main-grid interconnection:** designing the mini-grid for easy integration with the main-grid to allow for either sale of the whole or part of the business to the main grid operator or adding the grid as another supplier or customer for the mini-grid.

The guidelines include a list of the key technical features and related policy and regulatory issues for the most common renewable energy options for SADC countries.

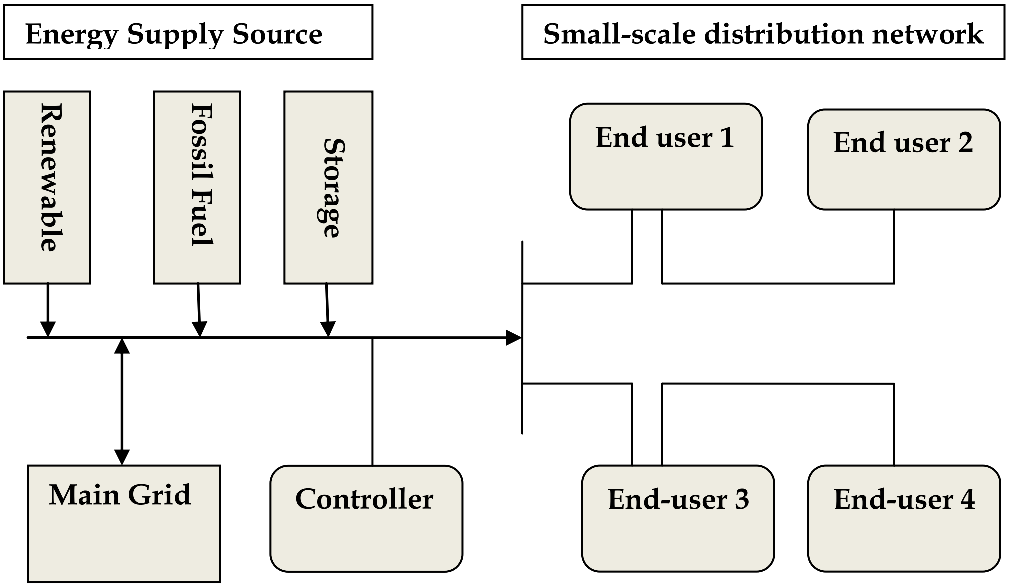
1 Introduction

This document outlines the technical operational and regulation principles for mini-grids and presents a compendium of key technical issues which mini-grid developers may face and the range of solutions which will guide local adoption.

1.1 Mini-grid definition and key technical elements

In this project, a mini-grid is defined as a small-scale distribution network supplied by a variety of energy sources including the main-grid and that can operate as an isolated system or with clearly defined physical and electrical boundaries when connected to the main grid.

This project seeks to promote mini-grids using renewable energy and hybrid generation to increase electricity access in an economically, environmentally and socially sustainable manner. Hybrid generation involves a combination of complementary supply sources for enhanced security and reliability. The following diagram provides a representation of a mini-grid using hybrid generation as well as the main grid.



Storage is required to cope with the variable and uncertain output that is characteristic of renewable energy sources. Storage is critical even for main-grid connected mini-grids if they are expected to support essential services when there is a breakdown of the main-grid. In developed countries which have achieved universal access there is increased interest in mini-grids because of this ability to provide supply to essential services such as hospitals during emergencies.

Storage is relatively expensive and is therefore usually limited to the provision of supply to the most essential services for a few hours while alternative options are being mobilised.

A control system is necessary to regulate the supply and demand of individual supply sources (for example to prevent batteries over charging or over discharging) and to coordinate the operation of the various supply sources (for example using solar during the day and diesel or batteries in the evening).

The relative cost of the mini-grid components including the energy source depend on technology. Appendix A1 provides a summary of the most commonly available renewable energy options for mini-grids in SADC. However the generation plant usually comprises at least half to two thirds of the total cost, assuming that the distribution network is restricted to a settlement with a high population density. It would not be financially viable to have a mini-grid network that extends to end users who are very far from the energy source. The excessive voltage drop on long distribution lines also provides a technical limit on the size of the network.

2 Technical operational and regulation principles

At regional and national level the key technical principles of concern to policy makers and regulators are compliance with renewable energy targets and localisation of technology. At project level the standard principles that they should require mini-grids to comply with are **safety, reliability, security, environmental and social impact, flexibility and economy**.

2.1 Market demand must determine technology choice

The most important principle for technology choice and technical regulation is the matching of supply and demand throughout the expected life of the mini-grid. Community based planning (CBP) is particularly relevant at this stage because of the need to manage the expectations of beneficiaries, especially at the preliminary stages of development of the mini-grid before scaling up as experience and resources permit. CBP is a process that helps communities to be involved in defining development interventions that are relevant to them. CBP is a tool that has been used by the non-governmental organisation, Practical Action, in technology based projects to help match the expectations of project developers and communities.[1] Mini-grids are not likely to be able to fulfil all energy needs and it is therefore necessary to ensure that the target beneficiaries understand and accept the limited services that can be provided.

2.2 Compliance with renewable energy targets

Policy makers need to influence choice of renewable energy technologies by taking explicit steps to increase awareness by project developers and financial institutions of renewable energy policy targets, resource availability and competitiveness. This is particularly important as technology improvements and cost reduction are making renewable energy technologies more competitive. Policy makers can address this through the following options:

❑ Establishing and publicising national **targets for renewable energy development** that are accompanied by fiscal and other incentives in order to influence the selection of renewable energy technologies for power generation. With the exception of South Africa, Botswana and Zimbabwe most countries in SADC already have more than 50% to 100% renewables in the generation mix. Targets can be set to maintain or increase current percentages and to increase the range of renewables beyond large hydro. Targets can also be met by importing power from renewable energy generators in other countries. For mini-grids cross

---

[1] Community Based Planning Manual 2010 (http://practicalaction.org/.../CBP_MANUAL_20May_2009). A simplified explanation of the application of CBP is illustrated in a booklet on micro-hydro at http://practicalaction.org/is-a-community-based-micro-hydro-electrification-scheme-suitable-for -your-village

border connections can provide competitive power for grid connected mini-grids along border areas.

- ❑ Undertaking **renewable energy resource assessments** as part of their renewable energy support programs. The objective of a renewable resource assessment is to provide a quantitative estimate of resources that can be economically exploited to generate electricity and other energy services. The national assessments need to map solar, wind, large and small scale hydro, bio-energy, geothermal, marine and other non-conventional renewable resources. The level of detail required must be sufficient to allow renewable energy technologies to be adequately assessed against other technologies during the comprehensive options assessment required to arrive at the optimum technology choice. The information should include hydrological records for perennial streams with hydro power potential, wind speeds and solar insolation for different geographic locations. More detailed site-specific assessments are then undertaken by project developers during project feasibility studies.

  The International Renewable Energy Agency (IRENA) has developed a publicly available renewables readiness resource assessment (RRA) methodology that can assist countries in the region to bring together all relevant stakeholders to map out issues such as renewable resource assessments that need to be addressed to increase investment in renewable energy technologies (refer to Box 1). Three countries in the region, namely Mozambique, Swaziland and Zambia, have piloted the renewables readiness assessments.

Box 1 IRENA Renewables Readiness Assessments

IRENA's Renewables Readiness Assessment (RRA) uses an inclusive approach to convene and empower the stakeholders who will help countries transition to renewable energy. RRAs foster a national dialogue among key stakeholders to identify renewable energy drivers, comparative advantages, and areas for improvement in order to plan the up-scaling of renewable energy. The RRA methodology assesses each country's overall energy market, its renewable energy potential, existing policies and institutional structures, infrastructure synergies, technology feasibility and competitiveness of local manufacturing. To date, RRAs have taken place in seven African countries: Gambia, Ghana, Mozambique, Niger, Senegal, Swaziland, and Zambia.

Source: IRENA 2012: Africa's Renewable Future. www.irena.org

- ❑ Coordinated **technology research** using national and regional institutions to reduce uncertainties for new technologies such as costs, lead times, reliability, and impact of renewable energy technology integration into the grid. Smart grid solutions are now available to manage the integration through more precise control of supply and demand response. Improvements in energy storage technologies are expected to help resolve the inherent intermittency of renewable energy technologies. Standardisation of equipment and system designs can help in skills training and in lowering costs through economies of scale for procurement or manufacturing.

2.3 Localisation

The localisation of technology – local manufacture of equipment, local development and adaptation of expertise and retention of experts – within the region, countries and project areas is critical for sustainability of minigrids. Policy makers need to address this by encouraging partnerships between local and foreign companies and universities, incorporating mini-grid technologies into industrial development policies. South Africa is ahead of other countries in the region in having an active research program to assess the localisation potential of power generation technologies in general and renewable energy in particular. This experience can be shared.

2.4 Safety

The protection of life and equipment is the minimum technical design requirement that must be enforced on all mini-grids regardless of size. Regulators must undertake assessments of the following key safety issues on a regular basis or on the occasion of a breach that results in an accident:

- Every mini-grid operator must prepare safety regulations for approval by the regulator;
- The design and operation of equipment must be under authorised personnel who have attended and passed a course of instruction in safety regulations as certified by the regulator or a more experienced undertaker such as the main-grid operator;
- All equipment used and system designs must comply with applicable national and international standards;
- Physical barriers and warning signs to energised equipment must be provided to prevent accidental or intentional entry by all non-authorised personnel;
- Protective relays and interrupting devices must be provided and maintained in working conditions as certified by regular testing procedures;
- An adequate earthing system must be installed and maintained to ensure correct operation of protective devices and for protection of equipment and personnel during maintenance work;
- Adequate lighting must be provided for normal and emergency working conditions;

- Fire risk protection;
- Workmanship and cleanliness;
- Operating manuals and documents must be developed and updated regularly and users regularly trained in the use of the documents.

The regulator must publicise the findings of the assessments. Serious penalties must be provided to ensure compliance.

2.5 Reliability

Mini-grids must provide **consistent quality of supply and service** demonstrated by:

- Voltages and frequency maintained within the statutory limits during normal and emergency operation;
- Harmonic distortion limited to permissible levels as defined in the grid or distribution code;
- Keeping to service response times publicised in a customer charter, to be developed by the mini-grid operator and approved by the regulator, which must address such service issues as new connections, fault repair, call-centre performance, handling of complaints and queries, metering, billing and cash collection;
- Timeliness of performance reporting.

2.6 Security

Mini-grids must provide continuous supply as measured by the frequency and duration of planned and unplanned outages and network availability. It is assumed that most mini-grids will be designed to supply on a 24/7 basis. Where for economic or other reasons the mini-grid is designed to provide limited supplies there must be a requirement for the operator to provide a predictable supply schedule that must be adhered to.

Measures to ensure security of supply include the following:

- Hybrid generation and storage technologies: a complimentary combination of generation technologies to deal with daily and seasonal variations. Appendix A1 outlines the key technical features of different renewable energy technologies that could typically be used as hybrid generation for mini-grids in SADC.
- Ring feeder design which allows at least two different supply routes for an end user can provide for continuity of supply during maintenance or single contingency faults;

- ❑ Physical security for strategic network locations.

2.7 Environmental and social impact

Mini-grids must comply with the minimum environmental and social responsibility standards consistent with the impact on the physical environment and host community. The national environmental management agencies specify the environmental benchmarks in consultation with the ministries responsible for energy. It is necessary to make the environmental management agencies aware of the minimal adverse impacts of mini-grids so that they are not judged by the same benchmarks and scale of fees used for large projects.

2.8 Flexibility

Mini-grids must be designed for flexibility to cope with increasing demand, changes in supply source including main-grid interconnection. The design must also be simple enough for operation and maintenance by semi-skilled personnel who are likely to be the people available in the remote locations where mini-grids are developed.

2.9 Economy

Subject to fulfilling the above requirements, the mini-grid must be designed to be the least-cost technical solution for fulfilling the market demand. Appendix A2 provides a case study of a comprehensive assessment of technologies to arrive at the least-cost solution. The comprehensive assessment takes account of supply and demand side measures, short term and long term, small scale and large scale and technical and non-technical options.

3 Compendium of key technical issues which mini-grid developers may face

The technical operation and regulation issues highlighted are relatively easy to comply with because the technologies involved are mature and there are comptent equipment and sytem designers who can develop projects to the expected standards. Nevertheless international experience shows that '***most (project) failures are not due to technical problems but to lack of a clear organisational scheme to operate the system (managing the operation and maintenance tasks and the user payments), and also to the lack of an energy management strategy which encourages the responsible use of energy where supply is limited***'[2].

3.1 Managing the operation and maintenance tasks

A mini-grid consists of four key elements - the energy supply system, the distribution network, the system operations and asset maintenance management system and the customer management system. Key technical issues and possible solutions that can be adopted for the different mini-grid elements are:

- **Energy supply system**: renewable energy sources all suffer from the problem of variable output – daily variations for solar, seasonal and annual variations for hydro and wind. Possible solutions include:
  - **Complimentary energy storage or back up from other renewable energy generators or fossil fuel generators:** main grid-connection can be a low cost supply alternative provided there are no generation constraints on the main grid;
  - **Demand response using smart grid technologies:** essentially real time two way communication tools which allow automated demand modification to suit available supply; the most common technologies include smart meters and sensors that can report faults before customers call, use of cell networks and smart phones to provide real time grid information to operators, and IT which can allow use of social media to communicate with customers on supply situation. Developed countries have demonstrated that small utilities and mini-grids are able to adopt the smart grid technologies quicker than the larger grids because of their need to closely manage supply and demand due to the much smaller reserve margins they have to work with. The investment pays for itself within a very short payback period.

Appendix A2 provides a case study of a comprehensive assessment of technologies to arrive at the least-cost solution.

---

[2] IEA PVPS Task 11, 2011: *Social, Economic and Organisational Framework for Sustainable Operation of PV Mini-grids.* www.iea-pvps.org

- **Distribution network**: must be able to deal with the twin challenge of high cost per customer and low revenue per customer due to low customer density and income levels. Possible options include:
  - **Adopting low cost but scalable design** to match initial and projected demand e.g. single phase network that is easily upgradable to three phase; it is however generally cheaper on a life cycle basis to over design than to upgrade later;
  - **Adopt simplified internal wiring approaches** e.g. using compact distribution boards which have circuit breakers with plug and light points ready to connect appliances after connecting to the main supply point.
  - **Standardisation** of network components helps to reduce costs and improve safety.
  - **Influencing community settlement patterns:** a designated growth centre with residential and business stands can be zoned for the provision of mini-grid electricity
- **System Operations and Maintenance management system**: the challenge is to balance supply and demand in a sustainable manner which is reflected in stable voltage and frequency and the safety of personnel and equipment. The mini-grid operator can consider the following options:
  - **Modelling software:** Accommodate operation as an isolated or grid-connected network and to deal with multiple supply sources that can include consumer installations. Fortunately software for modelling the integration is easily available from several sources on the internet.[3]
  - **Using smart grid technologies to manage the energy supply and network operations:** unlike the main-grid where Supervisory Control and Data Acquisition (SCADA) systems are restricted to the high voltage grid, in a mini-grid SCADA can be used at lower level voltages to automate system frequency and voltage control using supply side and demand response measures and to monitor and control the different renewable energy supply sources and network assets and to reduce network technical and commercial losses; the data accumulated helps to improve demand forecasting;
  - **Smart phones:** communication with workforce should take advantage of the latest communication technologies such as smart phones which can provide real time network information; semi-

---

[3] For example the Homer energy modelling software (www.homerenergy.com) is a popular tool that is used for analysing hybrid power systems using renewable and fossil fuel technologies

    skilled workers used at the project site can easily be backed up by remotely located skilled people.

  - **Connection to the main-grid where feasible:** the regulator needs to have net metering and energy banking as well as third party access rules defined in the appropriate network codes;

  - **Time of use tariffs**: which help consumers to modify demand by shifting from peak to off-peak; these also help customers to see value in energy efficient appliances. Productive use applications can become more profitable from reduced energy costs if undertaken during off-peak periods.

  - **Skills development:** using the main-grid operator or rural electrification agency to train and certify network operators and maintenance personnel.

- **Customer management system**: the key issues are to have efficient metering, billing and revenue collection systems as well as monitoring and controlling customer service standards as specified in the appropriate regulatory instruments. Possible solutions include:

  - **Smart or pre-payment meters** to provide customers with information that helps them to control consumption patterns and levels;

  - **Use of mobile phones and internet banking** to improve revenue collection rates for customers in remote rural locations;

  - **Automated compilation and analysis of customer service statistics** such as fault response times, waiting times for new connection, number and type of complaints, for submission to the regulator.

3.2 Main-grid interconnection

If SADC countries all aim for universal access by 2030 according to the SE4ALL and Regional Energy Access Strategy and Action Plan then many mini-grids will be interconnected to the main-grid and they must therefore be designed to accommodate this eventuality. This is the reason for flexibility in design to allow for seamless transition between islanded and parallel operation.

The key technical and commercial issues for main grid interconnection are:

- **Business model impact**: Unless the mini-grid was developed on a Build Operate and Transfer (BOT) basis where there is a pre-agreed arrangement for transfer from a private to a public sector operator, the interconnection does not necessarily mean the integration of the mini-grid business into the main grid; the mini-grid simply adds the grid as one of its principal or back up supply sources and as another customer should there be surplus power. The mini-grid must therefore be designed to be easily synchronised or disconnected from the mini-grid without interrupting supply to customers (close cooperation with the main grid utility is needed to ensure adequate safeguards against damage to life or equipment);

- **Parallel operation:** During parallel operation the main grid controls supply quality (frequency and voltage stability); this mode of operation is good for a mini-grid which also has its own generation because the main-grid absorbs the excess output or supplies the deficit during peak , low flow, sun or wind conditions.

- **Isolated from grid:** During island operation the mini-grid controls supply quality as was the case during off-grid operations. Matching the output of the generation and mini-grid demand is difficult in off-grid situations. Solutions include the use of electronic load controllers to keep a constant load output or to modulate the output of the generator to match the load. The challenge is to deal with the cost of inefficiencies of wasted energy or low load operation – the commercial arrangements must take care of this. For example if the island operation is due to planned or other interruption within the control of the main-grid operator, the main-grid must pay for the energy that could have been generated (this is achieved through a "take or pay" clause in the power exchange agreement).

Tenenbaum, Greacen, Siyambalapitiya with Knucles in Chapter 10 of their May 2013 working draft of the book, *From the Bottom Up, how Small Power Producers can deliver Electrification and Renewable Energy in Africa – An Implementation Guide for Regulators and Policymakers* suggest the following policy options for encouraging investors when mini-grid have to interconnect with the main grid:

- **The mini-grid operator can become a Small Power Distributor (SPD) option:** this is the option when the existing mini-grid energy source is decommissioned and substituted with a wholesale contract for purchase from the grid.

- **The mini-grid operator can become a Small Power Producer (SPP):** this is the option when mini-grid operator retains the energy supply source and the main-grid operator purchases and takes over the distribution network.

- **The mini-grid business is not affected**: it simply adds the main-grid as an additional supply source and customer as explained above.

- **The mini-grid sells the business to the main-grid:** this is an option similar to the BOT option given above except for the fact that the transfer occurs before the full concession period.

A1 Renewable energy options for SADC countries

The most feasible renewable generation sources for off-grid mini-grids in Southern Africa are small hydro, solar PV, solar thermal, small wind (< 100kW) and bio-energy. Hybrid systems would comprise a combination of these technologies backed up by grid- connection or diesel generation. The use of biodiesel could reduce the need for imported fuel although the current cost of production in most countries is too high compared to import of the fossil fuel diesel. Geothermal, large scale wind and marine resources such as tidal power have restricted availability and skill-requirements which limits their use for mini-grids.

Table 1 Renewable energy technologies for SADC Mini-grids

Energy supply option	Key technical features	Policy and regulatory issues for mini-grid application
All renewables	High upfront investment costs but low lifecycle or levelised cost of energy (LCOE)	o Capital subsidy or long term concessionary funding to keep tariffs close to levelised cost of energy
	Daily, seasonal or annual variability in energy production	o Hybrid and energy storage systems including main-grid back-up
		o Time of use tariffs
Small hydro power (SHP)	Run of river, no storage for annual and seasonal variations. Not easily scalable to meet increasing demand	o Extensive and publicly available hydrological records to be kept and made available to developers o On grid interconnection, maximise dispatch through take or pay power purchase agreements (PPAs), and energy banking using net metering
	Restricted locations and widely variable site-specific costs, ranging from <US$1500 to >US$8000/kW	o Technology or site specific tariffs may be more appropriate than averaged feed-in tariffs
	Mature technology; low operating costs; long life > 50 years	o Technology easy to localise - most components and civil works can be locally sourced
Solar PV	Daily variation; easily scalable to match increasing demand	o Battery storage essential – encourage local manufacture at national or regional level; provide for safe disposal of old batteries when they are changed every 5 or so years
	Sunlight is the most widely available resource in SADC; costs are not site-specific but depend on size of installation; costs now ~US$1.0 to 2.2/W	o Amenable to standardisation at national and regional level; suitable for feed-in tariffs;
	Maturing technology; low	o Limited potential for local

Energy supply option	Key technical features	Policy and regulatory issues for mini-grid application
	operating costs; long life >20 years for PV panels	manufacture; improved prospects with regional market; technical standards for panels must take account of extreme heat otherwise panel efficiency is reduced and life is shortened
Solar thermal	Daily variation; provides heat for direct use (e.g. solar water heating, SWH) or to drive steam turbines (e.g. CSP); scalable at high cost	o Promote solar water heating (SWH) by providing affordable financing options e.g. incorporating geyser costs in house loans that are services over several years.
	Extensive land use for solar collectors; CSP energy cost ranges from 14-36 USc/kWh and installation costs range from US$4600 – 10000/kW.	o Most suited to sites where there are no competing land uses; mini-grids connected to CSP plants are for the host community as CSP plant size are for supplying the main grid
	CSP is emerging technology; SWH mature technology. CSP requires more technically skilled personnel at project site for operation and maintenance	o High localisation potential as many components can locally manufactured; SWH suitable as a demand management solution for mini-grids
Small Wind (= or < 100 kW)	Hourly, daily and seasonal variation; scalable	o Works well as a hybrid with solar and/or diesel
	Site variation very extensive; noisy; extensive wind measurements needed; competitive costs of 6-14 USc/kWh and installation costs of $1800-2200/kW.	o Feed in tariffs suitable for this technology
	Emerging technology: long life > 20 years	o Research and development required; high localisation potential
Bio-energy	Solid fuels: crop processing and forest residues e.g. bagasse. Relatively high O&M costs (9-20% of LCOE) and capital cost (US$2000 -7000/kW)	o Mature technology but restricted to locations of fuel source due to transport costs
	Liquid fuels: e.g. Biodiesel which can be used to run a diesel gen-set. Feedstock availability is the main challenge. Energy can be stored as liquid fuel	o Requires strong integrated planning with feedstock (mostly non-food) producers
	Gaseous fuel e.g. Biogas. Easier and more efficient and economically viable to use the	o

Energy supply option	Key technical features	Policy and regulatory issues for mini-grid application
	gas directly for thermal energy than for power generation.	

Sources: Some costs quoted from IRENA: Renewable Power Generation Costs

A2 Case study on comprehensive assessment of technology

The Gobabeb Research hybrid mini-grid in Namibia provides a good case study that illustrates the analysis of market needs and selection of technology.[4] Gobabeb was first electrified by the Ministry of Works in 1972 using 2x50 kVA diesel generators that provided free power to the residents from 0600 to 2200 every day. However as the costs of maintaining the ageing generators continued to increase this became unsustainable and a review of the energy supply system was undertaken in 2000.

It was noted that there were both supply side and demand side inefficiencies that needed to be addressed. The diesel generators were operating inefficiently due to low capacity factors. On the demand side users were unaware of their consumption patterns as there was no metering and they did not pay for the power. It was noted that daily consumption could be reduced from 230 kWh to 135 kWh by undertaking the following measures:

- Using more efficient appliances – CFLs instead of incandescent lights, efficient refrigerators, etc
- Revenue metering and charging for the service
- User education to achieve behavioural changes – switching off lights and computers when not in use, coordinating heavy power uses through prior notice to system operator, replacing worn out refrigerator seals, etc
- Using LPG for cooking and heating.

The following table provides the summary of the energy usage before and after these demand side measures.

Table 2 Needs Assessment: Gobabeb Research hybrid mini-grid in Namibia

Section	**Diesel only period (16 hour service)**	**PV/diesel Hybrid (24 hour service)**
	kWh/day	**kWh/day**
Main station	69.0	31.7
Bungalow and old home	16.5	2.9
Staff houses	47.0	40.5
Slums	16.0	8.0
Pool, water and sewerage	8.0	8.0
Workers' houses	24.0	12.0
Training centre	3.3	2.8

---

[4] Desert Research Foundation of Namibia, 2007: *Proceedings of a symposium held at Gobabeb in 2007.*

Section	**Diesel only period (16 hour service)** **kWh/day**	**PV/diesel Hybrid (24 hour service)** **kWh/day**
Library	3.0	2.6
Offices	6.0	5.1
Reserve capacity	39.0	22.0
TOTAL	**230**	**135**

Source: Desert Research Foundation of Namibia, 2007

This thorough assessment of existing needs avoided over-investment. The technical options available at Gobabeb to meet this demand were grid extension, diesel generation, solar PV or a solar PV diesel hybrid. All options had to provide 24 hour service over a 20 year period. For the diesel option it was assumed that there would be an annual 5% escalation in the price of diesel and a 5% salvage value for the machines at the end of this period. All options were going to use LPG for cooking, escalating in price at 2% per year. Other assumptions used in the analysis were an inflation rate of 10% and real loan and discount rates of 5%.

The following table summarises the life cycle cost calculations for the different options.

Table 3 Least-cost analysis: Gobabeb Research hybrid mini-grid in Namibia

Item		**Diesel**	**Grid**	**Solar PV**	**PV/Diesel Hybrid**
		N$'000	**N$'000**	**N$'000**	**N$'000**
Initial costs	System	86	1925	2375	1200
	Upgrade	-	-	50	50
	Conversions	-	-	14	14
	TOTAL	86	1925	2439	1264
On-going costs	O&M	2773	1655	190	1189
	LPG	224	224	581	581
	TOTAL	3083	3804	3210	3034
Annual life cycle cost		**247**	**305**	**258**	**243**

Source: Desert Research Foundation of Namibia, 2007. The currency figures are year 2000 N$

The hybrid system that was installed for the new demand scenario comprised 26 kWp solar PV for day operation, 200 kWh battery bank for night operation, and the 2x50 kVA diesel generators for back-up battery charging, standby and heavy duty applications. An analysis done soon after installation indicated that the actual daily consumption averaged 112.3 plus or minus 22.8 kWh with a peak of 228.4 kWh and a low of 72.8 kWh.

EUEI PDF is an instrument of the

euei
EUROPEAN UNION ENERGY INITIATIVE
for poverty eradication and sustainable development