Integrating off-grid solutions into South Africa's electrification programme

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Content

1. EXECUTIVE SUMMARY

There are a number of barriers to mini-grids in South Africa, which have slowed its development to date.

These barriers include capacity gaps in public energy institutions in the following key areas;

- A lack of understanding about which electrification strategy is best deployed for unserved communities in the long term;
- Few successful mini-grid precedent projects from which to take learnings;
- A lack of practical tailored guidance to local government, municipalities, project developers and communities in South Africa on how mini-grids can easily be adapted for different locations, and the best ownership models and financial models to use;
- A centralised utility thinking concentrated historically on grid extension for electrification, including the policy environment and national funding streams;
- An internal skills gap and/or an inability to mobilise funding and manage project developers and the supply chain;
- Inexperience in accessing international funding for clean energy projects and feasibility studies; and
- Perceived threats to the public sector revenue model, whereby the introduction of new models, especially those moving away from local government ownership could threaten much needed revenues.

The objective of this toolkit is to address a number of these barriers, to act as a key reference document for the development of sustainable business models and operational off-grid projects in South Africa. In parallel, we hope that this toolkit will support the case for government-guided initiatives that will enable off-grid projects, vital to this being the creation of a national off-grid management authority.

In terms of energy access, South Africa is atypical for sub-Saharan Africa (SSA), with a unique set of challenges and opportunities. South Africa is an energy intensive, growing middle-income economy, with an average per capita consumption of 4,326 kWh and 84% of its total emissions from energy (as of 2012). Only 9% of South Africa's 45GW of generating capacity is renewable (86% coal). There is therefore a big potential for renewable energy to drive the move to a more sustainable energy system. Rural electrification rates are atypically high, at 77% nationally compared to an average of 17% for SSA. Expectations of grid connection and quality of service are therefore high. However, the South African National Energy Development Institute (SANEDI) estimates that this leaves in excess of three million people without electricity in rural areas.

Grid congestion, and increasing grid connection costs, is a major challenge for South Africa. Eskom, the national utility, operates South Africa's aging transmission grid infrastructure. There are serious capacity constraints on the network, with around 50% of feeders in thermal overload. Eskom has been unable to secure a sufficiently high settlement with the regulator, NERSA, to make the necessary grid upgrades to relieve all grid congestion in the country. Therefore, many potential generators and consumers are not able to connect to the grid. This includes independent power producers and key industries such as those found in South Africa's Industrial Development Zones.

Grid-tied mini-grids can be used to ease grid congestion by reducing demand loads at key points of constraint, and providing services (such as frequency response) back to the grid. 'Grid-tied' mini-grids, also called interconnected mini-grids, utilise a small electrical connection to the national electricity system. Grid-tied mini-grids provide a number of additional benefits over other connection options, including;

- the flexibility to address local needs,
- the use of local renewable energy resources and labour, and
- providing the lowest cost option in many unserved areas. Grid-tied mini-grids are cheaper per connection than both isolated systems, as the grid connection can replace some of the expensive storage needed to balance supply and demand, and main grid connection.

Mini-grids offer a number of additional community benefits over other off-grid electrification solutions. Electrification of previously unserved communities significantly affects socio-economic development, especially among lower income households. Lighting enables increased literacy and gender equality by enabling women and children to study during the evenings. Electric lighting often replaces the use of kerosene and paraffin, which is used daily by over 17-20 million households in South Africa, which can cause severe respiratory complications while exhausting a significant proportion of household income. Mini-grids can provide a much higher household energy consumption than solar home systems, however, enabling income generation opportunities through the operation of appliances such as refrigerators and battery charging stations. Mini-grids can also power water-pumps, eliminating the need for women and girls to walk for miles every day to collect water.

The majority of mini-grids will be solar-powered, grid-tied, AC (grid-compliant) systems, utilising storage. Solar is the ideal renewable resource in South Africa, with countrywide and seasonally invariant sunlight at a similar intensity as California (direct normal irradiance averaging over 7.0 kWh/m^2/day). This seasonal invariance reduces the need to rely on integration with other technologies such as diesel back-up. The systems should use before-the-meter energy storage as a shared resource, with the level of storage scaled according to the ability to use the grid connection to balance supply and demand. This model is valid for urban and peri-urban areas as well as in informal settlements.

Municipalities have a strong business case for developing mini-grids. Municipalities in South Africa have a mandate for service delivery including energy provision and electrification for populations between 75,000 and 5 million. Mini-grids ease budgetary strain for municipalities by enabling the development of local industries and create jobs, as well as poverty alleviation and sociological development. Where and when a mini-grid is ultimately connected to the grid it will be the primary provider of electricity locally. This will reduce the local demand for grid electricity, and decrease budgetary pressure on municipalities to subsidise low-income households beyond 50 kWh/household/month. This will also reduce the amount of grid infrastructure that the municipality must build to connect new customers.

Pilot projects will be required to unlock mini-grids as a mainstream energy technology in South Africa. The lack successful business models and precedents in South Africa means that key stakeholders, including investors, perceive mini-grids as high risk. There is a need to demonstrate key technical, business case and contractual aspects of mini-grid models for South Africa. Successful pilots can then unlock public financing that is currently available for other modes of electrification. Grid initiatives under the Integrated National Electrification Plan (INEP) receive almost 100% capital and operational cost subsidies, while off-grid initiatives do not. Pilots will not require a licence, and should be able to access international donor funding. This funding can include global mechanisms such as the European Union’s Electrification Financing Initiative or the Africa Enterprise Challenge Fund (if privately-led), as well as multilateral, national and international development organisations such as the International Finance Corporation, the UK’s Department for International Development and the African Development Bank.

A Public-Private Partnership business model is recommended, with municipalities driving the pilot projects and the private sector subsequently taking a more active role. Municipalities and the South African Local Government Association (SALGA) should be the driver of this model, identifying the local opportunity for mini-grid development (via Integrated Development Plans), bringing together relevant stakeholders and leading early-stage community engagement and fundraising. The private sector would conduct resource assessments, feasibility studies and deliver the pilot projects under a PPP.

Eskom and the Department of Energy will play a key role in the development and operation of mini-grids in South Africa. Historically Eskom has focused entirely on grid expansion for electrification. Recent schemes delivering solar standalone systems to remote communities were only moderately successful, with difficulties in coordination and in ensuring the quality of service provision. We believe that Eskom now sees mini-grid systems as an electrification option, given financial constraints and a congested grid, to deliver future electrification. As such, Eskom is developing a number of pilot projects. In parallel, the Department of Energy continues to guide macro-energy policy and biennially publishes its Integrated Resource Plan that provides visibility on the likely energy mix required going forwards[1]. To date, this has not explicitly considered off-grid solutions, and so it has recently started working with stakeholders in the market to understand how to tackle the 15% of households not presently electrified, and how to meet electricity demand growth fuelled by population and economic growth. A recent exercise funded by the EU has resulted in the decision to set up an Off-grid management Authority within the Department. The Department of Energy is presently reviewing regulations for small-scale and mini-grid renewable generation.

South Africa is far from alone on this journey; nearly all countries globally are looking at local energy solutions. Cost reductions, business model innovations and novel technologies are making mini-grids and other decentralised energy systems cost effective electricity solutions. Mini-grids are able to address the energy challenges of middle-income and developing countries, with isolated systems serving remote, lower-consumption communities and grid-tied systems easing national grid constraints and providing near grid-level service. Public and private-sector stakeholders worldwide have acknowledged this opportunity, and are acting to integrate mini-grids into national and regional energy frameworks. Our ambition is that South Africa is successful in proving this technology and business case, providing a strong and positive case study for other countries to follow.

Acknowledgements:

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[1] Last publication was 2011.

2. PURPOSE AND OBJECTIVES OF THE TOOLKIT

This project aims to assist the development and financing of mini-grids in South Africa. This will be achieved by determining how off-grid electricity solutions can fit in to South Africa's electrification programme (including eligibility for the electrification grant), and developing a South Africa specific business model that enables mini-grid project development. This process began by identifying the key drivers of - and stakeholders involved in - electrification in South Africa, especially of green mini-grids (using the common definition of a green mini-grid as a mini-grid integrating renewable energy for power generation), and establishing what support was needed to achieve the crucial next steps towards the development of mini-grids in South Africa.

The primary targets for this toolkit are municipalities and metros (henceforth referred to only as municipalities) who have a mandate for the provision of electricity service. The national utility Eskom, the Department of Energy and the national regulator NERSA are also major stakeholders alongside private sector developers and investors.

There are a number of barriers to municipality-driven mini-grids in South Africa, which have slowed its development to date. These include;

- A lack of understanding about which electrification strategy is best deployed for unserved communities in the long term;
- Few successful mini-grid precedent projects from which to take learnings;
- A lack of practical tailored guidance to local government, municipalities, project developers and communities in South Africa on how mini-grids can easily be adapted for different locations, and the best ownership models and financial models to use;
- A centralised utility thinking concentrated historically on grid extension for electrification, including the policy environment and national funding streams;
- An internal skills gap and/or an inability to mobilise funding and manage project developers and the supply chain;
- Inexperience in accessing international funding for clean energy projects and feasibility studies; and
- Perceived threats to the public sector revenue model

This toolkit's principal aim is to be a key reference document for the development of sustainable business models and operational off-grid projects in South Africa. This aim is split into a number of sub-objectives:

- To support the development of efficient decision processes for the type of projects to be developed
- To recommend a realistic and pragmatic pathway to demonstrate the business case and revenue model for mini-grids
- To guide project initiators' and developers' design of effective mini-grid business models, financing strategies and stakeholder and community engagement
- To illustrate learnings and best practices from mini-grids in other countries

In parallel, we hope that this toolkit will support the case for government-guided initiatives that will enable off-grid projects, crucially including the creation a national off-grid management authority, municipal capacity building, and the mapping of pilot project opportunities and identification of supply chain organisations.

3. PROGRAMME CONTEXT

3.1. MINI-GRIDS

WHAT ARE MINI-GRIDS?

Mini-grids are decentralised generation and distribution systems, built to supply a group of end-users in an unserved location. Fundamentally such a system comprises of generation assets connected to customers by a distribution network. This will also include a control system, and a converter for AC systems. Mini-grids can be built using single or multiple generation sources, with grids with more than one source known as *hybrid systems*. Hybrid systems can incorporate diesel generation and one or more renewable sources such as solar PV, hydro, wind or biomass. For grids without diesel generators, a battery storage system will typically be included to balance supply and demand and the intermittent generation patterns associated with renewable energy sources. The choice of generation sources used, the level of storage required in the system, and the overall scaling of the system with demand, has a large effect on performance and costs. Mini-grids can also be connected - or *tied*-to main grids in order to help balance supply and demand[2].

Mini-grids serve the same purpose as the main grid, to provide electricity to households and settlements, which is then used for lighting, cooking and other services such as water pumping or refrigeration. Mini-grids range in capacity from a few kW to several MW, though there is no universal definition (grids with a capacity smaller than a few kW are referred to as micro/pico-grids generally). Larger mini-grid systems can provide the same quality of service level as the main grid, but this tends to be cost prohibitive in most developing countries. Most mini-grid systems provide an intermediate quality of service level, above the basic lighting provided by solar home systems (SHSs) but below main grid quality of service levels. The appropriate service level is normally determined by the ability to pay of the connected households and business (Chapter 5).

Quality of service is defined by two features:

- The volume of electricity available for use by the customer;
- The maximum demand that a customer can draw at a particular time of day.

Both of these features are also vary seasonally according to renewable energy resource availability for renewable-only systems.

In South Africa, mini-grids are ideal for electrifying remote communities far from the main grid or communities close to the grid that cannot be connected due to capacity constraints. For remote communities, a combination of geographic isolation and low consumption makes grid extension too financially costly, as well as requiring significant planning and implementation timeframes that can leave communities un-electrified for decades. For communities close to the congested main grid, the high cost of upgrading the main grid to accommodate their connection can also be uneconomic.

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[2] Grid-tied mini-grid systems are different from just adding additional generation and/or storage to the grid, as local generation supplies customers directly through a distribution network independent of the main grid. The grid-tied mini-grids are often self-sustaining without power from the grid, with the single-point grid connection used only to deal with infrequent, larger discrepancies between supply and demand.

Mini-grids that connect to the main grid network can also be used to ease grid congestion by providing generation and other services (such as frequency response) back to the main grid. Given the extensiveness of the grid, and its highly constrained nature, this is an important application in South Africa. In order to be able to connect to the grid, the mini-grid must be built to meet South Africa's grid code, including using AC current. 'Grid-tied' mini-grids, also called interconnected mini-grids, utilise a small electrical connection to the national electricity system. Grid-tied mini-grids are potentially cheaper, as the grid connection can replace some of the expensive storage needed to balance supply and demand, also often allowing the downsizing of the generation capacity required. Grid-tied mini-grids can be used to ease demand on the grid at key points of constraint.

BENEFITS OF GREEN MINI-GRIDS

Mini-grids have significant benefits for communities, including job creation, and educational outcomes and improved gender equality. Green mini-grids have the added benefits of improved health and lower cost of energy. The level of service from mini-grids can be sufficient to enable the powering of small companies, thereby enabling the growth of productive activity and poverty alleviation. The operation of the mini-grid will also usually involve support services such as maintenance, controls and customer account management, which can offer local jobs. There are a number of other benefits such as a reduction in respiratory health issues that result from kerosene and biomass lighting[3]; increased education hours and improved safety through night-time lighting. A sufficiently sized mini-grid can also use excess capacity to drive water pumping, which can reduce the amount of time spent gathering water. This enables further educational and work opportunities for women. A large enough grid may provide further health and educational benefits, such as powering vaccine refrigeration or school computers, although the supply stability necessary with such appliances is a challenge.

Green mini-grids provide a number of benefits over other energy options, including a flexibility to address local needs and use local resources as well as providing the lowest cost option in unserved areas. Chapter 5 demonstrates that mini-grids could be the least cost option in unserved areas looking for a level of consumption above the level provided by SHSs. In particular, grid-tied, or interconnected, mini-grids can utilise the high grid penetration in South Africa (Section 3.2) to provide high quality electricity access at a much lower cost than traditional main grid connection. These interconnected mini-grids could ease capacity and connection constraints on the national grid, as well as reduce the cost of electrification for municipalities when expanding the grid.

MINI-GRIDS IN AFRICA

In Sub-Saharan Africa, around 634m people do not have access to electricity[4]. Mini-grids are likely to be the most effective method by which to access electricity for up to 40% of these people[5]. This is expected to increase to almost 650m by 2030 without a significant change in current conditions. Currently the average level of electricity access in Sub-Saharan Africa is 32%, with 59% in urban areas and 17% in rural areas[1]. Electrification is seen as a crucial vehicle for poverty alleviation, presenting widespread social benefits (increased literacy and gender equality opportunities, reduced respiratory issues from reduced kerosene use

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[3] World Health Organisation: Household air pollution and health – Fact sheet No. 292

[4] International Energy Agency – Energy Access Database, 2013

[5] World Economic Outlook, 2011

etc.) as well as the opportunity for economic development through increased income generation opportunities and a smaller proportional household expenditure on energy. In recognition of this, the UN set its Sustainable Development Goal 7 as universal access to affordable, reliable and modern energy services by 2030.

Governments and planning agencies increasingly recognise mini-grids as a vital component of a countries' rural electrification strategy, in conjunction with SHSs and grid network extension. The 15 Member States of ECOWAS[6] (Economic Community of West African States), for instance, adopted the ECOWAS Renewable Energy Policy in July 2013 that includes the following targets for the ECOWAS region:

- The implementation of 60,000 mini-grids between 2014 and 2020 for a total capacity of 3,600 MW in order to serve 71.4 million people for a total investment of €13.2 billion across six years.
- The distribution, by 2020, of 2.6 million stand-alone appliances in order to serve 21 million people by 2020, for a total investment of €390 million[7].

The shift in approach to off-grid rural electrification requires a number of institutional, legislative and policy changes. Countries like Kenya, Senegal and Mali have created dedicated rural electrification agencies and regulators, and are introducing tax relief, tariff and incentive schemes relating to decentralised energy. For more than a decade there have been renewed efforts to advance rural electrification, with many countries developing rural electrification visions and master plans. Examples of policy changes required in some countries include tackling perceptions of government institutions and communities alike in terms of their right to electricity and a certain level of service. Countries like Ethiopia and Mozambique have an established right to electricity, and Ethiopia's government provides significant subsidy to the national utility, Ethiopian Electric Utility (EEU), in order to provide a low, flat rate tariff to all customers. Mini-grids are not viable at such a rate, or need to be subsidised in a similar fashion, and so countries like Ethiopia are reviewing their tariff structures to accommodate mini-grids[8].

3.2. SOUTH AFRICA

ENERGY SECTOR

The energy sector in South Africa is overseen by the Department of Energy, which is responsible for preparing energy policy and legislation. It has a key role in forecasting the likely energy mix required in the future, and setting policies and enabling environments to bring that mix to fruition. As an example, it has been very successful in bringing about the development of renewable energy assets through its REIPP programme. The Electricity and Nuclear branch of the Department of Energy is responsible for electricity and nuclear-energy affairs. The Hydrocarbons and Energy Planning branch is responsible for coal, gas, liquid fuels, energy efficiency, renewable energy and energy planning, including the energy database. The national regulatory body is the National Energy Regulator of South Africa (NERSA). The vertically integrated national utility, Eskom, is responsible for generation and transmission, and distribution in certain areas. Distribution is mostly handled

[6] Member countries making up ECOWAS are Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal and Togo
[7] From conversations with the ECOWAS Centre for Renewable Energy and Energy Efficiency, 2016
[8] Based on stakeholder consultations on behalf of the Carbon Trust for the African Development Bank's Green Mini-Grid Market Development Programme, 2016

by 175 metros (large cities) and municipalities. Eskom generates approximately 95% of South Africa's electricity[9], with the rest from independent power producers (IPPs).

South Africa's national grid provides access to 85% of South Africans but suffers from serious capacity and connection constraints, which represent a serious barrier to the development of renewable energy and the economy generally. The Eastern Cape (64.5%) and Kwazulu Natal (67.0%) have lowest grid connection rates in South Africa. South Africa had a network of 27,770 km of transmission and approximately 325,000 km of distribution lines by 2007[10]. Since then Eskom has built over 4,416 km of transmission lines[11], and Eskom's Transmission Development Plan outlines a further 2,958 km of power lines to be constructed by 2020[12]. However, there are serious capacity constraints on this network and Eskom has been unable to secure a sufficiently high settlement with NERSA to make the necessary grid upgrades to relieve all grid congestion in the country. Connection issues due to localised grid capacity constraints present an additional concern, because of South Africa's vast geography and aging infrastructure. Therefore, many potential generators and consumers are not able to connect to the grid, including IPPs and key industries such as those found in South Africa's Industrial Development Zones (IDZ).

South Africa is atypical in Sub-Saharan Africa, with a rural electricity access rate in 2013 of 77% compared to the average of 17%[13], but the need for off-grid generation remains. The grid has reached further into rural areas than is typical for Sub-Saharan Africa. However, the South African National Energy Development Institute (SANEDI) estimates that in excess of three million people remain without electricity in rural areas[14]. In addition to this, lighting is the dominant use of kerosene and paraffin in rural areas and among the poorest populations, and about 17-20 million South Africans use kerosene daily (40% of population)[15]. In addition to the health risks associated with household kerosene use, over 200,000 people are injured or lose property each year in South Africa due to kerosene-related fires[16]. There is therefore still a significant need for rural electrification in South Africa, a proportion of which mini-grids will be best placed to address. Indeed, the New Household Electrification Strategy, initiated by the Department of Energy in 2011, states that a 90% grid electrified target is possible, but that the rest will need to be off-grid.

South Africa has approximately 45 GW of generating capacity, of which about 9% is currently renewable energy and 86% is coal[5]. The Department of Energy has committed South Africa to increasing renewable energy generation from around 4GW to 13.225 GW by 2025, through its Integrated Resource Plan. South Africa has good solar resources, with direct normal irradiance averaging over 7.0 kWh/m^2/day [17]. This is the same approximate intensity as California. Solar irradiance is also relatively uniform across the country, and forms the best renewable resource available for mini-grids. Wind potential is generally insufficient, at around 4-5m/s

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[9] REN21 - REEGLE Clean Energy Portal
[10] Eskom Website
[11] Eskom Generation and Transmission Expansion Plans, Presentation by A. Etzinger, 2013
[12] Eskom Transmission Development Plan 2016-2015, 2015
[13] International Energy Agency – Energy Access Database, 2013
[14] SANEDI, DEA – Sustainability of decentralised renewable energy systems, 2015
[15] N. D. Rao, Kerosene Subsidies in India: When Energy Policy Fails as Social Policy, 2012
[16] Health Impacts of Fuel-based Lighting, Lumina Project Technical Report #10, 2012
[17] Direct Normal Irradiance (DNI) is the solar radiation received per unit area by a surface that is always held perpendicular to the rays coming in a straight line from the sun at its current position.

along coastal regions, only reaching approximately 8m/s in some mountainous areas[18]. 4.2% of South Africa's nominal power capacity of 45 GW is from wind[8]. Hydro power also provides relatively low potential, with low average rainfall and seasonal flows. The Eastern regions of South Africa have greater potential, with several pumped-hydro schemes such as the 1 GW Drakensberg Pumped Storage Scheme in operation[6]. Other options such as biomass, waste-to-energy and wave energy provide further opportunities for renewable generation.

South Africa is an energy intensive, growing economy, with 84% of its total emissions from energy in 2012[19]. The average in developing countries is 49%. Unlike Sub Saharan Africa, which in 2013 had an average per capita consumption of 488 kWh, South Africa's was 4,326 kWh[20]. This high proportion of energy use is due to extensive mining and mineral processing and a coal intensive electricity system, which accounts for 60% of national electricity consumption[8]. Current analysis suggests that, in the 'business as usual' scenario, South Africa's emissions could grow up to fourfold by 2050[21]. Current emission levels are around 400 MTCO2e per year[7]. However, the government aims to plateau emissions at 398-583/614 MTCO2e by 2020/2025. This provides a challenging but motivating platform from which to drive low-carbon initiatives in the energy sector.

SOUTH AFRICA – OPPORTUNITIES AND CHALLENGES FOR MINI-GRIDS

The challenges and opportunities for the development of mini-grids in South Africa are summarised in Table 1. They demonstrate that there are a number of key lessons that can be drawn from the experience of mini-grids in other global and sub-Saharan African countries. However, it also shows that there are key differences within the South African context, and that a bespoke approach will need to be developed to successfully serve South Africa's unserved communities.

Table 1. Challenges and Opportunities for mini-grids in the South African context.

Context	Opportunity	Challenge
High electrification rate and closeness to the grid (90% of non-electrified population within 10 km of grid – Department of Energy, 2011)	• Opportunities for cheaper grid-tied mini-grids that utilise low voltage grid connections to balance supply and demand. • Grid-tied mini-grids may ease demand (and/or export generation) at key times and help address capacity constraints experienced across the grid.	• High expectations of quality of service as well as of grid connection. Renewable energy and mini-grids can be seen as inferior and a barrier to getting grid connection. • Liaising with Eskom and knowing their plans for electrification and potential capacity constraints is key.
Either Municipalities, Metros or Eskom have the responsibility for distribution	• Opportunity for municipalities and metros to drive and	• Municipalities often see mini-grid as a threat to their revenue rather than supporting electrification

[18] REN21 - REEGLE Clean Energy Portal, IT Power Consulting - Solving South Africa's Power Crisis, 2015
[19] Greenhouse Gas Emissions in South Africa, USAID Factsheet, 2016
[20] World Bank Database (Using IEA Statistics, OECD/IEA 2014)
[21] National Climate Change Response White Paper

and connection of citizens within their regional electricity supply	benefit from the development of successful mini-grids.	• Lack of practical guidance on how mini-grids can easily be adapted for different locations, or the best ownership models and financial models to use.
High expectations of quality and level of service	• Greater consumer desire and economic feasibility for mini-grids over standalone systems. Increased willingness to pay.	• Significant project risk of asset misuse if the system fails consumers' expectation. • Comprehensive training is needed for users to understand system limitations and required modes of use
Local public sector money available for off-grid electrification but not mini-grids yet	• Funding should be available once successful mini-grid projects are established, and their business models proven	• Accessing the INEP grant means that mini-grids will need to be grid-code compliant, adding some cost and complexity for early adopters
Availability of R&D and manufacturing	• Cost reduction potential from utilising local R&D and supply chain	• Absence of skills (in mini-grids especially) and manufacturing capabilities
Mobile money payment services available	• Enables business models that utilise mobile money services for efficient management of payments.	• Mobile money is currently more expensive in South Africa compared to other African countries.
Lack of demonstrated mini-grid projects and business models	• Early mover advantage through access to institutions, communities, local supply chain and local knowledge.	• Institutional, regulatory and funding structures as well as user preferences reflect the traditional monopoly of centralised generation.
Lack of relevant local clean energy skills and environmental awareness	• Significant local job creation potential.	• Locals (including some local government members) might be opposed to renewable and novel solutions.
Relatively consistent level of sunlight, with direct normal irradiance averaging over 7.0 $kWh/m^2/day$, and low seasonal variation.	• Solar-based systems can provide a similar quality of service in winter, unlike many countries, reducing reliance on integration with other technologies such as diesel back-up.	

MUNICIPALITIES/METROPOLITAN CITIES AND ELECTRIFICATION

Municipalities and Metros have a significant role to play in the energy sector. All municipalities are responsible for electricity reticulation, as per the constitution. Eskom fulfils this role where municipalities do not hold a distribution licence. Municipalities and Metros (henceforth called municipalities for brevity), as well as Eskom, are therefore responsible for delivering electrification and quality of service to their customers. This requires a coherent electrification strategy, meaning municipalities need to consider a portfolio of electrification options, both on and off-grid. Mini-grids are a necessary component of this portfolio due to grid constraints, connection bottlenecks and the service limitations of standalone systems.

Integrated Development Plans (IDPs) are the major method that municipalities use for planning new connections and receiving the INEP electrification grant. Currently there is not sufficient capacity or knowledge of mini-grids within municipalities so that the only electrification projects they specify in their IDPs are traditional, expensive main grid connection. As the market develops, mini-grid practitioners should work with municipalities to get high quality mini-grid projects into IDPs, which should be produced biennially.

This mandate and responsibility provide the opportunity for municipalities to drive - and benefit from - the development of successful mini-grids. These benefits include job creation, poverty alleviation, economic and sociological development as well as revenue generating opportunities for the municipality itself. Municipalities are also crucial partners to private sector mini-grid developers, for example having a better understanding and access to local knowledge and data, which is a critical and resource intensive stage of developing energy projects.

However, municipalities face a number of barriers to capitalising on this mini-grid opportunity, including a lack of practical guidance on how mini-grids can easily be adapted for different locations and which business and financial models to use. The lack of tailored guidance, in conjunction with the relative nascence of mini-grids in South Africa, means there are also institutional capacity gaps. This report strives to address this gap by providing practical guidance to the key stakeholders implementing electrification schemes (municipalities, Department of Energy, Eskom and NERSA). This is especially valuable as developing electrification projects will require the involvement of a number of different stakeholders, including practitioners and supply chains, and there are a number of critical success factors that must be considered. These considerations are included in this report, as well as a Theory of Change provided in Chapter 4 below.

Concerns have been raised over municipalities' reliance on energy related income. Electricity makes up a significant proportion of their revenue for municipalities and metros, 29.5% in 2013/14[22]. In fact, for some of the smaller municipalities that figure is closer to 50%. Although municipalities receive an 'equitable share' grant to assist them in providing basic services to low income houses, a bias is nonetheless created towards servicing higher consumption, higher paying users. As rising costs of electricity supply from Eskom place greater financial burden on municipalities, this also creates potential conflicts of interest, as ways need to be found to reduce costs while safeguarding services.

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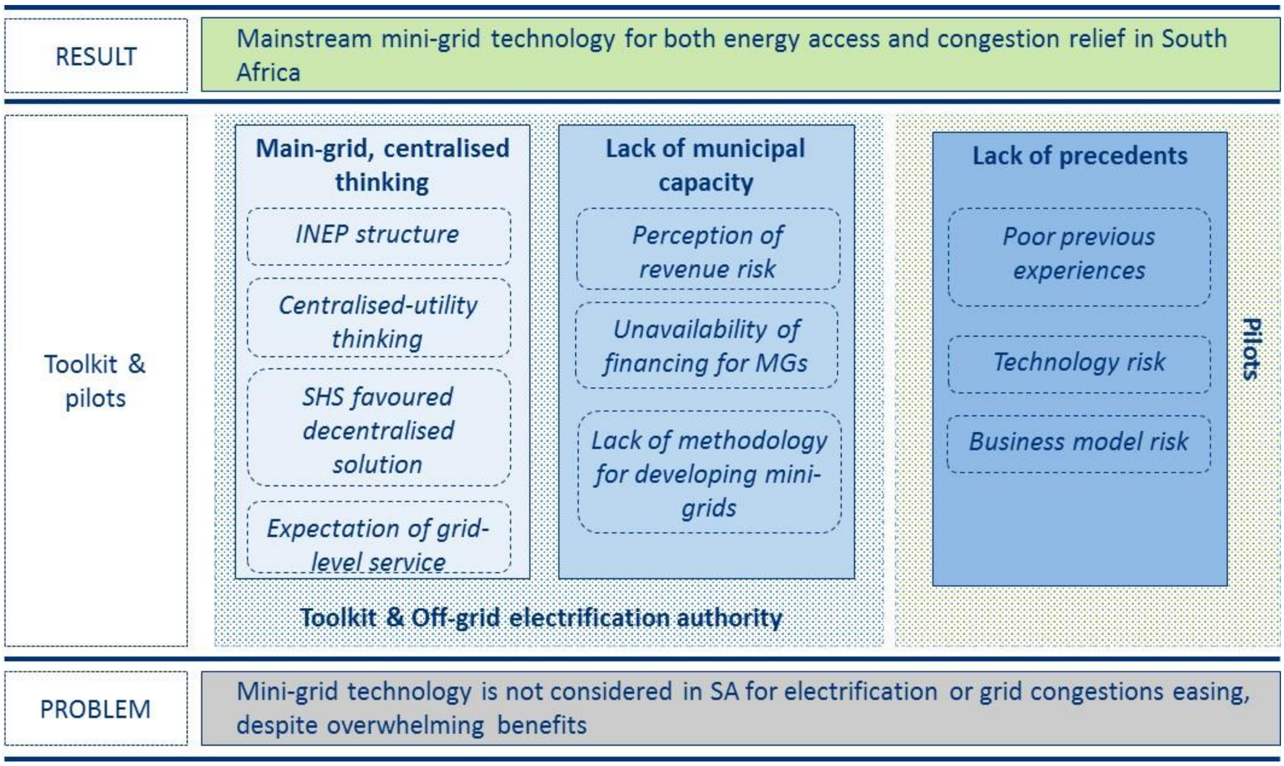
[22] StatsSA, 2014 (http://www.statssa.gov.za/?p=3236)

4. THE PATH TO MINI-GRID DEVELOPMENT IN SOUTH AFRICA

4.1. THE THEORY OF CHANGE

Grid-tied mini-grids, combined with isolated mini-grids for deep rural locations, offer the best route for 100% electrification in South Africa. This toolkit, alongside the proposed Off-Grid Electrification Authority, has been developed in order to challenge the main-grid centralised thinking in South Africa and provide initial support to interested municipalities. We also believe there is a strong case for a series of pilot projects, particularly for grid-tied mini-grids, to prove and demonstrate the technology, business case and the associated contractual structures. This is outlined as a theory of change in Figure 1.

Figure 1: Theory of Change for mainstreaming mini-grid technology for both energy access and congestion relief in South Africa



4.2. MUNICIPALITIES HAVE A BUSINESS CASE FOR INTERVENTION

There are multiple beneficiaries from mini-grids, critically including;

- Eskom as the operator of the national grid, and
- the Department of Energy as the government agency overseeing South Africa's electricity and the customer.

The benefits to these stakeholders are covered in sections of this report. However, there is also a strong business case for the municipalities themselves, built around municipalities' mandate for provision of electricity. This business case includes that:

- Where and when a mini-grid is ultimately connected to the grid it will be the primary provider of electricity locally. This will reduce the local demand for grid electricity, and decrease budgetary pressure from the

municipalities' obligations to subsidise poor households beyond 50 kWh/HH/month. This will also reduce the amount of grid infrastructure that must be built by the municipality to electrify an area;
- Autonomous mini-grids can provide the lowest-cost electrification option in remote areas; and
- Mini-grids enable the development of local industries and create jobs, as well as poverty alleviation and sociological development, further reducing pressure on the municipality's budget

4.3. FROM PILOT TO BEYOND

The pilot phase is about establishing local confidence in mini-grids and the high levels of quality of service they can provide. Pilots will serve to:

- Showcase mini-grid technology and a high quality of service across the country and collect real-world evidence for potential customers;
- Overcome the objections to mini-grid technology based on the failed pilots of 15 years ago;
- Prove the technical, business case and contractual cases for mini-grids in South Africa;
- Give confidence to South African municipalities that mini-grids can form part of their electrification strategy and their Integrated Development Plans;
- Provide NERSA with evidence of the appropriate regulatory treatment for mini-grid and energy storage;
- Give the Department of Energy the confidence that mini-grids can receive INEP electrification grants;
- De-risk the sector for commercial finance; thereby reducing cost of implementation further; and
- Allow Eskom to test and verify the ability of grid mini-grids to ease main grid congestions and to measure the benefits of the services (such as frequency response) to the main grid.

We recommend the following for the pilots:

- **A grid-tied system**: This enables a maintained level of service at any time, regardless of potential system failures. The capacity required could be achieved through a 60A *farmers cable*, reducing regulatory constraints as well as costly storage requirements;
- **A public-private partnership**: This is detailed in section 6.2, and allows for municipalities to access the significant technical understanding required to deliver a successful mini-grid project;
- **An accessible location**: Choosing a location near knowledge and logistics centres, as well as good road access, would accelerate the resolution of operational issues (e.g. equipment replacement);
- **Community engagement and local stakeholder communication:** As with any pilot projects, community and stakeholder engagement is key and should be proactive. This includes management of expectations, especially demand scheduling.

Beyond the pilot the challenge will be to secure sustainable financing sources, as well as to define which communities municipalities would like to serve through mini-grids. There are two types of communities of concern to municipalities that will potentially be best served through mini-grids;

1. off-grid rural settlements
2. informal settlements within metropolitan cities.

Establishing mini-grids within these two different communities will lead to different beneficiaries, grid designs and financial profiles, and these will have to be defined on a case-by-case basis.

Our recommendations for success in the rest of the report apply to both cases.

An additional recommendation to the Department of Energy around the benefit of implementing a progression-dependent feasibility-funding model is provided in Annex I: Recommendations on the Enabling Environment for Mini-Grids.

5. PRIORITISING ELECTRIFICATION SOLUTIONS

5.1. SERVICE LEVEL

The different electrification models are generally grouped into the main (national) grid, mini-grids and stand-alone systems (also called solar home systems, SHSs). As discussed in section 3.1, mini-grids typically deliver an 'intermediate' level of service demand, serving communities in areas where the grid extension is uneconomic and which require a consumption and service above that offered by SHSs. The specific level of service provided by each solution is well framed through the UN's Sustainable Energy for All (SEforALL) Global Tracking Framework[23]. This Global Tracking Framework has 6 tiers, from 0 – 5, based on household electricity access level. A simplified version is presented in Table 2[24].

Table 2: Simplified Electricity Consumption Tiers

Level of Access	Indicative Applications	Consumption (kWh/household/year)
Tier 0	Torch or single light	Less than 3
Tier 1	Task lighting and phone charging or radio	3 – 66
Tier 2	General lighting, air circulation and television, computing or printing	67 – 321
Tier 3	Tier 2 level plus small appliances, e.g. washing machine	322 – 1,318
Tier 4	Tier 3 level plus medium appliances, e.g. ironing, refrigeration or water pumping	1,319 – 2,121
Tier 5	Tier 4 level plus large appliances, e.g. air conditioning	Greater than 2,121

The typical mini-grid developed to date in Africa is an autonomous (not grid-tied) basic service mini-grid. This is as defined in the IRENA Innovation Outlook: Renewable Mini-Grids 2016 report. This different description of the service level of mini-grids groups mini-grids by two categories: high vs low level of service, and autonomous vs interconnected (to the grid)[25].

Mini-grid systems can be scaled to the required level of service, and are able to deliver tiers 2, 3 and 4 of the Global Tracking Framework (approximately 50 – 2000 kWh/household/year). The limiting technical challenge for mini-grids is on handling fluctuating generation and times of peak demand, rather than average consumption, as smaller systems are less able to deal with fluctuations in supply and demand. Solar home systems provide tier 1 levels of consumption and are better considered as a product rather than a service due to their mobility and cost. Individual, wealthy households could purchase much larger solar household systems as required, with a corresponding higher capacity. However once sufficient numbers of households in a

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[23] Sustainable Energy for All (SEforALL) Global Tracking Framework - https://sustainabledevelopment.un.org/content/documents/13139Global%20Tracking%20Framework_World%20Bank.pdf

[24] F. F. Nerini et al. A cost comparison of technology approaches for improving access to electricity services. January 2016

[25] IRENA Innovation Outlook: Renewable Mini-Grids, 2016

settlement have this level of demand then a mini-grid or grid-based electrification project would usually be considered by the relevant electrification agency. Grid systems are only the option typically providing tier 5 access, although South Africa's main grid suffers from constrained connection and supply.

5.2. COST

Precise costing of grid, mini-grid and standalone systems is highly site specific, but both grid and mini-grid systems have a lower cost of energy for systems that provide a higher tier of consumption. Both grid and mini-grid systems have shared assets between households, so cost per household decreases with the density and number of households. The other main drivers of grid expansion costs are distance from the settlement to the existing grid and any infrastructure upgrades required if the grid is congested. Extending the grid by 10 km can increase the levelised cost of energy (LCOE) by up to 60%, for a typical national tariff[24]. Distribution lines may be extended from existing lines by up to 10 or 15 km, but beyond this is less technically feasible[24]. Transmission lines may also be built to transmit HV power to a region, which can be done over distances of approximately 50 to 60 km[26], but this adds significant costs. A project requiring long distance lines (and the associated substations and other infrastructure) will typically only be economical for large, dense communities with high per capita consumption. For low consumption communities the least cost option is either mini-grid and standalone systems, depending on household density and demand. Below a certain threshold no grid-based system will be competitive. For illustration *Nerini et al.* conducted a sensitivity analysis on the cost of energy of each option using Nigeria and Ethiopia as case studies[24]. They found that standalone systems had a cost of energy of about $500 /MWh. Mini-grids were found to have a cost of energy from $250 /MWh, and grid systems from $200 /MWh, and hence more economical than standalone systems. Both main-grid and mini-grids reached over $10,000 /MWh for very low consumption and density communities.

Another key cost factor will be the capacity constraints of the local grid, especially if upgrading of the local substation is required. A fully constrained grid may mean that new connections are not possible, or are only available at significant costs by upgrading infrastructure. In South Africa there are very long connection backlogs in some parts of KwaZulu-Natal and the Eastern Cape. As a result, the national annual connection rate has steadily decreased, from 499,000 in 1996/97 to 141,000 in 2011/12[14].

5.3. SUPPLY- AND DEMAND-LED APPROACHES

Geospatial information systems (GIS) are used to prioritise electrification solutions, categorised into supply and demand-led approaches depending on whether cost or service level is the key driver. GIS involves georeferenced data layers such as the location of settlements and the national grid network. These can then be manipulated electronically to enable complex analyses of potential solutions for electrifying a settlement or an entire continent. Supply-led approaches assess the suitability of mini-grids through a measure of the techno-economic competitiveness of each option, usually based on the levelised cost of energy for each technology. This produces a least cost solution, but careful consideration needs to be given to parameter choices to ensure robustness of results. The choice of demand, for example, will affect significantly which option is chosen. Demand-led approaches address this concern by focusing first on the level of consumption required, taking into account the needs of service facilities such as hospitals or schools to work out which settlements have priority for grid electrification (higher demand equals higher priority). Remaining un-electrified settlements are then allocated stand-alone or mini-grid solutions depending upon resource availability and other factors. This approach is centred on the level of service, not the least cost, and so can

[26] Carbon Trust interview with Ethiopia Electric Power, August 2016

result in bias towards grid extension as well as higher total project cost. Select examples of GIS-based tools, which support the prioritisation and design of electrification solutions, are given in Annex II: Selected GIS-Based Electrification Support Tools.

South Africa has a greater availability of geospatial datasets available than is typical within SSA, as well as GIS-specialist organisations like the Centre for Scientific and Industrial Research (CSIR). GIS systems will therefore be invaluable for analytically comparing electrification models, and will enable significant improvements in planning efficiency. The appropriate choice of tool in South Africa will depend on whether a whole region's electrification options are being considered, or a single site, and will most likely require the contracting of a GIS-specialist organisation. South Africa and case-specific criteria can then be inputted, such as the level of service required and an estimated demand.

6. BUSINESS MODEL FOR MINI-GRIDS

6.1. DIFFERENT BUSINESS MODELS

A variety of different business models are available for mini-grids, split into four categories:

- **Community-based model**: The community is the owner and operator of the mini-grid, with a cooperative often established to own and manage the system. This model usually relies on initial capital support from governments or philanthropic organisations, as well as technical support for project implementation;
- **Private sector-based model**: The construction and operation of the mini-grid are managed by a private organisation(s), with varying levels of external financial support depending on the level of government engagement and type of subsidies available;
- **Utility-based model**: The construction and operation of the mini-grid by the national utility, the traditional driver of rural electrification in developing countries; and
- **Hybrid model**: There are multiple permutations possible, e.g. a public-private partnership where the government finances the construction of a mini-grid that is then managed by a private organisation, or a privately owned mini-grid that is maintained by the community it serves.

Different types of developers may have different preferred models, depending on the type of organisation and its objectives. A key consideration is the financial viability of the project under each business model. A brief summary of the advantages and disadvantages of each model are outlined in **Table 3.** Currently most community or private models require some level of government/external financial support to be viable, although this is no different to the main grid that also relies on public sector support to deliver new connections. In some cases, the availability of subsidies and other financing can dictate the choice of business model (Chapter 9). The best model can also be dictated by, and in turn dictate, the level of sector regulation. **Figure 2** shows an illustrative link between the level of government regulation, desired speed of rollout, and the applicability of different business models.

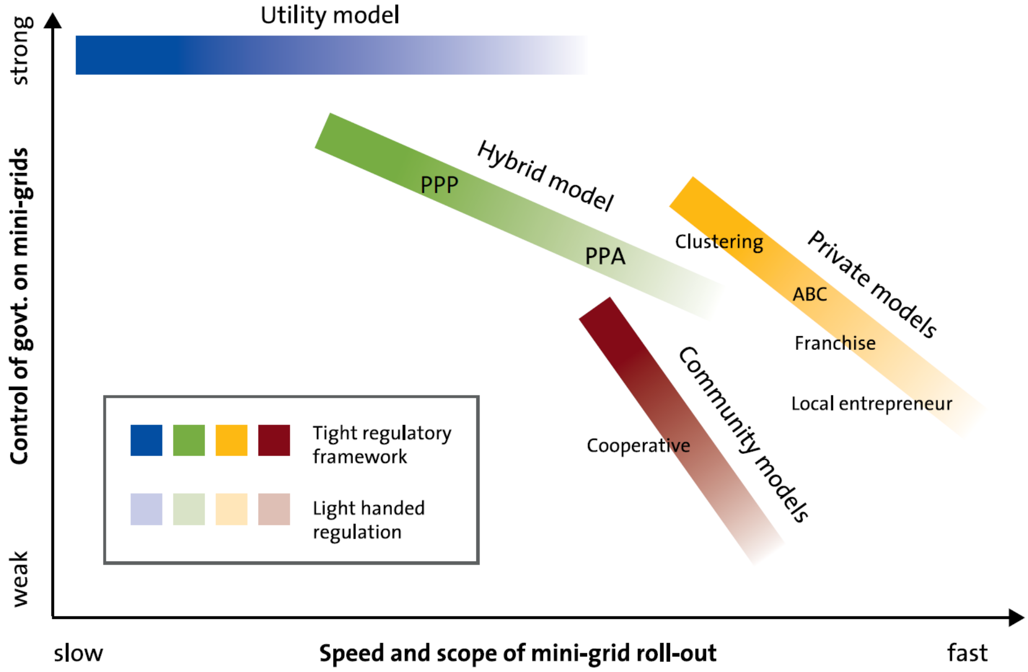
Table 3: Advantages and disadvantages of different mini-grid business models

Ownership Model	Advantages	Potential Issues and Disadvantages
Community	• High community ownership, engagement and employment • Available in low priority regions for the government or private sector • Often low levels of bureaucracy relative to utility model	• Extensive support needed due to lack of technical and business experience • Governance systems and community dynamics needs to be carefully managed • ‘Tragedy of the Commons’ risk: Less likely to effectively measure and limit use of each user to avoid collective failure
Private-Sector	• Financial incentive for expansion of scope or number of operating mini-grids • Greater efficiency and potential understanding of political and operational/logistical challenges to a project	• Potential focus on profitability or cost reduction over user service • Lack of experienced mini-grid practitioners and supply chain • Access to low-cost finance barriers due to lack of financial services’ understanding of project risk
Utility	• Privileged legal position and better access to public-sector financing mechanisms • Experienced institution at in-country electrification projects	• Often slower and less agile internal processes • Often pressured by political agendas, potentially negatively impacting focus on consumer need or long-term planning

	• Utilities' large scale increases access to supply chain and financing	• Liberalised, market-driven utilities may not prioritise off-grid systems in rural areas based on cost
Hybrid	• Can achieve the benefits of other models without some of the problems, providing access to technical and financial expertise for the owner while offering cost saving	• Dependent on model: Multiple-stakeholder management and operational models can lead to inefficiency, as well as higher transaction costs.

Sources: USAID/ARE, Hybrid Mini-Grids for Rural Electrification: Lessons Learned, 2011; Carbon Trust analysis.

Figure 2: Indicative applicability of different business models.



Source: RECP Mini-Grid Policy Toolkit, 2014.

6.2. BUSINESS MODEL RECOMMENDATION

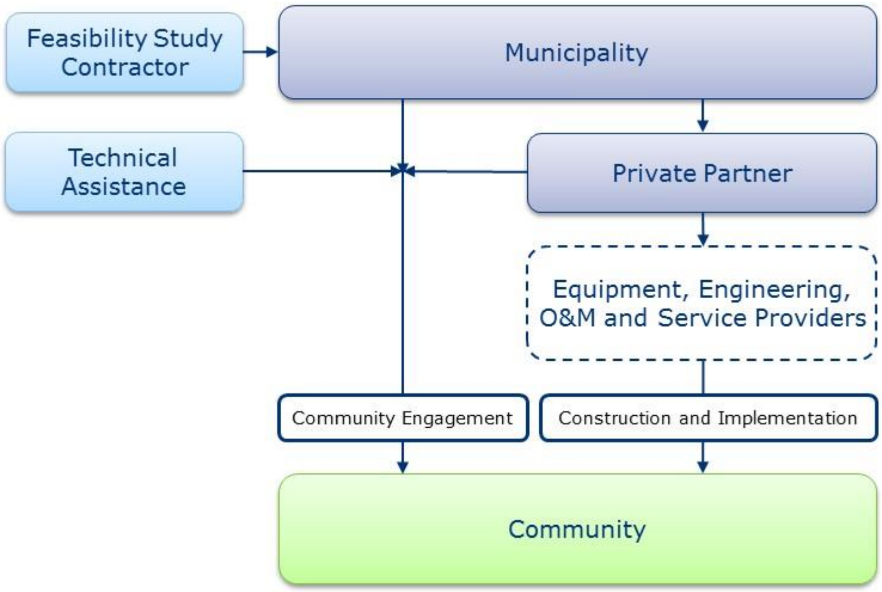
Based on our investigations, we believe that in the South African context, a Public-Private Partnership business model (PPP) could be the optimal arrangement. Municipalities would be the driver, working in partnership with a number of supply chain agents for construction and operation, and technical assistance. This model is shown in Figure 3.

A PPP model is preferred for a number of reasons:

- Municipalities, or Eskom in some cases, are responsible for electricity distribution and the connection of customers, so are already the driver of electrification in their region. This therefore replaces the utility model in these regions. The municipalities may therefore also have greater access to communities and data than private developers;
- Nevertheless, the PPP model is preferred as municipalities don't have the capacity to deliver mini-grids without the support of stakeholders such as an implementing technical organisation;

- Community models are not seen as viable currently in South Africa due to a mixture of factors including the poor perception of renewable energy and mini-grids[27], the expectation of future grid connection and a lack of technical capacity and understanding of regulations, funding and relevant stakeholders;
- Specific public funding for electrification is available, notably through the Integrated National Electrification Programme (INEP), that may be accessed by municipalities (and passed through to private sector operators) for off-grid projects once the business model is demonstrated and projects form part of Integrated Development Plans (IDPs); and
- Municipal or local government support would help unlock international funding for mini-grid schemes. This funding is available due to mini-grids' potential role in poverty alleviation and rural development.

Figure 3: Recommended PPP business model in South Africa



In the pilot phase, it is likely the municipality would be responsible for leading all upstream project activities, including identifying the local opportunity for mini-grid developments, bringing together relevant stakeholders, supporting pilot location, leading early-stage community engagement and fundraising. The primary source of financing for pilot projects will likely be international donor funding given the levels of uncertainty and risk. The municipality then hires a third-party contractor to conduct resource assessments and feasibility studies, and tenders for a mini-grid practitioner with which to form the PPP. The project developer is then responsible for the implementation of the mini-grid, most likely through a vertically integrated Design, Build and Operate model (it may sub-contract some of these tasks to third parties, including local practitioners to support the local economy). Although not certain, we envisage at this stage the municipality would own, if not all, then at least a large proportion of the assets, since the private sector is unlikely to want to contribute finance. Both the municipality and project developer would be involved in continuous community engagement, with technical assistance from organisations (e.g. local development agencies, section 9.3).

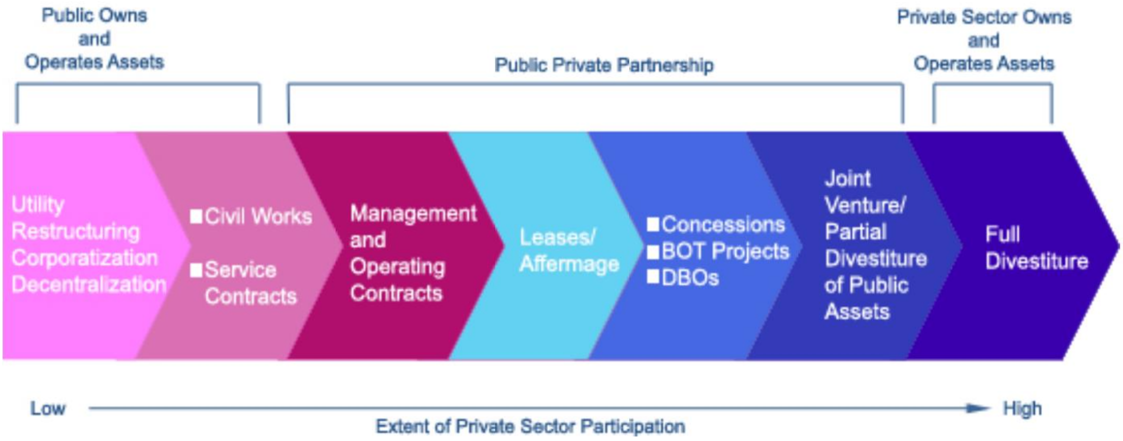
In later stages, when the business model is proven through pilot projects, we expect the private sector will become a more proactive driver of mini-grid deployment in South Africa. The municipality's role will then focus more on facilitation:

[27] A Survey of Energy Related Behaviour and Perceptions in South Africa: The Residential Sector, DoE, 2013

- catalysing private sector development by providing economic and demographic data;
- facilitating community engagement; running competitive tenders;
- and maintaining a well-defined path to applying projects in an area.

There are a number of different PPP models, with different characteristics, that could be utilised for municipality-led mini-grids in South Africa. The World Bank breaks down the PPP model into multiple sub-models as seen in Figure 4. Table 4 (see later) illustrates key characteristics of the different, most-used PPP models, and we indicate how the PPP model proposed here differs.

Figure 4: Types of Public-Private Partnership Agreements



Source: World Bank PPP IRC[28]

A majority private-owned PPP model is recommended for post-pilot projects. Post-pilot projects will access public grants through the INEP, as requested in the IDPs from municipalities. Projects may also access private sector financing. Municipalities will then contract the construction and operation of the system to a private developer, most likely under a concession or Design, Build and Operate model. The private partner will hold the majority share. This is a necessary condition for most private sector developers, needed to ensure that the system assets can be operated commercially. The public sector will have a material minority share in the project, retaining the ability to ensure the quality of delivery of this public service. The private sector will be responsible for day-to-day operation of the system. The developer would also be responsible for revenue collection, most likely using pre-payment meters in order to continue to benefit from the Free Basic Electricity operational subsidy for poor households (section 11.2).

The exact business model that will work best in South Africa needs to be explored and validated through the proposed pilot projects. As the South Africa mini-grid sector evolves, the characteristics of the optimal PPP model may change. The final model will often differ between projects, requiring negotiation between the public and private partners.

A service delivery agreement entered into by a municipality with an external service provider must comply with the Municipal Systems Act, the Municipal Finance Management Act and the Energy Regulation Act. This has implications for feasibility of utilising long-term service delivery (PPP) agreements. This issue is addressed in section 8.2.

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[28] https://ppp.worldbank.org/public-private-partnership/agreements

Table 4: Characteristics of Recommended Business Model in South Africa vs "traditional" Public-Private Partnership Models

	Mini-grid PPP models in SA		World Bank PPP models				
	Pilot mini-grid model in South Africa	**Scale up mini-grid model in SA**	**Management and Operating contracts**	**Leases**	**DBO/BOT**	**Concessions**	**Joint Ventures**
Asset financing	Donor & public sector grants	Private & public sector (INEP)	Public sector	Public sector	Public sector	Private sector or mixed	Mixed
Asset ownership	Either public or private sector	Mixed - Private sector majority ownership	Public sector	Public sector	Public sector	Public sector	Joint owned company usually established.
End-users payments made to private sector	Yes, but may be shared between private and public sector	Yes	No	Yes	Yes	Yes	Usually
Fee payment from private to public sector	No	No	Yes	Yes	No	Yes	Not usually
Contract duration	Long term	Long term	Short term	Medium	Long term	Long term	Long term

7. SUCCESS CRITERIA TO DEVELOPING FUNDABLE, SUSTAINABLE AND SCALABLE MINI-GRIDS IN SOUTH AFRICA

7.1. PROJECT PROCESS

PROJECT STAGES

Although many different categorisations are valid, we have split the development and implementation of a mini-grid project into five stages:

1. Opportunity assessment and prioritisation
2. Feasibility assessment
3. Design and implementation
4. Operation and maintenance
5. Project scale up

Opportunity assessment and prioritisation is where the success factors for the project are determined from the initial business concept. Remotely sourced information is collected, preferably based on geospatial data, to enable the assessment, identification and prioritisation of different sites (i.e. distance from a major city or grid network, population density, resource availability, mobile payment coverage). Initial engagements with enabling stakeholders are also needed, such as first approval from the regulator (NERSA) and potentially a letter of support from the Department of Energy. Regulation is covered in Chapter 8.

Feasibility assessment is the second phase, where the technical and sociological viability of the project at the prioritised site(s) is established. The primary element of this stage is the feasibility study, which may require a certified assessment of the resource availability for the chosen site. This is especially necessary for hydro, biomass and wind-based projects due to the high site variability. Developers should also identify potential financing sources at this stage (Chapter 9). Other questions include the communities' needs for electrification, level of development, energy demand, ability to pay and hierarchical structures.

The third phase, design and implementation, entails the completion of the project design, including the technical plan and finalisation of the business and financial model. By this stage the baseload customers should have been secured, as well as the project financing and regulatory compliance. Once this is complete, construction can begin. There are a large number of elements to this phase, which are detailed further in subsequent sections.

Operation and maintenance is the fourth stage, involving coordination and management of the different stakeholders. Energy and operational performance monitoring is required to assess actual load patterns and use of system characteristics, which can detect issues as well as help determine the need for scale up. Regular and unplanned servicing by the private developer or a contractor is required. This is also the case for collection of fees and customer service, unless done remotely, as shown in *Develop a payment model adapted to customer's ability to pay and consumption growth* (section 7.2). Effective stakeholder engagement and management is critical in effective delivery, as detailed in Chapter 12.

Project scale up is the fifth phase, where the continued successful operation is dependent on expanding the project size or service. Need for expansion could be due to increased customer participation, expansion to other areas or increased service level. In relation to rural areas, this can be a welcome result of the successful economic development of households due to electrification and the many development opportunities afforded by a well-designed and delivered system. Project scale up may entail new connection of customers, new generation or distribution asset upgrades and complex design changes.

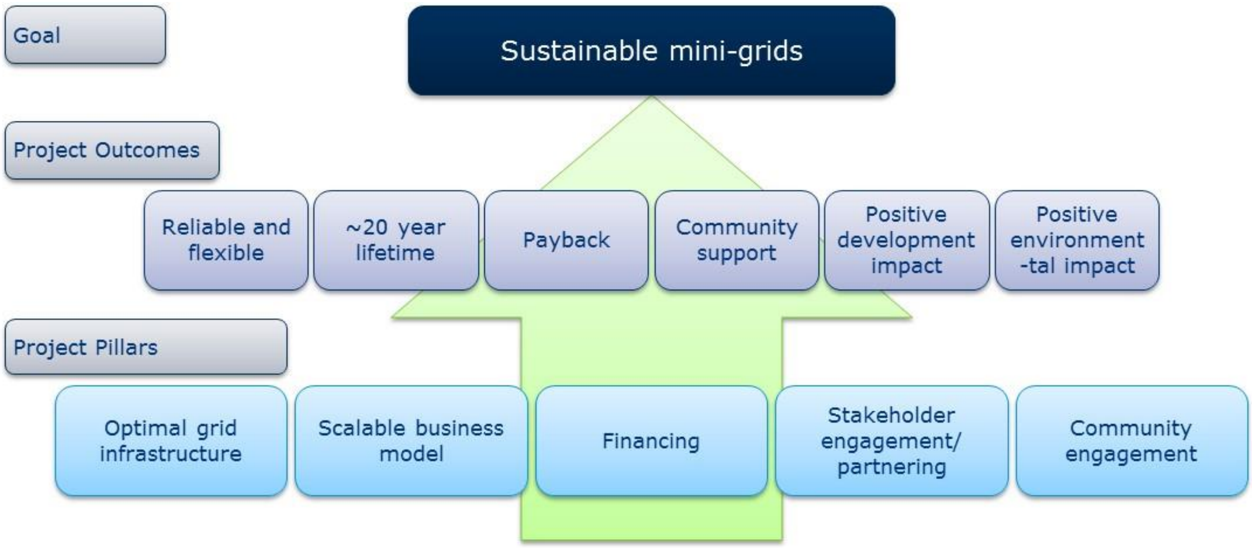
PROJECT PILLARS FOR SUCCESSFUL, SUSTAINABLE MINI-GRIDS

Successful, sustainable mini-grid projects are achieved by delivering against a number of critical project outcomes, shown in Figure 5, the most important of which are;

a. payback for the developer
b. community support.

A project without suitable payback is financially unsustainable, and would therefore be un-scalable and only be possible through continuous public or philanthropic support. A project without community support will suffer from issues such as non-payment, vandalism and misuse, and communities may seek other solutions. The other necessary project outcomes are a reliable and flexible solution, an approximate 20-year project generation lifespan, positive development impact and positive environmental impact. The first two outcomes relate to technical feasibility, the latter two reflect the programmatic feasibility (how the project aligns to a country's economic, energy and development goals).

Figure 5: A top-down approach to developing successful, sustainable mini-grids

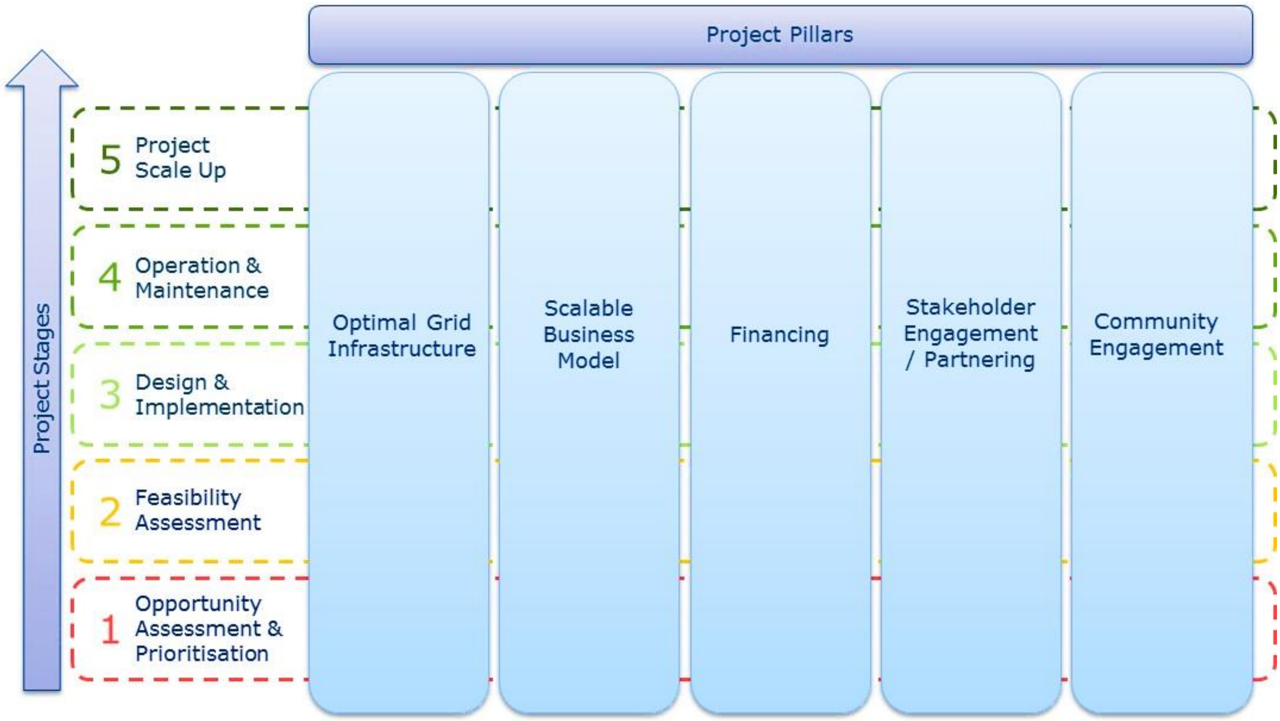


These outcomes are built upon five project pillars:

- optimal grid infrastructure;
- scalable business model;
- financing;
- stakeholder engagement;
- community engagement.

These have been defined through understanding of the success factors and learnings found from case studies and best practice for mini-grids globally, as detailed in section 7.2. These are not sequential, such as the project development stages, but must permeate the entire process. This top-down approach for developing sustainable mini-grids is shown in Figure 6.

Figure 6: Cross-cutting project pillar across project development stages



7.2. SUCCESS CRITERIA

This section lists key success criteria for a mini-grid project, corresponding to a project pillar. These may be either applicable across the project stages or apply to a single stage. To illustrate this, the following icons are used to show which project stages the success criteria applies to.

Table 5 summarises these success criteria for each project pillar.

Table 5: Key success criteria

Project Pillar	Success Criteria
Optimal mini-grid infrastructure	Design simple, integrated, replicable, modular grid
	Target highest possible quality of service
	Plan for demand management & scheduling tools
	Leverage existing infrastructure for balancing
Scalable business model	Develop a public-private partnership initially
	Develop payment model adapted to customers' ability to pay and consumption growth
	Define clear ownership and responsibilities model with project developer(s)
	Target accessible off-grid population zones
	Identify local champions and baseload customers
	Maximise data collection and utilisation
Financing	Identify sources of capital and operating subsidies early on in the process
	Adapt source of finance to stage of project development
	Identify local innovative providers of finance
Stakeholder engagement & partnering	Exchange information with peer projects
	Identify and engage with key market entry enablers
Community engagement	Ensure buy-in through direct and early engagement
	Develop local employment and ownership
	Deliver training and manage expectations
	Align with community structures, other initiatives and local and national economic development goals

Case studies are also provided to demonstrate key learnings and best practices. A good further reference is the AEEP *Energy Access Best Practices*, 2016, which contains 24 African energy access and off-grid systems case studies. Other Case Studies are given in the clean energy ministerial report.

DESIGN A SIMPLE, INTEGRATED, REPLICABLE, MODULAR GRID

Simple, integrated, replicable and modular systems are more scalable and cost effective:

- **Integrated systems refer to mini-grids that are designed as part of a wider poverty alleviation, health and environmental solution.** Beyond energy production and distribution for powering appliances, they take into account, integrate with and/or enable improved water treatment, sanitation and agriculture. Access to clean water in particular is as important as access to energy in many rural areas and informal settlements. A mini-grid that recognises and leverages this connection to achieve holistic impact is more likely to present better value – economic, social and environmental – for money, and hence receive greater financial and community support. In South Africa this is represented by inclusion in the IDP.
- Mini-grid systems are typically built in unserved communities which then results in substantial increases in use of service as a result. Even for previously electrified communities, increases are expected in a number of factors such as the number of willing customers, average household consumption, the ability to pay and expectation of service.
- Three to six years is a typical timeframe before successful projects will likely need to be scaled up, with the first two years used to measure the actual load patterns and use of system characteristics[29].
- Modular systems save costs and construction time by using standardised designs and processes, building a system from a series of modular sub-components which can be independently created and used in multiple different systems. This gives the additional value of augmentation, where a new system or expansion can be added purely by 'plugging in' a new module. A good example is solar panels, where the size of the system required is achieved by combining the sufficient number of modular panels. The flexibility of such modular systems increases replicability.

Modular, replicable systems can be applied easily in different locations, which reduces the cost of developing a mini-grid portfolio. Banks and investors tend to prefer investing in portfolios as there are lower due diligence costs relative to the size of the project. Portfolios tend to be built upon more proven business models, to reduce project, technology and commercial risks. Significant cost-saving can be achieved through a portfolio of projects, as economies of scale on fixed costs such as legal due diligence, insurance and certification are achieved. Research found that current mini-grid providers in Africa would require at least 250,000 customers to reach profitability - and still be reliant on cross-subsidising to maintain operability – demonstrating the need for scalable and replicable mini-grids[30].

In South Africa, we believe that the following infrastructure should be implemented:

- Solar PV (potentially combined with solar thermal) should be the generation technology of choice given the high, year-round solar irradiation South Africa enjoys and the low development and O&M costs for solar panels;
- Grid-code compliant AC systems should be used in all cases. Low Voltage Direct Current (LVDC) is unlikely to become a significant technology in South Africa and implementing grid-code compliant AC avoids the potential for stranded assets as the main grid grows;

[29] Consultation with TTA, 2016

[30] How a New Breed of Distributed Energy Services Companies can reach 500mm Energy-poor Customers within a Decade. P. Bardouille, D. Muench. June 2014.

- Mini-grids should be grid-tied, via a 60A farmer's connection, where possible;
- Mini-grids should utilise before-the-meter energy storage as a shared resource. Li-Ion battery technology is currently best in class for this application and should be used ahead of Lead Acid due to lower lifetime costs;
- Using the energy storage and generation of a mini-grid to provide services back to the main grid (energy, frequency response, etc.) should be explored;
- A charge controller and demand scheduling technology should be used to manage the mini-grid and protect the integrity of the batteries; and
- Demand should be metered using a PLC system with a concentrator providing consumption (and other operational data) to the mini-grid operator
    - Class 2 meters (meaning an accuracy of + / - 2%) are normally used for residential customers and Class 1 meters for (+ / - 1%) for commercial customers. Given the relatively low consumption per meter we would propose to use lower cost, less accurate meters.

The design elements addressed here integrate with the success factor *Maximise Data Collection and Utilisation* under the pillar of Scalable Business Model.

A good case study is the standardised design of off-grid projects within the ERSEN Off-grid Solar Energy Programme. The programme, funded by GIZ and the EU, has 18 mini-grids implemented as Local Rural Electrification Initiatives (ERIL) in line with the Government of Senegal's national electrification strategy. These 18 projects are within the Kolda, Sédhiou, and Kaolack regions and are 10% financed by the customers, 10% by the private operator and the rest by the donor. GIZ standardised the design of the systems, which uses ERSEN solar PV/hybrid AC-coupled technology, to ensure quality and reduce maintenance and technology issues. This also reduces significantly the fixed costs such as legal due diligence, insurance and certification. A further learning from this project was the greater need to integrate the financial sector, with involvement de-risking investment across the portfolio and enabling access to lower-cost financing.

Cross-Cutting

TARGET HIGHEST POSSIBLE QUALITY OF SERVICE

The development potential of mini-grids, which fundamentally depends on the quality of service provided, is a primary reason for its popularity with public sector and development institutions. Some of these benefits, such as enabling job and income creation, health and educational benefits, are detailed in section 3.1. Although some benefits can be achieved through low capacity SHSs, significant development potential requires a higher per capita consumption. Mini-grids are able to provide a higher consumption and level of service over SHSs and other solutions, as detailed in section 5.1. This is one of the key factors driving their implementation, and solutions should therefore maximise the feasible quality of service. The level of service is limited by the consumer's expectations, needs and ability to pay, as well as what can be technically and financially delivered. A higher capacity system will be generally cheaper in terms of cost of energy, but may still be financially limited on an absolute cost basis (e.g. lack of availability of local financing for capital costs of project implementation).

Customer satisfaction, and hence community acceptance, is another key reason for targeting the highest possible quality of service in South Africa. Unlike SSA, which in 2013 had an average per capita consumption of 488 kWh, South Africa's was 4,326 kWh[31]. Coupled with the high grid access rate of 85% this means there are higher expectations of the quality of service than typical for SSA. The expectation is that settlements will be grid connected and receive grid quality of service. This is a tough target, despite South Africa's grid system suffering from blackouts and load-shedding, and can only be realistically achieved with grid-tied mini-grid combined with demand-scheduling.

The system characteristics – storage, interconnection - affect the level of service possible. Autonomous (not grid-tied) basic service mini-grids, supplying between tier 3 and tier 4 electricity under the SEforALL Global Tracking Framework, uses limited storage to reduce costs, but provides less than 24-hour power and can only power household appliances such as TVs or fridges. This is different from the high service *autonomous full service* mini-grid type, which has large storage and backup to enable 24-hour, tier 5 service. Interconnected mini-grids can achieve a higher level of service than autonomous systems due to the ability to use the grid for storage and/or generation, making it possible to supply larger-consumption customers and ensure continuous supply.

A grid connection to the mini-grid could also be used as generation back up in pilot projects. This model is introduced in section 4.3, to mitigate against the (currently low) local confidence in mini-grids. The grid would serve as a back up to ensure that no interruption to service was experienced should the pilot mini-grid system fail. This could even be done without informing the customers of their shift to using mini-grid generated power, addressing the issue of customer perception of off-grid and renewable solutions. To reduce costs this could also function as a 'grid-as-storage' solution described in the section *Leverage Existing Network Infrastructure for Storage Capacity* below. This would utilise the grid to deal with peaks in demand and enable lower requirements for generation capacity.

Cross-Cutting

PLAN FOR DEMAND MANAGEMENT & SCHEDULING TOOLS

Demand management & scheduling is crucial to avoid blackouts, system failures and ultimately dissatisfied customers. This issue stems from the *tragedy of the commons*, where individuals gain from exploiting a shared asset but lose out completely when the asset eventually fails from being overexploited. Due to their scale, mini-grids are not as robust as national grid systems against variations in supply and demand. A mini-grid which was built without any way of managing consumption of its customers is extremely likely to be exploited; either through increased household consumption or 'illegal' connections added to the system. In South Africa the income level is higher than in other SSA countries, so high-consumption equipment such as hot plates and kettles may be added. This occurred in the Hluleka reserve projects in the Eastern Cape, where the initial success of the system encouraged people to obtain additional appliances[32]. This is especially likely if system limitations are not fully understood by the community.

There are a number of demand management options, through combination of technical (load limiters, schedulers and metering) and business model (specialised tariffs and payment schedules) implementation options. The simplest technical solution is for each connection to be fitted with a load limiter, which is often a simple fuse which will trip if the household consumption exceeds a set threshold. The consumption threshold

[31] World Bank Database (Using IEA Statistics, OECD/IEA 2014)

[32] Hybrid mini-grid systems, modular form of off-grid electrification, smart grid technologies. Presentation to the Parliamentary Portfolio Committee on Energy by CSIR, January 2012.

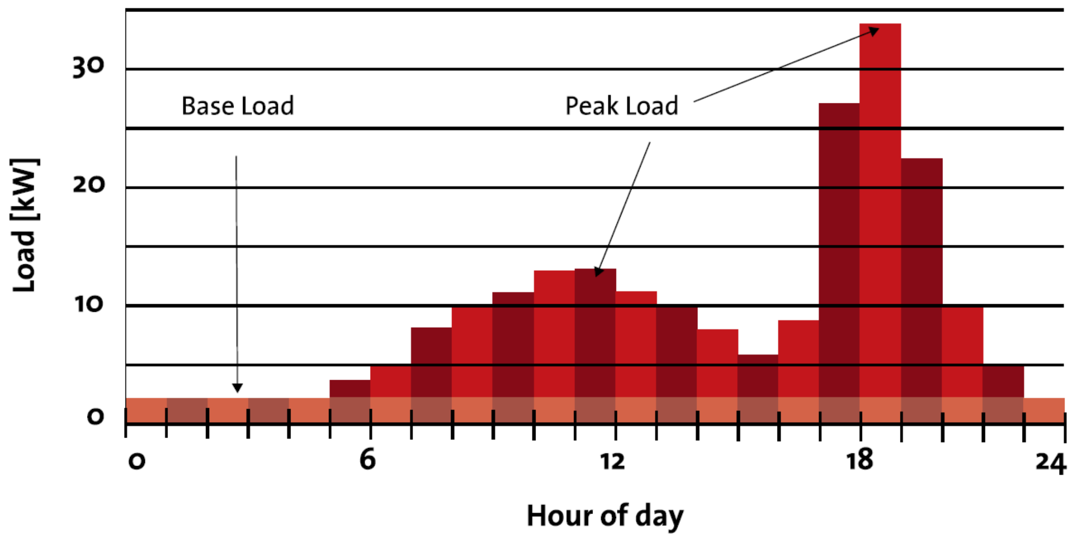
is set through a fixed tariff structure. The advantage of this method is its simplicity and low cost, and it can be easily understood by the community. However, this is an inflexible method, and there is no incentive to reduce load below the set threshold as payment is not linked to consumption. Metering allows more sophisticated approaches, a simple example of which is the pre-pay model. In this model a regular payment unlocks a set electricity allowance, sometimes called an Energy Daily Allowance (EDA). There are other tariffs such as peak-off-peak tariffs which incentivise use during low demand periods to balance the overall system demand. Additional tariff models are described in section 11.1.

Training is necessary to ensure that customers understand system limitations, the demand management solution used and associated tariff structure. Most customers in typical settlements will be technically illiterate, and some may not be used to electricity or service payment systems. There are many case studies illustrating the potential failures of a system due to insufficient training, as well as the benefit of training on system performance. This is covered in the section on community engagement below.

Energy efficiency is a key component of demand management, crucial to ensuring a cost-effective solution. One of the lessons learned from the NREL village power program is that *"investments in energy efficiency have much more economic value than adding generation capacity to meet the demand of inefficient appliances."*[33] This includes the use of energy efficient appliances as well as training on energy efficient practices, which can be combined with the training highlighted above. Such measures are a vital part of delivering a low cost service by reducing the system scaling, which is a major factor in the cost of energy of a mini-grid.

A typical load curve of a large mini-grid is given in Figure 7. This illustrates the typical household pattern of highest electricity use in the early evening and a smaller peak corresponding to lunchtime.

Figure 7: Typical large mini-grid load curve.



Source: EUEI PDF Policy Toolkit, 2014.

[33] Lessons Learned - NREL Village Power Program. 1998. NREL/CP-500-24938.

LEVERAGE EXISTING INFRASTRUCTURE FOR BALANCING

Leveraging existing infrastructure for load balancing can reduce project costs, of which storage represents between 20% and 40%. Storage also reduces generation requirements by better balancing supply and demand. Storage allows power to be used at a different time to when it was produced, allowing customers to use renewable energy when they need rather than when it is produced. In the simplest case of a storage asset integrated into the system, such as a battery, this entails collecting power generated during high-generation, low-demand times such as the middle of the day. This power is then released during high-demand times such as the early evening. Generation of wind and solar resources is variable, but demand typically varies substantially. Therefore, storage is needed to avoid having to build a system with sufficient generation to serve peak demand, which will be under-utilised during the rest of the day and lead to a much higher LCOE.

There are a number of different storage options:

- **Integrated storage technologies**, such as electrochemical (i.e. lead-acid or lithium-ion batteries), mechanical (flywheels) or other systems (pumped hydro or thermal, less applicable for mini-grids). Mini-grids are almost entirely based on battery-based storage, which has the advantage of relatively rapid response times but suffers from high costs and short lifetimes.
- **Diesel generation**, while not technically storage, performs a similar function in addressing generation-demand deficits. Such 'dispatchable' generation cannot store excess power, but can respond quickly to supply and demand fluctuations unlike most renewable sources.
- **Grid connection** can be used as storage or as a generation source only, depending on the license arrangements with the network operator (Eskom) and the distribution network owner (the municipality in some cases). This option is very likely to be cheaper than the previous two options, reducing the operational and capital costs of a project, but is subject to greater regulation and involves operational relationships with more stakeholders.

Storage, most likely electrochemical, may be possible through existing infrastructure from other sectors such as telecoms. Telecoms towers have batteries that may be partially unused, and therefore this represents sunk cost for the operator. A deal where this power was made available when unused could be very cheap, but sufficient availability of power on-demand is not guaranteed.

SCALABLE BUSINESS MODEL

DEVELOP A PUBLIC-PRIVATE PARTNERSHIP INITIALLY

The business model assumed in this report, and the model best able to deliver the scale up of mini-grids in SA, is a public-private partnership (PPP) model. Municipalities play a leadership and facilitator role in this model, especially in the early phases of mini-grid development in South Africa. Given that the business models and financial returns on mini-grids needs to be proven in South Africa, a fully commercial or community-owned model is unrealistic in most cases. Therefore, donor and/or public financing will be necessary at least initially, although the aim is to achieve a sustainable, privately-funded solution over time. Further explanations and justifications are given in section 6.2. In either case municipalities will play a facilitator and leadership role in this model, catalysing private sector development by identifying off-grid areas, running the competitive tenders and maintaining a well-defined path to applying projects in an area.

DEVELOP A PAYMENT MODEL ADAPTED TO CUSTOMER'S ABILITY TO PAY AND CONSUMPTION GROWTH

There are a number of different payment models, both in terms of the type of tariff and the payment collection method. Tariffs could be charged based on consumption (kWh), capacity (W), the number of devices used or the time of use. These can be flat-rate, tiered or bespoke (see full details in Chapter 11.1). Payment could be collected pre- or post-electricity consumption. Pre-paid tariffs require the purchase of credit to unlock access to electricity. Payment post-consumption includes monthly bills based on electricity use. The common goal of all models is the need for full cost recovery through the tariff (and any subsidies available), but there are different impacts and challenges with each model.

The payment model should allow for electricity consumption growth within the customer's ability to pay. Electricity consumption growth is an integral part of a viable financial model, as higher electricity consumption means higher revenue. Un-electrified villages may initially have too low a household electricity consumption to make the project viable were they not to increase their consumption over time. Capacity based tariffs, such as those using load-limiters to apply a maximum power threshold, leave no room for consumption growth over time (as well as no incentive to reduce consumption below the threshold). Formalised tiers of tariff are advantageous over flat rate tariffs in that they allow for the growth of electricity consumption as can be afforded. Tariff tiers allow for cross-subsidisation of poorer residential customers by leveraging the greater ability to pay of commercial, industrial and wealthier residential customers. This can be combined with a modular system design, where a customer that upgrades to a higher-consumption tariff is allowed to connect extra modular appliances.

Customer perception and the logistics of fee collection has a big impact of the effectiveness of the payment model chosen. Comparison of cost and service levels to the grid's cost and service level is a particular issue in South Africa, due to its high penetration rate. It is likely that a mini-grid charging a higher tariff than the grid will be judged unfavourably by the community, especially if the quality of service is lower. One solution is to avoid tariffs that are based on per kWh consumption, for example instead defining limits in terms of hours of appliance usage. This reduces the likelihood of customers calculating the $/kWh rate they are being charged for in comparison to the grid rate. The remoteness of the off-grid areas usually targeted by mini-grids increases the costs of access and logistics, though this is less of an issue for grid-tied mini-grids. South Africa has much greater rural access to financial services than other African countries, but still only 65% of the population use formal banking. Only a small fraction of the population does not rely on other non-bank and other informal means of financing (i.e. burial society)[34].

The most typical fee collection model is through a settlement leader or established settlement cooperative that manages collection and delivery of payments. Both community leaders and cooperatives allow a significant reduction in logistics around payment collection directly from households, but both require training to be effective. A further issue experienced under these models is illustrated by the micro-hydro cooperative schemes established by GIZ in Ethiopia under the EnDev program. These schemes used a cooperative to manage payments, but had to regularly check the books for omissions. Village dynamics meant that customers who were high in the village hierarchy were often let off for non-payment due to their perceived standing. Enforcing sanctions such as loss of power sometimes required involving local government.

Mobile phone enabled or other remote payment models offer a significant reduction in the cost of payment collection, **enabling individual households to pay the supplier directly**. This makes it easy to develop models

[34] FinScope South Africa 2014 – Financial Inclusion Survey. Note: A burial society is a group constituted for providing voluntary subscriptions for the funeral expenses of family members

that reduce the need for direct enforcement of payments. An example is the pre-paid model where electricity is accessed by purchasing an access code to key in to their system.

Therefore, if remote 'payment-before-service' models are available then it is likely that these will be the most effective, if not the cheapest, solution. For smaller mini-grids cheaper models may be required, and here a local established cooperative can be the most appropriate model. This cooperative would then be trained and monitored for malpractice by the private developer.

Cross-Cutting

DEFINE A CLEAR OWNERSHIP AND RESPONSIBILITIES MODEL WITH PROJECT DEVELOPER(S)

Within a PPP model clear ownership and the allocation of responsibilities is key to conflict mitigation and efficient project delivery. Private developers will be most concerned with cost recovery risk. Business and management challenges may arise around the sharing and management of investments, revenue and responsibilities within a PPP. The different types of PPPs are detailed in section 6.2 and entail different distributions of project ownership, investment and ultimately risk. Private developers will be more risk sensitive when considering a partnership, especially given their option to deliver the project independently. Guarantees or funding support may be needed to give confidence that the partnership doesn't affect their bottom line. However, given the need for donor/public financing within most mini-grid projects currently, as well as the facilitating role of the municipality, a well-managed partnership will probably be an advantageous model for a project developer.

There are a number of organisations looking into the ownership and responsibility models for mini-grids within the South African context, as well as internationally. These include government ministries such as the Department of Environmental Affairs and local development organisations like GreenCape. Such non-financial support is listed in section 9.3.

Prioritisation 1

TARGET ACCESSIBLE OFF-GRID POPULATION ZONES

Market size and population density are the key physical factors influencing mini-grid feasibility. The feasibility of grid extension, based on the distance to the existing grid and available capacity, will also determine which areas are best suited to the development of autonomous or grid-tied mini-grids. There are a number of other factors such as existing community structures, growth potential and the availability of baseload customers, which are outlined in section 7.1. The importance of each of these factors varies with the site and project, but mini-grids are most feasible in accessible off-grid population zones. Therefore, targeting such zones is one of the key parts of the site identification and prioritisation project stage.

Interconnected, grid-tied mini-grids can be utilised differently, electrifying either communities that will be reached by the grid in the future or to communities that already live close to the grid. There are a number of technical and financial challenges that need to be overcome to achieve sustainable interconnected mini-grids projects, and a number of national and international standards are given in section 9.3. One condition for grid connection is that the system must be AC and built to the national grid code, and it must also be ensured that the financial model delivers the required return once there is a connection to the grid. If done successfully interconnected grids can deliver a number of benefits, the first being cost savings on storage and system scaling by utilising the grid connection to balance supply and demand better (see *Leverage existing infrastructure for balancing)*. The mini-grid can also reduce localised grid capacity and connection constraints, as well as reducing the amount of traditional electricity infrastructure municipalities have to construct to electrify the settlement or region.

Many factors have a strong impact on the viability of a mini-grid project beyond the typically considered aspects such as physical resource and surrounding grid network. The opportunity assessment stage was highlighted in section 7.1, and an illustrative list of different relevant factors given. A number of the factors on this list are *intangible* factors such as the pre-existence of appropriate community structures or the strength of local partners, which can have a big impact on project viability. Access to communities is highly resource intensive and can be sensitive and so, for example, local partners may have pre-existing relationships. Community structures are vital for project de-risking as they enable effective fee collection, maintenance and proper use of the system. The existence of such structures can be established through site visits or by proxy through the existence of other networks in sectors like micro-finance, agriculture or telecoms.

Resource availability is not a key factor for solar-based systems due to broad availability of solar irradiation, but availability and potential of hydro, biomass and wind resources is highly site specific and requires time and cost intensive site assessments. The cost-effectiveness of solar projects is less dependent on resource than other system design aspects due to the broad availability and consistency of solar irradiation. This is especially true in South Africa, which additionally has lower than average seasonal variability[35]. However other resources are more variable, even between different sites in a region, and certified resource assessments are needed to ensure sufficient availability. Initial assessments done without specialised technical firms can be significantly different from the resource estimates obtained through a certified assessment[36]. For resources such as hydro and biomass, there are typically only a handful of pre-identified sites in a country, which are unlikely to have been properly assessed and certified. A certified assessment of a hydro site can take between 2 and 3 years and cost around 30- 50,000 USD, although this cost is highly site specific. This should be conducted as part of the feasibility Assessment stage for all projects other than those based on solar or diesel.

Most of the data required for prioritising sites can be found remotely, in national datasets and censuses. Statistics South Africa, for example, is responsible for conducting community surveys and the national census (last conducted in 2011), which includes information such as household income and expenditure on energy. Wind data is available from the Wind Atlas for South Africa (WASA)[37]. Solar satellite data is available from the PVGIS dataset[38].

IDENTIFY LOCAL CHAMPIONS AND BASELOAD CUSTOMERS

Baseload customers help to support consumption and the associated revenue required to ensure financial sustainability. For autonomous systems a certain level of guaranteed consumption is often required before a developer will be able to secure investment. Residential customers are risky for developers as it is hard to secure enough commitments to reach this level. One reason is that rural customers are likely to want to see the system demonstrated or operational before they will commit to spending money. The contribution of an individual household is small, typically, so a large number of household commitments would be required. Subsidies, where available, can help mitigate the need to secure baseload customers. Potential sources of subsidies in South Africa are detailed in Chapter 9.

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[35] Comparison of aerosol and climate variability over Germany and South Africa. H. Power, A. Goyal. 2003.
[36] Consultation with ENCO, a leading hydro site assessor and engineering consultant in East Africa, May 2015
[37] http://www.wasaproject.info/
[38] http://en.openei.org/wiki/File:PVGIS-SouthAfr-g13-opt.png

One solution to identify local champions is to build a demonstration system, to illustrate the opportunity and engage residents. One practitioner consulted by the Carbon Trust places centralised control and management infrastructure of its mini-grid in the house of a 'local champion'. This champion will get free electricity in return for protecting and maintaining the infrastructure. This organisation builds a small demonstration system around the local champion's house, and then relies on the local champion to secure enough commitments within a certain timeframe. Otherwise the demonstration system is removed. This efficiently encourages local engagement, as the local champion has an incentive to persuade their neighbours to engage with the scheme.

The more common solution, which is not mutually exclusive, is to identify local businesses, critical services or industry that would benefit from a guaranteed supply. Such institutions, like hospitals, schools or local government buildings, have a much higher consumption. Crucially these institutions have a greater need for a threshold level of uninterrupted power, and are therefore more likely to be willing to engage and commit to the project. These baseload customers are used to deliver the required financial stability, which is typically 40-60% of the total consumption (project dependent). Early engagement and signing of commitments with these baseload customers de-risks the subsequent project development phases. These customers are then valuable local champions, with a vested interest in the project's success, becoming an important driver for engaging other residential customers. If the need for electricity is great enough for these baseload customers, they may be willing to take on some payment liabilities (e.g. guarantee other customers' payments). This model is utilised by GIZ's EnDev program when developing mini-hydro community projects.

Design 3

MAXIMISE DATA COLLECTION AND UTILISATION

Systems that communicate via the mobile telecommunications network can be used for remote data collection. Traditional maintenance methods would include a regular service by trained technicians, who would only know of a fault during servicing or if a customer contacted the operator. However, there are now a number of robust remote monitoring and analysis systems that utilise the low cost microelectronics and the effectiveness of wireless networks in remote locations. These systems allow for faults to be detected remotely, sometimes before the customer has noticed. According to one SHS developer, their software is also able to determine when systems have been misused or vandalised. Whilst these systems are highly technical, and may require significant expertise and training to operate, the cost is likely to be covered by the reduction in logistical costs for remote areas, as detailed in the section *Develop a payment model adapted to customer's ability to pay and consumption growth*. Intelligent systems that utilise the data collected in this manner can be more reliable as well, with better short- and long-term controls and easier integration of multiple technologies[25].

Systems using remote data collection and utilisation are also more scalable. Data collected in this manner can be fed back to the operator to support the ongoing development of successful business models and tariffs. For example, the model could be adapted to further incentivise increased electricity consumption, utilising shifts in customers' patterns of electricity consumption over time. Consumption typically increases quickly following electrification, as customers quickly become accustomed to a higher service level.

FINANCING

Cross-Cutting

IDENTIFY SOURCES OF CAPITAL AND OPERATING SUBSIDIES EARLY ON IN THE PROCESS

Failure to identify sources of capital and operating subsidies early in the project leads to significant project fundraising and scale-up risk. Timely availability of finance enables the progress of mini-grid projects through their stages of scaling up. Early engagement is also important as financing for mini-grids can be hard to access, especially through commercial financing, for reasons detailed in section 9.2. Therefore, public sector, international donor or philanthropic funding may be required, particularly for pilot projects, which can have longer lead-in times and bureaucracy. The types of funding sources of financing available in South Africa are detailed in Chapter 9. An indicative timeframe for such engagements is given in Chapter 12.

The type of finance that is accessed within a project affects a number of elements of its design, including what tariff can be charged to the customers and as a result what type of business model is possible. Restrictions may be placed on the level and type of tariffs charged to customers through public, international and philanthropic financing sources. Government financing may also be restricted to certain types of customers or services, such as the FBE mechanism targeting low-income, low-consumption households. Therefore, a thorough understanding of the types of financing available should be established in time to inform the business model development and contracting of partners.

Cross-Cutting

ADAPT SOURCE OF FINANCE TO STAGE OF PROJECT DEVELOPMENT

International funding is anticipated to be required in the initial stages of mini-grid development in South Africa, especially for pilot projects. International funding is readily available for mini-grid schemes, due to its role as a poverty alleviation and rural development vehicle. This funding can therefore be accessed to subsidise pilot projects that are not yet able to access commercial funding sources. However, such non-commercial sources of financing have longer lead-in times and increased bureaucracy, are unsustainable in the long run, and place limitations on the scalability of the model. Therefore, the eventual transition to commercial and public financing mechanisms will be key to achieving sufficient uptake of mini-grids in South Africa.

Once the business case and revenue model for mini-grids is demonstrated then public funding sources and low cost commercial financing is expected to become increasingly available, as part of the integration of mini-grids into the national energy system. In addition to new funding mechanisms that may be developed, current electrification funding mechanisms such as INEP and FBE could be tailored to be accessible to municipalities for off-grid projects. Portfolios of projects can also be developed at this stage, and this would provide opportunities for more structured debt financing as well as delivering economies of scale for project development and financing costs. The cost of commercial financing will also decrease with the reduced perceived risk of mini-grid projects' business cases.

Cross-Cutting

IDENTIFY LOCAL INNOVATIVE PROVIDERS OF FINANCE

In addition to the traditional sources of financing addressed in Chapter 9, innovative finance models could in time be used to accelerate the future speed of mini-grid development. One example is microfinance, involving the distribution of small loans to low income households, which could be used to help them pay for connection costs. This model has been used in many other countries, for example in Ethiopia. Here the World Bank funded Development Bank of Ethiopia project has provided medium to long-term small loans to green technologies and businesses. Some projects have also used microfinance (MF) officers for installation and collection of payments. Such microfinance networks can also be used to more easily aggregate community contributions in the absence of access to crowdfunding platforms and internet banking. However due to the lack of a proven business model such funding is not currently available for mini-grids in South Africa.

Another funding example is local customer saving schemes, such as the South African Stokvel, where members pool savings every month. These funds are either given to one person to pay their expenses or spent on joint investments. Stokvels could be used to finance installation, operation or other project costs.

EXCHANGE INFORMATION WITH PEER PROJECTS

The nascence of mini-grids in South Africa means there is no optimised solution, so shared learning between different engagements in this space will be critical to swift development and effective uptake of successful models. There are a number of different types of organisations working on mini-grids, either together or independently:

- Public sector policy, regulatory or financial bodies i.e. the Department of Energy, NERSA
- Public sector implementing bodies i.e. Eskom, municipalities
- Public sector special purpose vehicles i.e. GreenCape or South Africa's Industrial Development Zones
- Mini-grid practitioners
- NGO's and philanthropic organisations

A number of these organisations produce information to support mini-grid development, such as papers on technical standards, reports on pilot projects or guidelines for developers. These sources of non-technical support are listed in section 9.3.

The funding body or driver of electrification should make contractual arrangements to ensure dissemination of learnings and best practice from a project. Private stakeholders may wish to stifle or prohibit the dissemination of a project, to try and gain an advantage over competitors. However, in a nascent sector like mini-grids, peer-to-peer knowledge exchange is critical. A case study on this is the UK Government funded £10m Urban Community Energy Fund. This fund supported local community groups to develop renewable energy projects, providing grants to facilitate preliminary studies and contingent loans towards project development costs. However, the first phase recipients were not fully engaged in passing on the best practice to other organisations. As this had been a key aim of the programme, future rounds of funding are expected to have contractual conditions on peer-to-peer exchange i.e. attending conferences, disseminating case studies. This demonstrates the appetite for dissemination across community and public sector bodies, but is perhaps more critical with market driven private-sector stakeholders. Private sector bodies will have certain information that cannot be shared, regardless of incentive, such as intellectual property (IP).

Lessons should be learned from other sectors, such as SHS project developers, as many work directly with the same communities and groups of stakeholders. Such local organisations have pre-existing access to communities, and can therefore provide key insights such as community structures and ability to pay, as well as facilitating access and engagement. Given the importance of community factors on the likely success of a mini-grid project, these insights are invaluable.

IDENTIFY AND ENGAGE WITH KEY MARKET ENTRY ENABLERS

Market entry enablers are hugely important to the development of the mini-grid sector and individual projects. A lack of effective stakeholder identification, engagement and management is a significant project risk. Potential impacts range from reducing the effectiveness of the intervention to preventing the implementation of the project. A good example is regulators, who have a final say in the authorisation of a project and elements such as the tariff(s) charged to the end user. Another example is the supply chain, which provides crucial services like the supply of components during the construction and maintenance stages. Chapter 10 details the supply chain and how to engage with it, while Chapter 13 details an effective stakeholder engagement model. Gaining community access is highly resource intensive so partnering with local organisations, such as micro-finance institutions or NGOs, can be much more efficient. These organisations can provide key insights, access and engagement, accelerating site identification and connection to relevant local authorities.

COMMUNITY ENGAGEMENT

Feasibility 2

ENSURE BUY-IN THROUGH DIRECT AND EARLY ENGAGEMENT

A project without community buy-in, or that does not understand pre-existing community structures and dynamics, will not be successful. There are a number of potential reasons for customer dissatisfaction, including failure to meet the aforementioned expectations of grid service level, a lack of community ownership or insufficient training to enable proper use of the system. These risks can be mitigated by direct and early engagement that develops local employment and ownership; delivers training and manages expectations; and aligns with community structures and other development initiatives. These three aspects are covered in separate sections below.

Neighbouring villages need to be identified, engaged and considered within all community engagement activities. This success factor is illustrated by the Lucingweni and Hluleka reserve projects in the Eastern Cape[32]. These were pilot projects developed by CSIR for the Government of South Africa to explore the potential of mini-grids for poverty alleviation and demonstrate the technology. It achieved this demonstration of technology but also highlighted key learning points around community engagement. For Lucingweni the timeframes imposed on the project's development phase meant there was insufficient community engagement prior to the start of the project. Crucially the neighbouring villages were also not engaged, and they felt that it was unfair for the host settlement to be getting free electricity. This led to recurrent vandalism which forced the village to store the equipment in the control house, dismantling the system. In Hluleka, which served a nature reserve, the management organisation failed to prevent visitors and locals coming to the site and doing household tasks such as ironing. This led to inefficient operation from overuse of the system, including use of its backup diesel generators.

Community access should not be established until it is very likely that a project will be developed, to avoid raising expectations. Although early engagement is important, it is equally important to have a good understanding of what is going to be done beforehand. Lessons learned from previous South African projects show that raising expectations unnecessarily can lead to great tension with the community. Therefore, the prioritisation of sites, and the determination of their feasibility, should be well established before engaging on the topic of electrification. This can be done by utilising national databases and censuses to determine inputs into the feasibility assessment, such as household income and expenditure on energy.

Cross-Cutting

DEVELOP LOCAL EMPLOYMENT AND OWNERSHIP

Local employment significantly increases engagement and appreciation of an energy project, reducing the risk of vandalism and customer dissatisfaction. The typical method is through local employment, both for maintenance and in-kind contributions towards the construction of the system. Low level maintenance can be done by training a local community member. This is the model used by Trama TecnoAmbiental in Senegal, where a local association was created to manage Operation & Maintenance, fee collection and replacement. The local technician and staff were sub-contracted for O&M, and the project was 20% financed (cash and in-kind) by the village. Such sub-contracting of local teams saves on costs while also increasing the financial benefits seen by the community from the project. However, as discussed in the section on community structures below, care must be taken to avoid this income disrupting traditional hierarchies.

Direct ownership is another option, such as the distribution of shares to the community. This is exemplified by the Samsø Vindenergi wind development in Denmark[39]. Here 2 out of 10 windmills were converted to community shares once the project had broken even, and the shares were distributed evenly to each person on the island. This created a stronger vested interested in the sustainability of the project. Ownership is also bolstered through regular consultations during the development phases, especially if community contributions can impact on the final design. Regardless of the effectiveness of the community engagement, insurance against damages and theft should always be taken out, and may be a prerequisite for investors.

Low level maintenance can be done by a trained local person in the community, with reduced operating costs and logistics versus external technicians. The most frequent maintenance needed for a mini-grid project is low level, such as changing faulty wires or replacing broken meters. These tasks can be done by a trained local technician, decreasing the costs and the response time while increasing ownership. Less frequent, more serious maintenance or repairs will require specialist technicians and possibly equipment, who will be located in a nearby city. It is not cost effective to train and maintain such specialists locally, especially given their infrequent use. For portfolios of projects, these specialists can service many projects, giving an economy of scale for maintenance costs.

Cross-Cutting

DELIVER TRAINING AND MANAGE EXPECTATIONS

Many of the stakeholders involved in rural electrification have little or no experience of mini-grids, renewable energy, electricity or electronic payment systems. This includes both the households and customers, local supply chains, settlement leaders, local government and other market enablers. Without training these individuals or organisations may feel isolated from the project, potentially resulting in non-engagement, alienation and possibly opposition. This training is especially necessary in South Africa due to the current poor perception of mini-grid and renewable-based projects.

Customer training is needed at various stages of the project, including to engage customers, ensure correct use of the system, manage customer's expectations and demonstrate the payment system. In addition to the perception of mini-grids mentioned previously, rural communities are unlikely to be aware of the limitations of a mini-grid. Training on using the system is therefore vital as mini-grids are less robust than larger grid systems, although grid-tied systems will come close. As a mini-grid serves a smaller number of customers, the actions of a single user can have a much greater effect than for a larger system. The most common challenge is a single user exceeding the expected or explicitly stated limit on household consumption, adding extra unanticipated load through additional appliances or customers. This can then result in the system having to deal with larger loads than it was designed for, leading to blackouts and damaged equipment. Options for limiting overuse through consumption management are detailed in the section *Optimal Mini-grid infrastructure*. Training is critical for a customer's understanding and effective use of such consumption management measures and payment models, especially if this utilises technologies such as smart meters.

Technical training is often required, both of local technicians to provide low-level maintenance and also of the local supply chain. The use of local customers or other citizens to perform low level maintenance was discussed in the section *Develop local employment and ownership*. It is unlikely that the community will have qualified technicians, so training will be required. The available local supply chain is also unlikely to have mini-

[39] http://www.samsovind.dk/

grid specific experience, and the operating partner will need to provide at least minimal training before they can be effectively utilised. For the provision of spare parts this could include a workshop on the type of components that will be required over the course of the project's operational lifetime. Mobile payment service providers can be utilised for remote data collection, as discussed previously, but two-way training may be required to integrate the two systems.

Cross-Cutting

ALIGN WITH COMMUNITY STRUCTURES, OTHER INITIATIVES AND LOCAL AND NATIONAL ECONOMIC DEVELOPMENT GOALS

Community structures, including social and professional power dynamics, can be easily disturbed by an energy project, especially if there are responsibilities or revenue streams allocated to specific individuals or groups. Traditional rural communities can have strong hierarchies driving the social dynamics of the settlement. An influx of income to certain individuals can destabilise such structures, such as a local business hosting the mini-grid or a local technician being employed for O&M. This may result in resentment and non-payment within certain parts of the community. Such hierarchies present other issues relating to payment collection, as covered in the section on Scalable Business Model previously.

Misalignment with local government development objectives and initiatives will affect the sustainability of a project. Local and national government agencies are key enablers of any rural community project, including as sources of financing, and must be engaged and satisfied with any project. This requires effective stakeholder management as well as alignment with development objectives and initiatives. This is true also for NGOs, multi-lateral donors and other organisations that provide either financial or technical support towards rural electrification. This can be mitigated through effective engagement using the methodology in Chapter 13.

8. REGULATORY, INSTITUTIONAL AND LEGAL ENVIRONMENT FOR MINI-GRIDS

8.1. THE NATIONAL ENERGY REGULATOR OF SOUTH AFRICA

The National Energy Regulator of South Africa (NERSA) is a regulatory authority for electricity, piped gas and petroleum pipeline industries, established as a juristic person in terms of Section 3 of the National Energy Regulator Act, 2004 (No. 40). NERSA's mandate is to regulate these industries by the terms of the Electricity Regulation Act, 2006 (No. 4), Gas Act, 2001 (No. 48) and Petroleum Pipelines Act, 2003 (No. 60).

Current NERSA generating licensing requirements (Schedule 2 of the Electricity Regulation Act, 2006) do not currently apply to demonstration or off-grid projects. However, a draft notice released by the Department of Energy, December 2016, details amendments to these licencing exemptions. In summary, mini-grid projects under 1MW would most likely not be required to obtain a license from NERSA, although they will need to register with NERSA. Mini-grid pilot projects would also not require a licence. The following generation facilities are exempt, under certain circumstances:

- Facilities connected to the grid at the same point as the load that they serve, i.e. where no wheeling takes place (with installed capacity under 1 MW)
- Facilities wheeling through the grid (with installed capacity under 1 MW)
- Off-grid generation (with installed capacity under 1 MW)
- Facilities used for demonstration purposes (no sales of electricity allowed)
- Back-up generation

Projects meeting the above conditions, but with a capacity between 1MW and 10MW would require a licence but no ministerial approval. Above 10MW, a licence and ministerial approval is required. The local municipality needs to provide a general operating license to the project developer. This is mainly for safety reasons and applies to all sizes of electricity generation infrastructure. One exemption condition for all grid-connected projects is that the generation limit given in the Integrated Resource Plan has not been reached.

A distribution license will be required for a mini-grid operator and operators will need to develop an annual cost of energy calculation according to NERSA guidelines, demonstrate compliance with grid codes and technical standards and demonstrate robust health and safety procedures. There is a fixed cost associated with a distribution license and an efficient licensee should be able to recover its costs.

8.2. KEY REGULATORY POLICIES

Annex III: Municipal Regulations further details the policies and acts described in this section.

A municipal service delivery agreement with an external service provider must comply with the Municipal Systems Act and the Municipal Finance Management Act (municipal policies) as well as the Energy Regulation Act (energy policy). The Energy Regulation Act 4 of 2006 is an Act to establish a national regulatory framework for the electricity supply industry. This includes establishing NERSA as the national regulator, with powers to provide for licences and registration and to regulate the reticulation of electricity by municipalities. The Energy Pricing Policy is also of relevance, setting out general tariff principles for operating energy systems.

The Municipal Systems Act of 2000 legislates for the municipal local system of governance. Chapter 8 of this Act details the regulatory framework for delivering municipal services, including defining the conditions for entering into service agreements with other municipalities and external service providers. This includes the responsibilities that can be allocated to the other party under such an agreement, including accounting and budgeting, collection of fees, operation and maintenance, and design and implementation.

The Municipal Finance Management Act (MFMA) of 2003 looks to establish sound and sustainable financial management of municipalities and other local government institutions. This includes provisions for establishing public-private partnerships, in clause 120. The primary condition is for the completion of a feasibility study that outlines the benefit to the municipality of such an agreement, as well as the impact on future revenue flows, the legal and obligated roles of the private party and the transfer of appropriate technical, operational and financial risks to the private party.

It is important to note that the MFMA restricts, but does not block, municipalities from entering into a contract that will impose financial obligations on the municipality beyond the three years covered in its annual budget, in clause 33**.** The main concern, which applies also to the public-private partnership clause 120, is the condition that the municipality must solicit the views of the National Treasury and other specified stakeholders, as well as the local community, to submit to the municipality comments or representations in respect of the proposed agreement. This process can be onerous and time consuming, especially for the local community engagement, potentially taking up to 18 months. Some municipalities have purportedly hired consultants to manage this process, while others have avoided commencing such projects in the first place. See Annex III.

A further useful reference is the National Treasury Public-Private Partnership Manual, which provides detailed guidance and best practice to public and private parties on establishing PPPs in South Africa.

8.3. PERMITS AND OTHER REGULATORY REQUIREMENTS

LAND

Electricity generation infrastructure projects with capacity under 1 MW do not fall under national land development permitting regulation. The relevant local authority may have developed specific rules and policies pertaining to the authorised use of the site land, and these should be adhered to.

PLANNING PERMISSION

Planning permission for a mini-grid will be subject to the relevant authority's planning rules and processes. The relevant authority is the municipality in which the project is situated.

ENVIRONMENTAL IMPACT ASSESSMENT

A mini-grid will most likely not require an Environmental Impact Assessment, based on the following criteria for the development of facilities or infrastructure for the generation of electricity (specific protected locations may require an EIA regardless of these criteria):

- No EIA required - the electricity output is less than 10 MW and the facility covers an area of less than 1 hectare. This will most likely be the case for a mini-grid.
- Basic Assessment required - the electricity output is between 10 and 2 MW, or less than 10 MW and the facility covers an area in excess of 1 hectare; excluding where such development of facilities or infrastructure is for photovoltaic installations and occurs within an urban area.
- Full EIA - the electricity output is 20 MW or more.

Always check with the local provincial department of the Department of Environmental Affairs[40] whether your project requires an EIA. They will also provide EIA forms and guidance. The Western Cape Government Environmental Affairs & Development Planning provides a useful EIA 'How to' guide that describes the steps, timeframes and best practices[41].

PROCUREMENT

The Municipal Supply Chain Management Regulations set a minimum procurement standard which all municipalities have to adhere to. Each municipality will have a Supply Chain Management Policy that sets out its standards, illustrated by this GreenCape guide: Regulation on procuring a municipal service under a public-partnership agreement is detailed in section 8.2.

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[40] Department of Environmental Affairs Provincial Departments: https://www.environment.gov.za/contacts/provincial_offices

[41] https://www.westerncape.gov.za/eadp/files/eia-process-how-to-guide.pdf

9. AVAILABLE SOURCES OF FUNDING AND SUPPORT

Financial sustainability of mini-grids is one of the main challenges for developers, and additional funding support is often needed. On the one hand mini-grids require significant investment costs for generation and distribution; on the other, revenues are constrained by regulations around tariffs or by the rural communities' ability to pay. There are a number of ways in which financial sustainability can be achieved, with the simplest being to design and scale the system to achieve a suitable payback period within the restrictions. Normally smaller systems are more expensive per customer, so this may not be possible, although cost factors such as local manufacturing can improve margins. The second option is to seek external sources of funding and support that help spread or decrease the cost of developing and operating a mini-grid, or support the development of efficient strategies – related for example to technology, stakeholder/community engagement, business model and finance - leading to enhanced financial sustainability. There are many different forms and sources of funding available in South Africa, and this section details the available options and the necessary steps and conditions to apply for access to this funding.

Successful applications for funding hinges on the preparation of all of the necessary documentation and financial and business models to assure financiers that there is an acceptable level of risk. While some project developers have successfully raised funds from international donors and investors, municipalities will have to be involved, and often lead the process of raising funds from the onset, especially for the establishment of a pilot project. A number of organisations offer technical assistance rather than funding and their support should be sought in the early stages of a mini-grid development.

9.1. FUNDING SOURCES

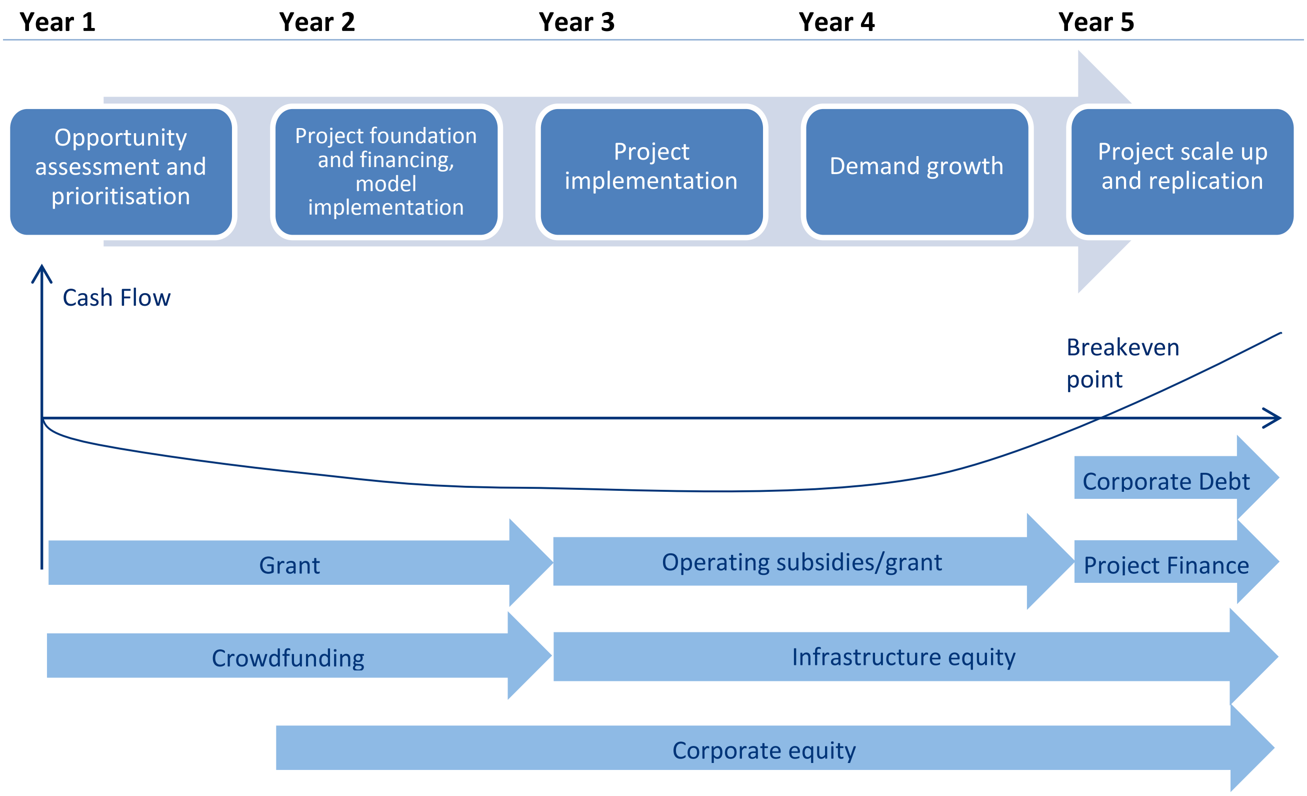
There isn't a history of specific mini-grid funding and financing projects that would help identify a core pool of mini-grid funders in South Africa. In this context, municipalities will need to make a good case for a mini-grid project to funding and financing organisations that have either been involved in decentralised energy systems in South Africa or mini-grid projects in other African countries. Databases of such funding and financing organisations – international donor funds, national funds and commercial banks - are available online and include information on the funder's funding instruments and the levels of funding available. Relevant databases include:

- The Green Mini-Grid Help Desk – Financing section: http://greenminigrid.se4all-africa.org/: the website provides a list of organisations that are funding mini-grids across Africa.
- The African-EU Renewable Energy Cooperation Programme (RECP) – Funding database section: http://www.africa-eu-renewables.org/. The database lists organisations that fund renewable energy projects across Africa. It is possible to filter for the Southern Africa region. In the Finance Catalyst section, matchmaking services are available as well for project developers.
- The SEforALL Africa Hub - http://www.se4all-africa.org/se4all-in-africa/regional-initiatives/mapping-of-energy-initiatives/. This report lists the mini-grid support initiatives in Africa, both financial and technical.
- GreenCape's Market Intelligence Report for Energy Services: http://greencape.co.za/resources/. The report includes a list of funding solutions focused on South Africa.

The different sources of funding by project development stage are shown in Figure 8, and the characteristics of such sources in Africa is given in Table 6.

In parallel, municipalities should leverage their existing international relationships. In particular, twinned governments (regional, local) may be interested in supporting the development of mini-grids for social and environmental purposes.

Figure 8 - Sources of funding by project development stage. Adapted from RECP Mini-grid Policy Toolkit.



INTEGRATED NATIONAL ELECTRIFICATION PROGRAMME (INEP)

In South Africa the Integrated National Electrification Programme (INEP), within the Department of Energy, is a key national vehicle for electrification, alongside municipalities and presidential projects. Capital grants for rural electrification are channelled through INEP, via an allocation from the National Treasury, which are then distributed by INEP to its various on and off-grid initiatives. Grid initiatives entail connections' infrastructure for Eskom and municipalities, while off-grid initiatives include concessionaires and municipality-led projects. INEP does not currently cover mini-grids, historically and because of the lack of proven projects. However, INEP is seen as a critical source of future funding to enable the sustainable large-scale roll out of mini-grids in South Africa, and projects are theoretically able to receive INEP grants.

Grid initiatives under INEP receive almost 100% capital and operational cost subsidies, while off-grid initiatives do not. For example, under the concessionaires' programme, INEP subsidises up to 80% of the capital cost of selected solar home systems. This is based in part on a cost-benefit analysis of each proposed project to determine whether an area should be electrified via a non-grid solution or not. This leaves off-grid programmes needing customers or other contributions, and are seen as a poor option compared to the free grid connections benefiting other (often close by) settlements. As of 2012, grid-connected customers paid no customer connection fee/down payment or tariff/service fee. By contrast, off-grid served customers paid ZAR 110 Rand connection fee and a monthly tariff/service fee of ZAR 89[14] (8.2 and 6.7 USD respectively at time of writing), although connection fees for basic supply have been subsequently removed for non-grid applications.

Municipalities will have a crucial role in engaging the Department of Energy to mainstream mini-grids within INEP and other national programmes, as well as encouraging the Department of Energy to support on and off-grid programmes equally. Within the early stages of mini-grid development across the country it is expected that INEP will part-fund mini-grid projects (the distribution elements of the project) as long as they feature in Integrated Development Plans and are grid-code compliant. It is also hoped that the level of subsidisation for on and off-grid projects will be normalised by this time. However, this will require a number of developments, including:

- Lobbying for stronger support of mini-grids within national programmes such as INEP
- Demonstration of the business case for successful municipality-led mini-grids, including proving the availability of sufficient technical and managerial skills to deliver projects
- Work to clarify the inter-relationship of the various electrification initiatives (i.e. INEP, municipalities and presidential projects) within the broader national electrification strategy

Important to the success of this approach will be communication with the Department of Energy and Eskom. For example, a better understanding is needed of the types of information and documentation that would be required by the Department of Energy to enable the funding of mini-grid projects. There will be a number of other conditions to be fulfilled, with another being the guarantees of quality of service to customers. An understanding of the range of barriers needing to be tackled will maximise the potential for them to be addressed through pilot project phases.

Table 6 - Characteristics of capital funders in Africa. From RECP Mini-grid Policy Toolkit. The scale in depth of market, engagement in mini-grid sector and risk appetite is illustrated on a scale from 1 low to 4 high.

	Grants		**Equity**		**Debt**	
	Subsidies/TA	Seed/ Start-Up	Growth/ Expansion	Infrastructure	SME/ Corporate	Project Finance
Sources	• Governments • Foundations • Donors/ DFIs	• Friends/ Family • Angel investors • Impact funds • Foundations	• Impact • funds • Venture capital funds • PE funds	• PE funds, most DFI-sponsored	• Local banks • Int'l banks w/ local presence	• Commercial banks • EXIM banks • DFIs
Depth of market	+++	+	+++	++	+++	+
Engagement in mini-grid sector	++	++	+	+	+	+
Risk appetite	++++	+++	++	++	+	+
Basis for funding decision	Business model, management / developer track record					
	• Dev impact • Status of • sector / need for subsidy	• Dev impact • Market potential	• Profitability • Balance sheet	• Stage of dev. • PPA / permits • Other contractual agreements	• Balance sheet • Collateral	• Debt service coverage ratios • Guarantees, other risk mitigations
Amount	$30k – 10m	$100k – 1m	$1 – 5m	$10m+	$20k – 10m	$15m+ (selected smaller transactions)
Expected tenure	N/A	3-7 years	3-5 years	5-10 years	6 months - 5 years	7 – 15 years
Typical return expectations	None (or return of capital)	Impact: 5 – 35% Commercial: 30%+	Impact: 5 – 20%+ Commercial: 20%+	15-25%	16-24% (local currency)	6-12% (hard currency)
Examples	• AECF REACT • EEP S&EA • TEDAP/ ESME • USAID DCA • USAID DIV	• Beyond Capital • Eleos Foundation • ERM Foundation • Invested Dev'mnt • NovaStar	• Acumen • Bamboo • Khosla Impact • LGT VP • Persistent	• Berkeley/ AREF • Frontier • IFC IfraVentures • InfraCo • ResponsAbility	• Barclays • CfC Stanbic • EcoBank • Equity Bank • StanChart	• AfDB • CfC Stanbic • FMO • Norfund • OPIC

9.2. ACCESS TO FUNDING

CHALLENGES OF RAISING FUNDING

There are a range of challenges faced by enterprises looking to provide energy to customers via off-grid electric technologies. These challenges include raising both patient and commercial finance, which we summarise in Table 7. This, amongst other sectoral challenges such as nascent business models, a lack of supportive, local institutional capacity and customer affordability, has hampered off-grid energy companies from scaling-up significantly.

Table 7 - Challenges that energy access enterprises face in raising finance

Summary	Detail
• High upfront capital costs	• Renewable energy projects have far higher upfront (and lower operational) costs than traditional energy projects, which means that return on capital takes longer than a traditional project. • Loan tenures tend to be much shorter than is needed for off-grid energy projects.
• Revenue risk	• Customers have low purchasing power. • Off-grid energy suppliers are subject to revenue risk, even when using pay-as-you-go models, which mitigate credit risk. • Limited data is available on successful revenue models that enable the productive use of energy and mitigate revenue risk.
• Small ticket size	• Off-grid energy projects have much smaller ticket sizes than traditional energy projects, often below the lending threshold and capability of commercial and development banks.
• Limited operational data	• Off-grid electricity is a nascent area and lenders lack multiple successful precedents which give them confidence in their investments.
• Technology risk	• Technology is often imported from abroad and may not be fit for the local environment.
• Regulatory barriers and risk	• Existing barriers may include fiscal and import barriers; risks may include, for instance, the lack of protection for a mini-grid operator in case the main grid reaches its area of operation.
• Human resources	• Limited availability of employees with requisite skills to operate and repair the equipment.

There are however, significant developments which will help the sector to scale including:

- Considerable technology and business model innovation happening at a local and international level
- Falling prices for PV modules, electricity storage and smarter payment and management systems
- The ability for poor and vulnerable communities to access and monetise their local renewable energy resources
- A growing appreciation that energy access policy makers, donors and practitioners must aim for the higher Tiers of access, if access to energy is to help meet all of the UN's Sustainable Developments Goals

Additionally, there are a number of barriers that can be addressed by a mini-grid developer to improve the project's access to financing, split into project and investor side barriers.

PROJECT-SIDE BARRIERS

Project-side barriers centre on proving the business case and mitigating risk. In order to receive funding a project must instil confidence in the financier on the (lack of) risk of non-repayment. There are a number of potential factors that need to be addressed to achieve this:

- **Information:** The project description must be clear and well-structured and presented
- **Technical feasibility:** A completed technical feasibility study and all vital stakeholders engaged
- **Financial feasibility:** Established bankability from cash flow model and demonstrated IRR/NPV
- **Capacity:** Demonstrated capacity for successful delivery, including sufficient project preparation, implementation and monitoring capabilities, particularly for project finance
- **Risk and responsibilities:** Proven understanding of project risks and mitigation actions. Clear allocations of risks and responsibilities between project developer(s) through formal legal agreements

A useful support tool is the financing and retail tariff tool provided with the EUEI PDF Mini-Grid Policy Toolkit - http://www.minigridpolicytoolkit.euei-pdf.org/support-tools. Other support tools are also available.

INVESTOR-SIDE BARRIERS

The first type of investor-side barrier is general investment environment barriers. General investment barriers include governance and political risk (weak legal enforcement for investor, political instability), systemic market risks (market volatility, liquidity crises etc.) and idiosyncratic credit risks. Due to the dynamism of a country's investment climate this is not covered further here, but an example of a detailed analysis can be found in the US Department of States' South Africa Investment Climate Statement, 2015, https://www.state.gov/documents/organization/241954.pdf.

The second type of barrier is investor capacity constraints for mini-grids, and usually entails a lack of understanding of mini-grids and their associated project risks. The relative nascence of mini-grids, especially in South Africa, means that project risk may be overestimated, increasing the cost of financing. This issue will be reduced with the operation of more successful mini-grid projects in South Africa, as well as with increased government support and initiatives. Other reasons for a lack of willingness to finance mini-grids include long payback periods and small deal sizes. Mitigate against investor capacity constraints by understanding the investment landscape fully, considering each investor's experience with financing off-grid projects.

9.3. TECHNICAL ASSISTANCE AVAILABLE

NATIONAL

National Rationalisation of Standards (NRS) and South African Bureau of Standards (SANS)

The South African Bureau of Standards is responsible for the promotion and maintenance of standards and quality in connection to commodities and services, including South Africa's representation in international standards. The National Rationalisation of Standards body is responsible for co-ordinating user requirements on a national scale prior to these being tabled as national specifications[42]. The NRS 097 series will be used to facilitate the interconnection of the small-scale embedded generation (SSEG) to the distribution network (not

[42] Standard Transfer Specification Website: About STS

currently complete)[43]. Once the series is complete, some parts of it will be converted into a Renewable Energy Grid Code (REGC) and adopted as part of a licence condition to the distributors. https://www.sabs.co.za/

Local development agencies such as GreenCape and Eastern Cape Rural Development Agency (ECRDA)
Local development agencies have been established to help develop the rural and green economies across South Africa. ECRDA focuses on agriculture, alternative energy and rural development. GreenCape operates in the Western Cape and has produced, amongst others, a resource pack for municipalities on small-scale embedded generation, including guidelines for setting tariffs and technical aspects[44]. http://greencape.co.za/ http://www.ecrda.co.za

Association of Municipal Electricity Undertakings (AMEU)
An association of municipal electricity distributers and other national, parastatal, commercial, academic organisations involved in electricity supply in South Africa. This association aims to promote quality of service and management excellence amongst its members, facilitating communication and providing advisory services. It produces research on various aspects of electricity supply, as well as storing databases of relevant bills, standards and legislations. http://www.ameu.co.za

South African Smart Grid Initiative (SASGI)
Developed and led by the South Africa National Energy Development Institute (SANEDI), built up of electricity distribution industry stakeholders, SASGI looks to provide smart grid-related policy inputs, address the gaps in standards and in the deployment and application of technology. This also includes renewable and green solutions and the assessment of smart grid related developments within the South African electricity supply industry. http://www.sasgi.org.za

INTERNATIONAL

Sustainable Energy for All (SEforALL) Help Desk, in association with Energy4Impact and INENSUS GmbH
Energy4Impact/INENSUS consortium provides business development services (BDS) to Green Mini-Grid developers, assisting them on a wide range of issues, from business planning, market development and grid design to project finance, grid operation and maintenance. http://greenminigrid.se4all-africa.org/

The main international technical standard for mini-grids is the International Electrotechnical Commission (IEC) Technical Specification Series 62257. This is a comprehensive set of standards covering the technical and organisational aspects of mini-grids, including contractual questions and implementation plans. These standards provide a comprehensive and logical framework for the design, installation, and maintenance of mini-grids, with a focus on efficiency, safety and user friendliness. A number of other standards are listed in Table 8.

[43] Note: Embedded generation is defined as a generation asset (i.e. power station) connected directly to a distribution asset, usually the national distribution network. However, a mini-grid often involves the construction of a separate, localised distribution network.
[44] GreenCape. Small Scale Embedded Generation (SSEG) Resource Pack - http://greencape.co.za/resources/small-scale-embedded-generation-sseg-guidelines/

Table 8 - Potential International Standards Organisations for Mini-Grids. Energy Access Practitioner Network, 2012.

Product/ System Standards	Institute of Electrical and Electronic Engineers (IEEE), International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), GIZ, Photovoltaic Global Accreditation Project (PVGAP), American National Standards Institute (ANSI), Lighting Africa
Installation Certification	North American Board of Certified Energy Practitioners (NABCEP), International Commission on the Rules for the Approval of Electrical Equipment (IECEE), American National Standards Institute (ANSI), International Renewable Energy Certification Organization (IRECO)
Training Workforce	Institute of Sustainable Power (ISP), International Accreditation Forum (IAF), American National Standards Institute (ANSI)

Source: http://www.iec.ch

10. UNDERSTANDING AND WORKING WITH THE MINI-GRID SUPPLY CHAIN

10.1. MINI-GRID SUPPLY CHAIN: RELATIONSHIPS AND ROLES

The various types of organisations in the mini-grid supply chain are given in Table 9, indicating potential roles, contractual arrangements, drivers and concerns and allocations of risk and liabilities. Understanding these different relationships is a key part of the stakeholder engagement methodology outlined in Chapter 13. A directory of supply chain organisations in South Africa and the United Kingdom are given in Annex IV.

The allocation of risk and liability between the public and private organisations within a mini-grid project is challenging, and no protocol or precedent has been developed or demonstrated in South Africa. This is in part due to the nascence of renewable mini-grid projects. This aspect is currently being investigated by a number of government and other public sector institutions. Example considerations for the municipality are given in Table 9, which must be included in the PPP agreement with the project developer. More extensive documentation is available through the World Bank's PPP Knowledge Lab and PPP Infrastructure Resource Centre. This includes a case study on the Australian, Chile and South African Government's managing of contingent liabilities in PPPs: https://ppp.worldbank.org/public-private-partnership/.

Standards: The local development agency, GreenCape, has produced a resource pack to assist all relevant stakeholders involved in the installation, management and ownership of small-scale embedded generation: http://greencape.co.za/resources/small-scale-embedded-generation-sseg-guidelines/.

Procurement: The Municipal Supply Chain Management Regulations set a minimum standard which all municipalities have to adhere to. Each municipality will have a Supply Chain Management Policy that sets out its standards: http://greencape.co.za/assets/municipalprocurementguideREPRO.pdf.

Table 9 - Summary of mini-grid supply chain roles, drivers, relationships and share of liabilities.

Supply Chain	Role	Contractual arrangement	Drivers and concerns	Allocation of risks and liabilities
Municipality/ Project developer	Partner. Responsible for the technical design aspects and day-to-day management	Competitive tendering to form a public-private partnership with the municipality. Long-term contractual agreement	Project returns on investment, cost recovery and risk exposure	Subject to negotiations. All risks and liabilities passed to private developer must be within the PPP agreement. Illustrative considerations: • Joint liability for corporate governance • Contractual limits on the ability of the private party to contract itself or affiliates • Municipality to retain veto rights over certain liabilities taken on by private party
National regulator (NERSA)	Enabler. Project authoriser through establishment of regulatory compliance	Licences and long-term contractual agreements (PPA) with municipality	Maintenance of national infrastructure, quality of service and contractual standards	No liability.
National utility (Eskom)	Enabler. Regulatory compliance, technical assistance and, if grid-tied, electricity supplier	Contacts with municipality for supply of energy by the system if grid-tied and for construction of distribution infrastructure	Impact of the system on national energy infrastructure i.e. capacity constraints, running costs	No liability unless involved in asset ownership or operation. If purchasing main power, then Eskom may be liable for quality of service under the purchase agreement.
Engineering firm and technical consultancy	Third-party contractors for site feasibility studies, construction and O&M (developer may deliver construction and O&M)	Competitively tendered discrete studies by municipality. Fixed term O&M service contract with project developer	Level of sales – number and scale of site studies commissioned	Liable for services provided under the contract, including construction risks. Contracted level of O&M service should factor in unexpected failures, malpractice etc.
Technology manufacturer and distributor	Contractor. Providing equipment and spare parts for the system	Commercial procurement to project developer	Level of sales – number and scale of systems installed	Liable for the quality of equipment and service provided under contract. Warranties should be sought.
Telecom and mobile payment provider	Contractor	Annual use-of-service fee for running monitoring and remote payment systems through project developer	Level of sales – Level and length of service required	Liable for the quality of service provided under contract.
Fuel distributer	Contractor. Fuel supply for diesel backup generation (if required)	Medium-term contract with project developer for supply of fuel	Level of sales – Number of projects, years of operation and level of demand	Liable for the quality of service provided under contract.

11. REVENUE MODEL

11.1. TARIFFS

TYPES OF TARIFFS

The choice and level of tariff affects both the willingness and ability of the consumer to pay, and the ability of the developer to recover operating and investment costs. However, the choice of tariff also affects the ability of the mini-grid to support the economic and social development of its customers, for example cross-subsidising low income, low consumption users with higher tariffs for higher consumption users. Different tariffs also incentivise characteristics of system use to help optimise performance, for example charging a higher tariff during peak hours. Some common tariffs are given below[45]:

- **Capacity-based tariff** is a flat-rate or subscription tariff, where the instantaneous maximum load is limited. There is no incentive to reduce consumption below the limit under this tariff.
- **Consumption-based tariff** is a pay per kWh of energy tariff, utilising regular meter readings. Unlike the lifeline tariff this is a flat rate regardless of level of consumption, making it hard for low income users to connect.
- **Per-device tariff** is where the rate is set by the number of devices. No metering or load-limiter required, but on-site control is needed to ensure that the correct number of devices are used.
- **Lifeline or inverted block tariff** increases with consumption, allowing cross-subsidisation.
- **Binomial tariff** varies according to power source (i.e. renewable or diesel generator) used or period of the day (i.e. peak/off-peak).
- **Seasonal tariff** varies according to seasonal variation in resource availability, promoting energy efficiency.
- **Energy-as-service tariff** charges not on energy consumed but on services provided, such as litres of water pumped or hours of TV service. Can help to avoid comparisons of per kWh cost against the grid.
- **Interruptible tariff** offers a discounted rate for customers who agree to an interrupted service. This allows for better system scaling through 'aggressive' demand-side management.

Hybrid tariffs incorporating aspects of multiple common tariffs are possible, but may be complicated.

SOUTH AFRICAN CONTEXT

A review of the national regulation of small-scale and mini-grid renewable generation is ongoing by the Department of Energy. Only certain municipalities are presently allowing the connection of small scale embedded generation in its absence. Currently there is a 1 MW cap on 'small-scale' embedded generation, although such projects are not to large-scale generation NERSA licencing regulations (normal asset regulations apply). All rights and responsibilities fall to the municipality, or Eskom if it is the distributer in that municipality. Municipalities such as those in the Western Cape have developed their own rules around small-scale generation, and with the support of organisations like GreenCape are trying to push these rules and bylaws nationally. GreenCape have produced a resource pack for municipalities on small-scale embedded generation, including guidelines for setting tariffs and various technical aspects[44].

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[45] Billing Models for Energy Services in Mini-Grids, GIZ PEP Workshop Daniel Philipp. 2014.

Only 'general tariff principles' are given in South Africa's Electricity Pricing Policy, and the most relevant of these is the guideline for municipalities to provide electricity to the customer at the lowest possible rate[46]. This does not limit the rate that can be paid to a generator, but when comparing electrification options this sets the national Eskom grid electricity price as a benchmark for mini-grid tariffs. Another consideration is the expectation for renewable to compete with non-renewables in terms of price, although price premiums can be agreed on a case by case basis. NERSA released a consultation in 2015 on regulating small-scale embedded generation[46]. The finalised regulation is expected to replace the 2011 *Standard Conditions for Embedded Generation within Municipal Boundaries* document, which only covers up to 100 kW generation.

Another tariff consideration within South Africa is community acceptance, where expectations around grid service level and cost are a barrier to mini-grid tariffs. Tariffs such as the energy as service tariff, which helps to reduce comparisons with grid rates by not charging on a per kWh basis, can help mitigate against this issue.

11.2. SUBSIDIES

TYPES OF SUBSIDIES

There are different types of subsidies that can be offered to projects and developers. Some form of subsidy will most likely be necessary initially to make a mini-grid project viable in South Africa. National public sector bodies provide most forms of subsidy, although it can include international and philanthropic financing. Subsidies can be on a project-by-project basis or programmatic, and are often reduced in level over time to avoid dependence. Some common types of subsidies are given below:

- **Capital expenditure subsidies** for construction, usually focused on distribution assets, or equipment purchase;
- **Grants for feasibility studies** such as the Urban Community Energy Fund case study illustrated previously;
- **Results-based financing (operational subsidy)** such as reimbursement based on each new connection;
- **Loan guarantees and other risk underwriting** reduces the cost of project finance by de-risking investment;
- **Tax and duty exemptions** including fuel tax, investment tax credits, deferred tax programmes, customs duty; and
- **Non-financial support** such as technical assistance or developing balancing mechanisms

SOUTH AFRICAN CONTEXT

There are a number of different subsidies already in place in South Africa that could be tailored to serve mini-grids projects:

The **Integrated National Electrification Programme (INEP)**, which is detailed fully in 9.1, currently focuses only on SHSs. However, it may be the case that the Department of Energy will expand INEP to include mini-grids in the future.

[46] NERSA Consultation Paper: Small-Scale Embedded Generation: Regulatory Rules. 2015

Free Basic Electricity (FBE) was introduced in 2003 as an operational subsidy to help municipalities enable electricity access to low income households, with a provision for 50 kWh/household/month for free. This was extended to include off-grid energy sources through the Free Basic Alternative Energy (FBAE) programme. This has had some limited success, with issues arising around the continuity of the subsidy and its application process[14]. However, this is a potential mechanism for subsidising municipal mini-grid projects in the future, and indicatively the iShack Project has managed to secure FBAE subsidies from Stellenbosch Municipality[47].

The **Renewable Energy Finance and Subsidy Office (REFSO)** sits within the Department of Energy and is responsible for the management, dissemination and advice of renewable energy subsidies. To date six projects totalling 23.9 MW have been subsidised, including small scale hydro, a biogas to electricity project, wind energy and landfill gas to electricity. However, this is unlikely to be relevant for mini-grids as it only applies to projects above 1 MW.

11.3. RECOMMENDATIONS

The chosen tariff should incentivise energy efficient practices, consider consumer expectations and allow for the connection of poor households. Although project specific, this means the tariff should reflect the level of consumption, comparisons to grid rates should be avoided if possible, and a subsidised rate should be available to low income customers (either through cross subsidisation or through accessing external subsidises). This combines elements of the consumption-based tariff, energy as service or per-device tariff and the lifeline tariff. A further adjustment could be to include a rate reduction for customers willing to have an interruptible service. In conclusion a suggestion would be to have a tariff that is charged in terms of the services provided, with a tiered system based on the level of services (i.e. consumption) and a subsidised bottom rate for low income, low consumption households.

For pilot projects, another possible option is to charge the same rate as Eskom's national grid rates. This would be appropriate for the case described in section 7.2, *Target highest possible quality of service*, where the mini-grid was being trialled in a settlement near an existing grid connection. Here the grid would serve as a backup to the mini-grid to avoid disruption of service, enabling the pilot to be done without affecting the customers' service should the pilot fail. Here continuity is the target, and so the rate would remain the same as they were paying for grid electricity.

The tariff rate targets a level at or below that of the Eskom grid rate, with subsidies used as needed to ensure project sustainability at this rate. Given municipalities' responsibilities for providing electricity services to its customers, mini-grids should target rate parity to ensure competitiveness with other electrification options. This is the target despite the other benefits offered by mini-grids, such as easing capacity and connection constraints to the grid, which mean a higher rate could still be attractive to municipalities and Eskom. Especially for the pilot phases it is likely that the sustainable rate without subsidies would be above the grid rate, and so subsidies would then be chosen at a level which ensures sufficient financial returns.

International donor funding is expected to be the primary source of subsidies during the pilot phase(s). There are many different types and sources of international donor funding, detailed in Chapter 9, including multi-lateral development banks and national development agencies. The environmental, sociological and economic impact of electrification of communities means that accessing such funding should not be restrictive

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[47] A project by the Sustainability Institute and University of Stellenbosch which provides electricity to informal settlements - www.ishackproject.co.za/

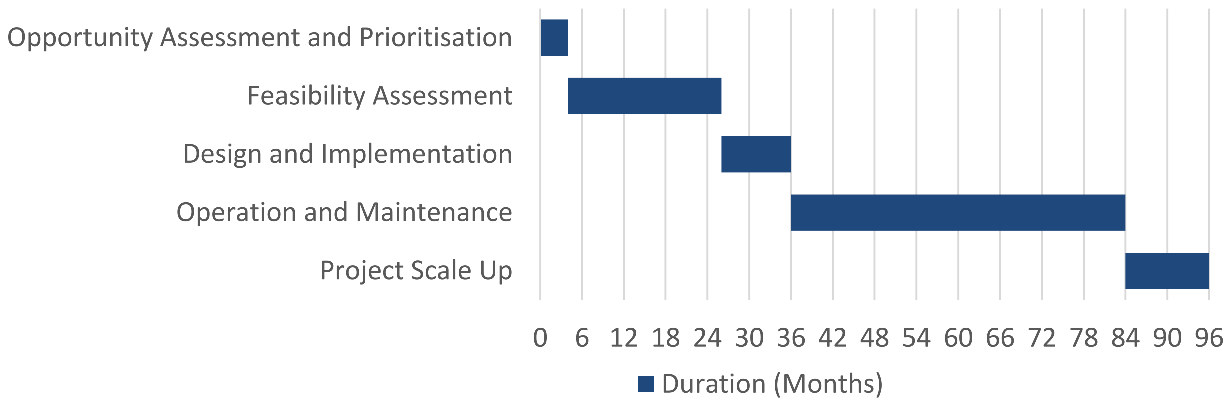
(dependent on the preparation of necessary documentation and sufficient de-risking of financing through preparation of financial and business models, detailed in Chapter 9).

Government funding is expected to be the primary source of subsidies for post-pilot projects. It is expected that the proven business case for mini-grids from pilot project will make mini-grids a nationally-supported mechanism for electrification. Mini-grids should therefore be able to access government funding, through new programmes or tailored existing national programmes like the INEP and FBE. The broader benefits of mini-grids to the South African energy system (highlighted in section 3.1) mean that the Department of Energy or Eskom is anticipated to bear some of the costs under such a programme, although predictions at this point are speculative. This could include the cost of the flexibility afforded by mini-grids, such as storage or distribution infrastructure.

12. PROCESS OVERVIEW: PROJECT TIMEFRAMES, COSTS, MILESTONES AND RISKS

This section details indicative timeframes, costs, responsibilities, key milestones and risks for a mini-grid project. An indicative timeframe is given in Figure 9. The guide is split into five general project stages: Opportunity Assessment and Prioritisation; Feasibility Assessment; Design and Implementation; Operation and Maintenance; and Project Scale Up. These stages are outlined in section 7.1. This section is not a step-by-step instruction manual for project development but a high-level framework to inform the successful development of a bespoke project(s).

Figure 9 - Indicative timeline of project stages.



Responsibilities and tasks are shared between multiple stakeholders, with the municipality as the facilitator and driving institution for the project. The municipality is responsible for management and coordination for all non-technical phases, as well as providing direction across all stages. A third party contractor would conduct the feasibility study and resource assessment. A mini-grid practitioner, in a public-private partnership with the municipality, would be responsible for delivering the technical aspects such as the system design, implementation and coordinating operation.

Three-year project development time is typical, although economies of scale are possible for portfolios of projects. The timeframe outlined here extends for 8 years, which concerns a single project. This includes three years until construction is finished and approximately four years of operation before project scale up (best practice for system scaling with anticipated demand growth). Multiple projects could be developed simultaneously over this timeframe, depending on capacity and financial restrictions. This is especially the case for the opportunity assessment and prioritisation and the design and implementation stages.

Cost estimates are highly project dependant, especially on system size, so will not be indicated here. The EUEI PDF Mini-Grid Toolkit financial model provides default cost estimates, and an indicative breakdown of capital costs is shown in Figure 10. Project management and engineering services make up approximately 10% of capital costs here, and capacity building and training 3%. A selection of further references are *Solar PV in Africa: Costs and Markets* IRENA 2016, *World Energy Outlook* IED 2015, *Green Mini-Grid Support Study* IED 2013, *Renewable Power Generation Costs in 2012: An Overview* IRENA 2012. Total installed costs for solar PV mini-grids, normalised by system size (USD/W), are given in Figure 11 - **Solar PV mini-grid total installed cost and breakdown by cost component, 2011-15. IRENA Solar PV in Africa: Costs and Markets, 2016.**

Figure 10 - Indicative CAPEX breakdown for a solar PV system. TTA, 2014.

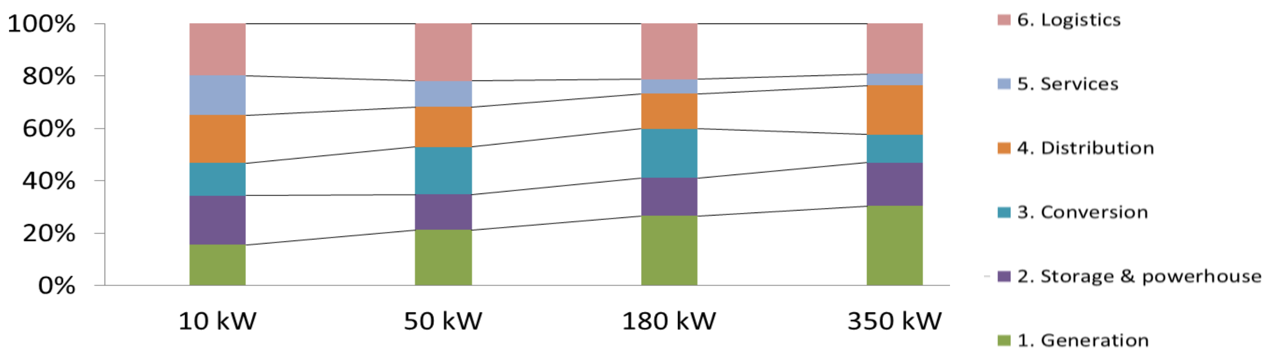
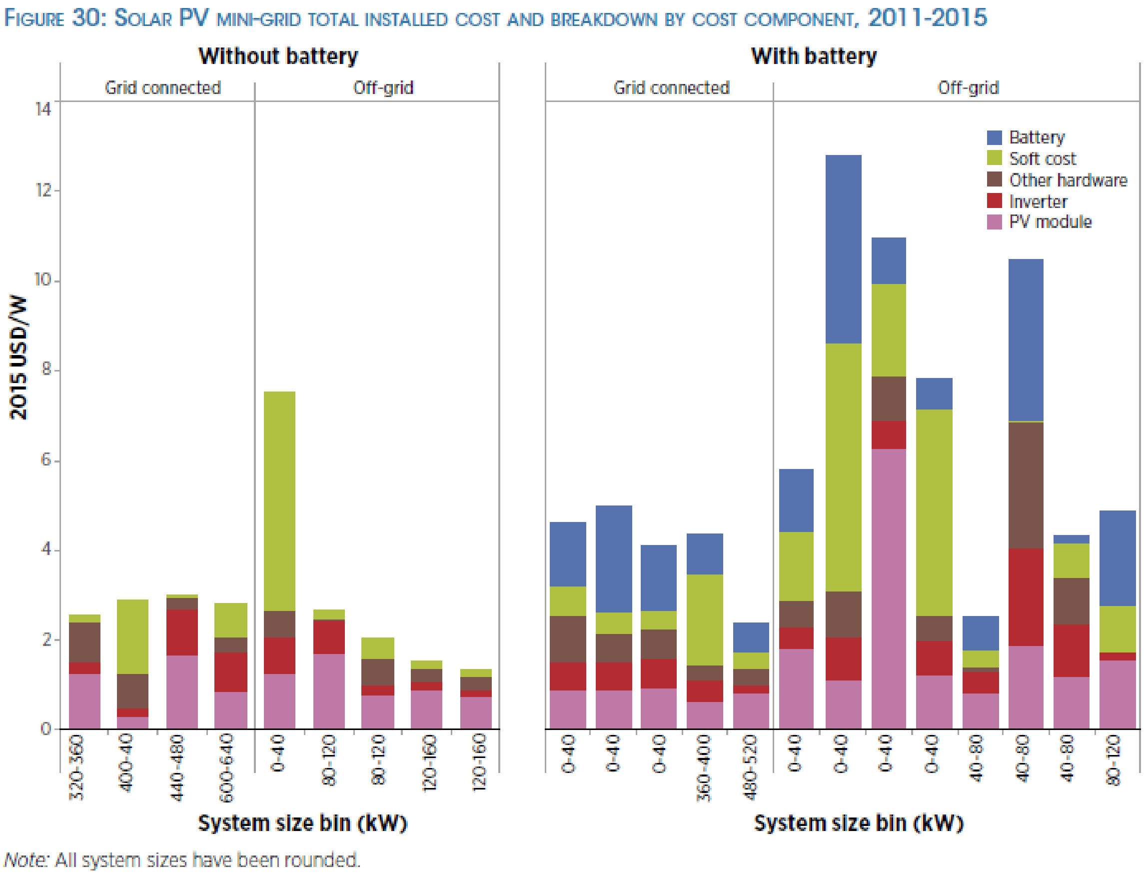
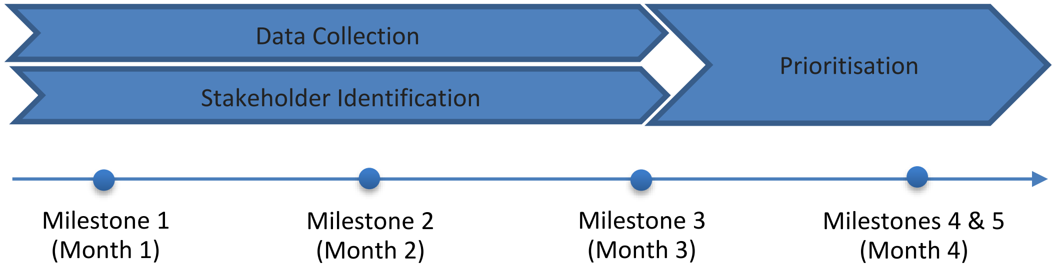


Figure 11 - Solar PV mini-grid total installed cost and breakdown by cost component, 2011-15. IRENA Solar PV in Africa: Costs and Markets, 2016.



12.1. OPPORTUNITY ASSESSMENT AND PRIORITISATION



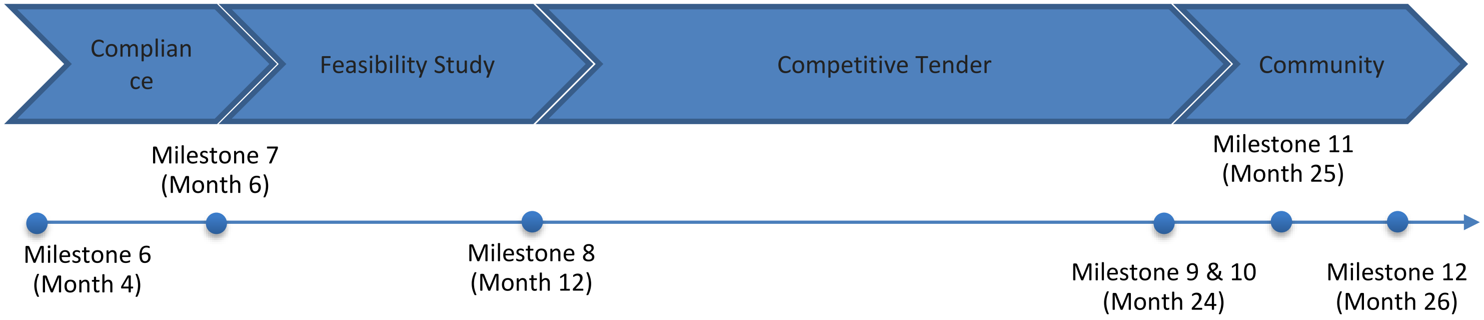
The municipality would be responsible for all stages of this phase. For a municipality that is already engaged with mini-grids and has established methodologies and priority sites, this phase could be reduced by two months. Key milestones are shown in Table 10.

Table 10 - Key milestones for the opportunity assessment and prioritisation phase.

Milestone		Description	Completion Date	Key Risk Mitigation Actions
1	Assessment methodology developed	Identify which criteria are to be considered and how (i.e. weighting of quantitative factors, holistically).	Month 1	Priority should be given to country-level, up-to-date and GIS-based data. South Africa has a number of GIS databases, including the South African Renewable Energy Resource Database. Must consider community and enabling factors as well as resource.
2	Stakeholders identified	Potential local partner(s) identified and preliminarily engaged	Month 2	See Chapter 6 for key stakeholders in South Africa. Ensure sufficient depth of partner's team for effective delivery of responsibilities (i.e. accessing local financing, regular community engagement, project championing). Local capacity will reduce operating costs.
3	Data gathering trip	In-country trip to gather in-country statistics and GIS data from key stakeholders (i.e. national office of statistics). Combined with satellite data and previous research	Month 3	Identification and engagement with the sources of data at least two weeks before trip. Age and granularity of data is critical, especially for human factors such as income which can vary substantially over time and between different regions. Local partner knowledge and networks may be valuable here. The preliminary demand estimation is a crucial part of this phase, informing the pre-feasibility study.

4	Prioritisation complete	Priority sites found for the planned number of projects	Month 4	Prioritise the same number of sites as there will be projects, as the following stage is highly resource intensive
5	MoU signed with stakeholders	Includes first approval from regulator and letter of support from the Department of Energy	Month 4	Effective stakeholder management is key, see Chapter 9. Three stages of engagement with the regulator (NERSA) and other key enabling stakeholders (Department of Energy and Eskom): Concept phase, pre-feasibility and before project commissioning.

12.2. FEASIBILITY ASSESSMENT



A third-party contractor would deliver the feasibility assessment, to avoid conflicts of interest, as well as the resource assessment. The municipality would deliver the competitive tendering for the project developer, who would probably lead on the community engagement and demand assessment. Key milestones are shown in Table 11.

Table 11 - Key milestones for the feasibility assessment phase.

Milestone		Description	Completion Date	Key Risk Mitigation Actions
6	Resource assessment completed for hydro, biomass or wind resources	Here we will assume 0 months for a solar based project. Shift timeframe by approximately 1 year for wind, and 2-3 years for biomass or hydro	Month 4	Initial estimates of resource potential can be orders of magnitude off for wind, hydro and biomass. Proper, independent certification by a specialist is required

7	Regulatory compliance understood	Permits, EIA and Land Agreements requirements understood and any identified risks mitigated	Month 6	See section 4.4 for permit requirements. Mini-grids are exempt from many regulations. Project development costs rise steeply from this stage, so any risk of non-compliance should be understood and mitigated as early as possible. Wayleave agreements and lease costs are critical risk and cost factors, this may be under agreement with the municipality or individual property owners.
8	Feasibility study	Completed by independent third-party contractor, not final project developer. Load modelling, system scaling, level of generation and storage and technology choice	Month 12 (6-12 months' duration bureaucracy dependent	Use proven technology (easier to maintain, cheaper, more secure in lifetime estimate) and the design lessons learned in section 3.2. Engage with the regulator to understand the minimum technical and quality of service standards that a project will have to meet, and incorporate this into the feasibility study.
9	Competitive tender for practitioner complete	Municipalities are expected to be required to competitively tender for such a PPP, although strategic partnerships would be preferable for post-pilot, programmatic projects	Month 24 (Only 3 months if non-competitive tendering)	Proposal will need to demonstrate that the minimum technical and quality of service standards required by the regulator will be met in the proposed PPP. Consumption management mechanism, payment model and business model must be developed before this proposal.
10	Community engaged	Meetings and workshops held with the community and its hierarchy to inform as to the proposed project, its characteristics and impact on the community	Month 24	Ensure a thorough understanding of the community structures and hierarchies as well as what their needs and wants may be. Be careful to manage expectations. This is why this engagement is only done after the feasibility study is complete and regulatory compliance de-risked.
11	Baseload customers identified and engaged	40-60% of demand for the grid to be ensured through local services and businesses (not contracted yet)	Month 25	Users with a need for uninterrupted supply will be the most willing to take on the risk of early engagement in the scheme. Education on the availability, reliability and affordability of off-grid RE technologies may be needed. Encourage or contract them to become local 'champions'. Local champions are effective at engaging other customers.
12	Full demand assessment complete	Direct engagement to establish demand, to inform the feasibility assessment and design stages	Month 26	For previously un-electrified customers any demand estimation is likely to be an underestimate. Household income and current expenditure on energy are good proxies for the limit to consumption. Consider potential for addressing other development needs (i.e. water, healthcare, or education) when estimating demand. Technical design is highly dependent on demand so accuracy is vital.

Figure 12 shows the key stages and considerations in a feasibility assessment of a mini-grid project. This is included here to illustrate the general process that will be delivered by the contracted third-party assessor. Some indicative inputs and factors underlying the stages and considerations are highlighted in Table 12, demonstrating the types of inputs that could be required from municipalities during this activity. The availability of such information is a vital catalyst for private sector engagement, giving business confidence in financial models. For example, an understanding of the existing and forecasted level of consumption from local businesses is a key element in forecasting demand within the initial needs assessment. This needs assessment then steers the construction of a more targeted scenario, which defines key project criteria such as the anticipated daily load profile and peak capacity required.

Figure 12 - Feasibility assessment: key stages and considerations.

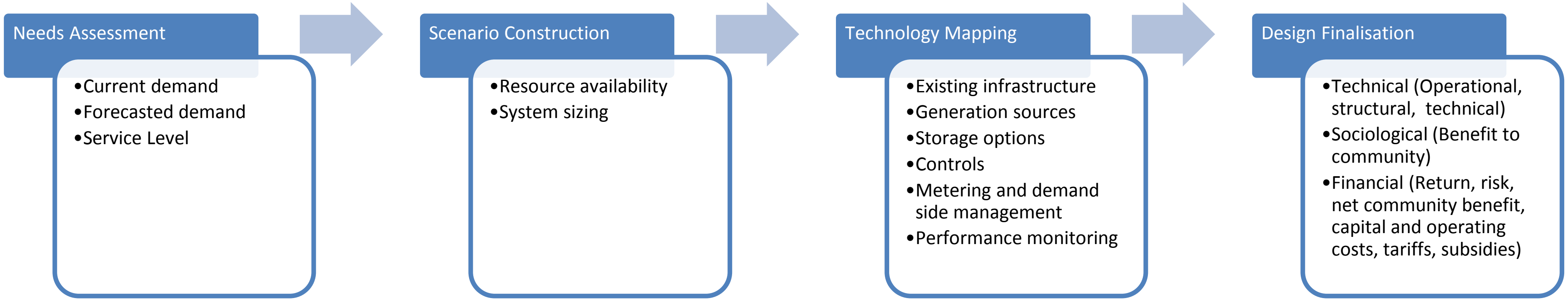
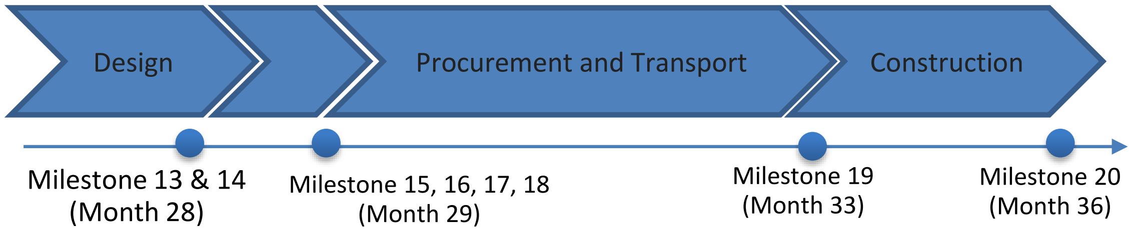


Table 12 - Indicative inputs and factors required for a feasibility assessment.

Stage	Consideration	Indicative Inputs and Factors
Needs assessment	Current demand	Number and density of inhabitants, existing appliances, economic activities, ability and willingness to pay (local diesel price, existing centralised power systems), seasonal variation (i.e. agricultural cycles, tourism)
	Forecasted demand (people and consumption)	Level of economic activities, population development, typical consumption patterns (i.e. change in lifestyle and financial status), historical growth rates
	Quality of service	Daily capacity and duration of service, reliability, level of appliances
Scenario construction	Resource availability	Resource availability (resource data, identified sites, peak capacity, intermittency), distance from community
	System sizing	System requirements for peak capacity, daily capacity and load profile, duration of supply, affordability, reliability, quality
Technology mapping	Existing infrastructure	Existing storage, electricity networks, baseload industries, existing individual generation sources (i.e. diesel generators)
	Generation sources	Single technology or hybrid system and required storage level, resource and need (not technology) driven
	Storage options	Existing storage (i.e. telecoms towers), grid connection, system storage (lithium-ion or lead-acid battery)
	Controls	Electronic controls and converters
	Metering and demand side management	Metering choice (passive load limiters, pre-payment meters), payment model (fee-for-service, monthly tariffs)
	Performance monitoring	Availability of mobile and mobile payment systems and smart control for remote monitoring, community or cooperative monitoring
Design finalisation	Technical	Operation (power quality, forced outage rate, response speed, efficiency, start-up time, capacity factor), structural (footprint, lifetime, modularity, lead time), technical requirements (maintenance, local technical knowledge, interconnection equipment)
	Sociological	Benefit to community: job creation, ownership, development service (i.e. water, healthcare)
	Financial	Return (payback period, NPV/IRR of investments), risk (theft, political), net economic benefit to the community ($/year), investment and operating costs, potential ancillary service supply, tariff (factoring for regulatory constraints), subsidies

Source: GIZ *What size shall it be? A guide to mini-grid sizing and demand forecasting*, 2016. ESMAP *Technical Paper 007: Mini-Grid Design Manual* (21364), 2000

12.3. DESIGN AND IMPLEMENTATION



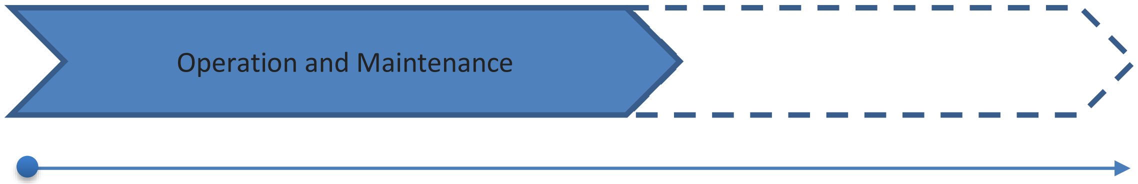
The municipality would lead on the activities relating to financing, regulatory compliance and tendering, while the technical delivery partner would lead on the other activities. Good further references on the technical design of mini-grids, as well as business models, is the Alliance for Rural Electrification's (ARE) *Rural Electrification with Renewable Energy: Technologies, quality standards and business models*, 2011; and the Energy Sector Management Assistance Program (ESMAP) *Technical Paper 007: Mini-Grid Design Manual (21364)*, 2000. Key milestones are shown in Table 13.

Table 13 - Key milestones for the design and implementation phase.

Milestone		**Description**	**Completion Date**	**Key Risk Mitigation Actions**
13	Technical design	Design of the system: the positions of distribution lines, what components are being used etc. Consumption management mechanism, payment model and business model developed	Month 28	Technical rigour is a sound investment. Robustness, reliability and robustness of design is key. Consider competitors' propositions
14	Customer rules established	Contracts and associated use-of-system rules for customers established	Month 28	Needs to ensure customer payment and effective enforcement options
15	Baseload secured	Contractual agreements signed with all baseload customers	Month 29	This is a pre-requisite to securing financing and project implementation so legally-binding agreements are necessary
16	Financing secured	All financing, including subsidies, secured	Month 29	Grant money is readily available for energy access projects, especially for pilots. Ensure sufficient financing is secured to guarantee a return on investment, see Chapter 5
17	Regulatory compliance complete	Land rights approved, licences secured and tariffs approved. Environmental Impact Assessment completed if applicable, and PPA secured if grid-tied	Month 29	Final approval from the regulator, see Chapter 4 for conditions. For example, if the mini-grid will be grid-tied the design must adhere to national grid codes. Insurance is needed

18	Operator selected	Operator(s) responsible for O&M selected and trained, including local technicians and supply chain. Training is especially needed if a local managing cooperative is established	Month 29	Ensure sufficient depth of the operating team to support their responsibilities. Basic business skills training can dramatically increase their effectiveness of support
19	Equipment procurement and transport complete	The supply of equipment must be secured, with a lead time of at least three months for imports. Locally produced equipment may take around one month to transport	Month 33	A supplier agreement may fall through, have at least one back up for each element. Encourage competition for business to foster innovation and improved efficiencies. Communication with the community before construction begins is crucial
20	Construction completed	System fully ready for operation	Month 36	Consider and address the legal implications for an overrun construction time (i.e. supply contracts, customers, regulator)

12.4. OPERATION AND MAINTENANCE



Operation and maintenance begins (21, 22, 23)

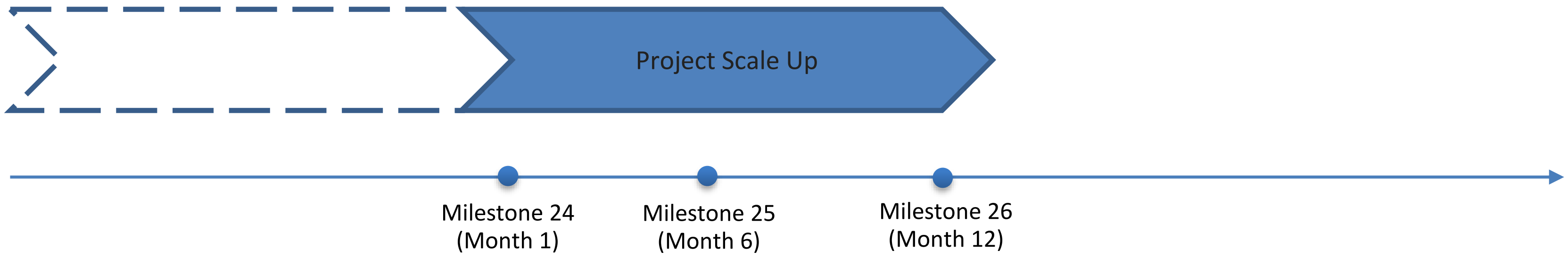
The technical delivery partner would be responsible for management of maintenance or the organisation(s) responsible for maintenance. The municipality would retain an oversight role, including the monitoring of performance against metrics such as quality of service. Key milestones are shown in Table 14.

Table 14 - Key milestones for the operation and maintenance phase.

Milestone		Description	Indicative Frequency	Key Risk Mitigation Actions
21	**Performance monitoring**	Energy and operational performance monitored and analysed, including overall and household load patterns	Continuous/ at intervals	Understanding actual patterns of use and system load is critical to lifetime performance and effective project scale up. Also critical to monitor the agency responsible for fee-collection if not done remotely

22	**Regular servicing**	Low level servicing by local technician, using spare parts collected through the local supply chain	Once per month	Check meters and monitoring systems for potential sabotage or interference
23	**Unplanned repairs**	More severe issues addressed by specialist	As required	Substantial economies of scale for this fixed cost are possible for portfolios of projects

12.5. PROJECT SCALE UP



Due to the uncertainties in estimating the actual demand patterns and growth of a system, the first two years of operation are used as a knowledge gathering stage. Should the design estimations for demand be substantially different from that observed, adjustments would be made from year 3 onwards. Therefore, best practice is to scale the system to take into account the demand growth for no less than three years, and no more than six years. Scaling the system for its size beyond year 6 results in sub-optimal system performance for too many years to be economical, but less than three years would leave no time to adjust the system to its actual measured performance. The scale up phase is a repetition of many of the steps from the first 4 phases of the original project development, and the same responsibilities for its completion. Key milestones are shown in Table 15.

Table 15 - Key milestones for the scale up phase.

Milestone		Description	Indicative Duration	Key Risk Mitigation Actions
24	**Need for scale up found**	Analysis from performance monitoring identifies need	< 1 Month	Service scale ups must align with ability to pay as well as demand
25	**Pre-conditions completed**	Includes community awareness of proposed changes, further training as required, consultation and agreement with all stakeholders including community and regulator, funding secured and amendment to all contracts	5 Months	Extensive community engagement is required, especially if affecting tariff level or use of system characteristics. Opportunity to survey customers and implement improvements over the first phase
26	**Completion of scale up**	Construction of required infrastructure	6 Months	Extensive communication with the community before construction begins is crucial

Table 16 - Indicative risk register. Adapted from Risk Management for Mini-Grids, Alliance for Rural Electrification, 2015.

Risk	Likelihood	Impact	Indicative mitigation action(s)	Owner
Technology and performance e.g. failures and defects	Low-med	V. high	Use standardised, quality components. Pass risk onto project developer to increase likelihood of using reliable installation and O&M sub-contractors	Project developer
Construction completion	Med	High	Backup supply chain. Target (where possible) accessible locations. Insurance	Project developer
Non-payment of bills including lack of subscription	Med	High	Utilise mobile money payment technologies and pay-before-service revenue models. Make customers aware of consequences of non-payment. Promote productive use of electricity. Local champions to generate subscription	Project developer
Political and regulatory e.g. instability, unrest, war, changes in legal frameworks	Low-med	High	Communication and involvement of local and national government. Monitoring of the political situation. Insurance	Municipality
Unpredictable demand	Low-high	High	Peer-to-peer knowledge sharing on local patterns of use. Use metering to allow more active management of demand and for identifying the need for up-scaling	Project developer

Resource price variability	Med-high	Med	Avoid diesel and biomass, or reduce share of generation in hybrid system to reduce exposure. Reflect resource price in tariff structure	Project developer
Social acceptance	Med	Med	Extensive community engagement and training throughout project development. Partnerships with local organisations where possible	Project developer
Resource availability	Low-med	Med	Low risk except for biomass, solar in SA has low seasonal variability. Design for multiple feedstock types and diversity of suppliers	Project developer
Theft and vandalism	Low-med	Med	Construct fencing around centralised assets. Develop a sense of community ownership through direct ownership, employment and involvement	Project developer
Foreign exchange risk	Low-med	Low-med	Use local investors. For international investment can use hedging instruments, but may be complex and expensive	Project developer
Environmental and force majeure	Low	Low-med	N/A. Biomass especially sensitive to environmental change, and to a lesser extent hydro	Project developer
Operational e.g. inefficient performance due to malpractice, conflicts of interest, miscommunication	Low	Low-med	Regular monitoring and auditing of project developer and any subcontracted organisations. Establish rules and operational protocols to standardise processes, including conflict resolution procedures	Project developer

13. AN EFFECTIVE STAKEHOLDER MANAGEMENT METHODOLOGY

13.1. RATIONALE

An important factor in reducing policy development risk and avoiding undesirable outcomes as a result of policy intervention is effective stakeholder management. Inadequate or incorrectly-timed stakeholder engagement is one of the biggest contributors to project risk; until you can be sure of your stakeholders and correctly understand their perspectives, you cannot be sure that your intervention will be effective. To be effective stakeholders must also be engaged in the right way at the right time, requiring an engagement strategy that determines the scope of the engagement, the desired outcomes and available timeframes. Therefore, a brief guideline for effective stakeholder management is outlined here.

13.2. METHODOLOGY

Stakeholder management can be done in different ways, but an effective model centres on 5 key steps:

Identification of the stakeholder groups, organisations and people that have an interest in, or effect on, the proposed project. This could include enabling and regulatory bodies (i.e. NERSA and the Department of Energy), beneficiaries (i.e. businesses and households), supply chain or other organisations. Even indirectly involved third-parties, such as a local SHS distributers or industry representative groups, should be considered at this stage.

Mapping of the stakeholders and their interests, goals and motivations. Information on these stakeholders is built up here to inform an effective engagement strategy. For example, this allows an analysis of the identified stakeholders by categorising them as either *Supporters*, *Opponents*, *Observers* or *Unknown*.

Prioritisation of the mapped stakeholders based on a ranking of their interest and potential impact on the project. This indication of stakeholder relevance allows a more targeted engagement that allocates more time and resources to high-priority groups. For example, high interest, high influence stakeholders are likely to be already engaged and could provide barriers to the projects' completion, so direct engagement should be used (i.e. one to one meetings, workshops, advisory committees and questionnaires). Less important stakeholders could be engaged efficiently through communication channels such as emails, public meetings or media releases.

Planning the engagement approach based on the prioritisation stage, with the key messages determined and then tailored to each audience. Specific tailoring will be required for organisations that are required to be actively engaged over the course of the project's development and implementation. Planned engagements should be aligned to the project plan (or Gantt chart) to ensure the correct timing of engagements.

Engagement is the final stage through which the stakeholders are contacted and connected to the project. Engagement activities should focus on gaining structured feedback, understanding key motivators and barriers, building up an assessment of risk profile and collecting any required data or information. All engagements should be captured in writing and feed back into the engagement methodology.

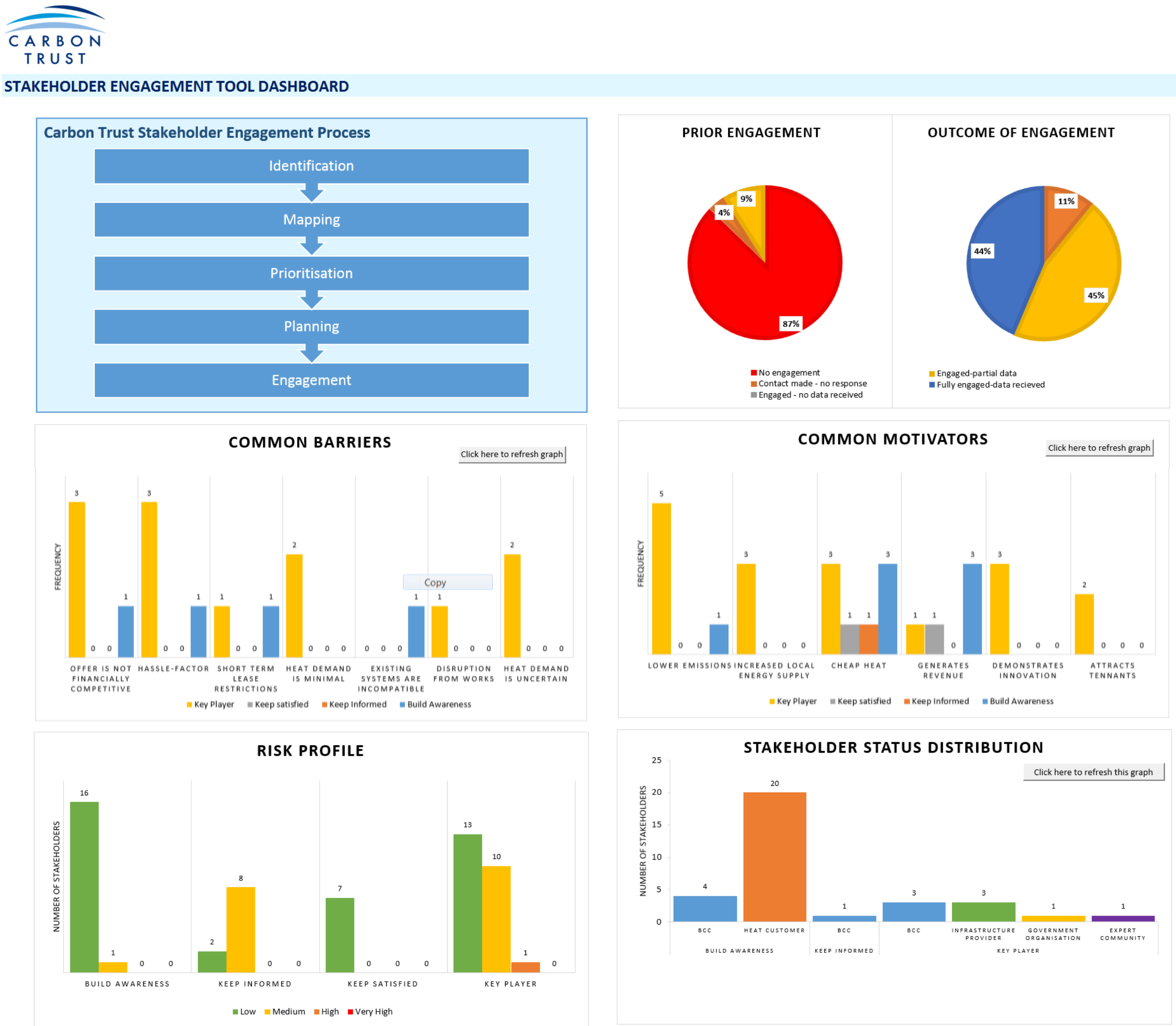
The first stage of this methodology, *identification*, should begin as soon as possible at the beginning of the project, with local stakeholders identified once the prioritised sites have been established. The final phase, *engagement*, should begin by the end of the feasibility assessment phase at the latest, as detailed in section 12.2. The majority of engagements should be complete before construction starts.

13.3. STAKEHOLDER MANAGEMENT MODEL

The most effective way to implement the suggested stakeholder management is through a purpose built stakeholder management tool. These support the development of the five steps detailed in the previous section, including developing the engagement strategy and capturing and reporting on outcomes. One example of such a tool is given below for reference.

Carbon Trust Stakeholder Management Model. The Carbon Trust has developed a unique, proprietary excel-based stakeholder management model that can be used to establish an engagement strategy, capture and report on engagement outcomes using the refined 5-step approach detailed in section 13.2. The model is capable of planning and tracking progress, capturing and sorting stakeholder information and views into a logical format and automatically generating reports to summarise engagement across groups and individuals. The model acts as a 'living' tool, which evolves throughout the engagement programme, reports can be generated at pre-determined intervals in order to track progress. A screenshot example of the dashboard for this tool is given in Figure 13. Interest in this model can be directed to Emma Ashcroft, Programmes Associate: Emma.Ashcroft@CarbonTrust.com.

Figure 13 - Carbon Trust Stakeholder Management Model Dashboard



14. ANNEX I: RECOMMENDATIONS ON THE ENABLING ENVIRONMENT FOR MINI-GRIDS

Progression dependent feasibility funding model

This model is recommended for consideration to the Department of Energy as a mechanism for incentivising the exploration of off-grid energy solutions by municipalities, developers or communities. This model was developed and used in the UK for county councils and community energy projects under the Urban Community Energy Fund. Funds are provided by the UK Government with grants of up to £20,000 available for early stage development such as prefeasibility studies and loans of up to £130,000 available towards later-stage project development costs. Crucially these loans are contingent loans as they are only repayable if the project is successful. This addresses a significant financial risk to the development of mini-grids as well as other infrastructure projects: the high cost of project development phases that may be lost if a project is not successfully implemented.

This report would like to highlight this case study as a potential additional funding model in South Africa to facilitate the development of mini-grids. This would be suitable once the business model for mini-grids in SA has been proven, and would align with the broader inclusion of mini-grids within the Government's energy model.

15. ANNEX II: SELECTED GIS-BASED ELECTRIFICATION SUPPORT TOOLS

Name and Author	Link	Example of use for rural electrification
Network Planner by Modi Labs, Columbia University	http://networkplanner.modilabs.org/	F. Kemausuor et al. Electrification planning using Network Planner tool: The case of Ghana - http://www.sciencedirect.com/science/article/pii/S097308261300121
GeoSim Integrated Rural Electrification Planner by Innovation Energie Developpement	http://www.geosim.fr/	Tanzania National Electrification Program Prospectus - http://www.ied-sa.fr/index.php/en/documents-and-links/publications/send/3-reports/33-national-electrification-program-prospectus.html
UNITE Electrification Access Tool by UNDESA	https://unite.un.org/sites/unite.un.org/files/app-desa-electrification/index.html	Mentis et al. 2015 – A GIS based approach for electrification planning – A case study on Nigeria - https://www.researchgate.net/publication/286243175_A_GIS-based_approach_for_electrification_planning-A_case_study_on_Nigeria
ECOWREX by ECREEE	http://www.ecowrex.org/	In progress. This is a project to evolve this mapping only tool to include levelised cost of energy estimates for different types of mini-grids (solar PV, small hydro, hybrid etc.), using IntiGIS software by CIEMAT - http://www.ciemat.es/portal.do?IDM=271&NM=2

16. ANNEX III: MUNICIPAL REGULATIONS

The Energy Regulation Act 4 of 2006 is an Act to establish a national regulatory framework for the electricity supply industry. It also legislates to make NERSA the custodian and enforcer of the national electricity regulatory framework; to provide for licenses and registration as the manner in which generation, distribution, reticulation, trading and the import and export of electricity are regulated; to regulate the reticulation of electricity by municipalities; and to provide for matters connected therewith. The Electricity Regulation Amendment Act 28 of 2007 details electricity reticulation by municipalities, as well as extending the Minister's power to create regulation.

The Energy Pricing Policy sets out general tariff principles, but no formal regulation or rules for mini-grid projects are in place to date. A selection of such principles include:

- An efficient distribution licensee should be able to recover its costs;
- The customer bill should be transparent and unbundled, showing clearly the cost breakdown to better enable customers to manage consumption;
- All forms of discriminatory pricing practices must be identified and removed, other than those permitted under specific cross-subsidisation/developmental programmes, or be transparently reflected to unlock the full potential of electricity to all;
- Renewable generators will compete with non-renewables in terms of price (taking into account all support mechanisms), although price premiums can be approved by NERSA if support mechanisms are deemed insufficient;
- Negotiated pricing agreements (NPAs) which deviate from the approved standard tariff levels are allowed, but must be structured in a way so as to minimise price distortions;
- Generator pricing structure can consist of the following: capacity, energy and ancillary service charges. In addition to standard products, provision must also be made for the development and introduction of special products and prices e.g. interruptible rates, peak pricing tariffs, or real-time pricing products;
- Electricity distributors shall undertake cost of service studies at least every five years, or at least when significant licensee structure changes occur, such as in customer base, relationships between cost components and sales volumes, whichever is sooner.

As yet there is no defined regulatory treatment for energy storage, although it is likely to be treated as generation.

A service delivery agreement entered into by a municipality with an external service provider must comply with Municipal Systems Act (MSA), the Municipal Finance Management Act (MFMA) and the Energy Regulation Act. The MSA, 2000, legislates for the municipal local system of governance. Chapter 8 of this Act details the regulatory framework for delivering municipal services. This includes stating that, in the case of entering into a service agreement with an external service provider, the municipality:

- Must first establish whether it has the means to deliver a new service internally
- Must establish a mechanism and programme for community consultation and information dissemination regarding the proposed service delivery agreement
- Must select the service provider through an equitable and transparent competitive bidding process
- Must regulate the provision of the service and monitor and assess the implementation of the agreement
- May choose to assign responsibility to the service provider for providing:
    - development and implementation of service delivery plans
    - operational planning, management and provision of the service
    - undertaking of social or economic development activities related to provision of the service
    - customer management and collection of fees
    - accounting, budgeting and investment and borrowing activities (this system must be auditable)
- May pass on funds for the subsidisation of services to the poor (this system must be auditable)

- May transfer staff to the service provider

The Municipal Finance Management Act (MFMA), 2003, looks to establish sound and sustainable financial management of municipalities and other local government institutions. This includes provisions for establishing public-private partnerships, in clause 120. The primary condition is for the completion of a feasibility study that outlines:

- The strategic and operational benefits of the PPP against the municipality's objectives
- The role (legal and perfunctory) of the private party
- The impact on future revenue flows and current and future budgets
- Demonstrating that the partnership agreement is affordable, will provide value for money, will transfer appropriate technical, operational and financial risk to the private party
- The capacity of the municipality to effectively monitor, manage and enforce the agreement

The MFMA also places additional restrictions on municipalities entering into a contract that will impose financial obligations on the municipality beyond the three years covered in its annual budget, in clause 33**.** These restrictions are not applicable to contracts for long-term debt, employment, certain goods or for contracts that are below a certain threshold value and/or percentage of annual budget. The main conditions, additional to those stated previously under the MFA, includes that the municipality must have:

- Assessed the projected financial obligations and budgetary impact on the municipality for each year of the contract, having taken into account the views and recommendations of the local community, other interest persons and the organisations mentioned previously
- Adopted a resolution that determines that the municipality will secure a significant capital investment or will derive a significant economic or financial benefit from the contract. This resolution must also approve the contract in its entirety and authorise the municipal manager to sign on behalf of the municipality

Solicitation of a number of stakeholders is a required condition under both the PPP clause 120 and the long-term service agreement clause 33. In both cases, the municipality must solicit the views (on the feasibility study or on the proposed service agreement contract respectively) of the National Treasury and relevant provincial treasury, the national department responsible for local government, and the responsible national department where the contract includes water, sanitation or electricity. Additionally, the municipality in both cases must invite the local community and other interested persons to submit to the municipality comments or representations in respect of the proposed contract/PPP agreement. This process is onerous and time consuming, especially for the local community engagement, potentially taking up to 18 months (although multiple conditions for this kind of engagement can be grouped for efficiency). Some municipalities have purportedly hired consultants to manage this process, while others have avoided commencing such projects in the first place. Critically however, the MFMA does not block PPPs or long-term service agreements, and there are purportedly cases of this process being successfully navigated. It may prove the case that greater development under the PPP and service-agreement frameworks can be unlocked solely through increased support to municipalities, potentially from development agencies.

17. ANNEX IV: UK AND SOUTH AFRICA STAKEHOLDER DIRECTORY

Type	Organisation Name	Head Office Base	Company Description (source: company website)	Business Areas	Contact Details	email	Link to Website
All	**BBOXX**	UK	Offers an on-grid experience powered through a financing model to sell solar home systems to the mass market on a monthly payment plan. BBOXX leads and manages all aspects of its business operations – engineered in London, manufactured in its factory in China, followed by distribution to partners in 35 countries and 30 local shops in Kenya, Rwanda and Uganda.	Solar home systems	Mansoor Hamayun, CEO & Co-Founder	m.hamayun@bboxx.co.uk	www.bboxx.co.uk
Energy Storage	**Firefly Clean Energy**	UK	Firefly is an innovative cleantech company headquartered in the UK. Leading manufacturer of hybrid power systems – making a positive social and environmental impact around the globe.	Hybrid power generators, storage technology (LIP, OPzV, AGM)	Ben Christie, Director of Strategy and Business Development	ben@fireflyce.co.uk	http://www.fireflycleanenergy.co.uk/
Energy storage	**OXTO energy**	UK	Innovative energy management company offering services based on technologies that it has developed in-house. Using these services potential customers can save substantially on energy and hence money spent.	Community-level energy storage	Dr George Prassinos, CEO	Prassinos@sdnc.co.uk	http://www.oxtoenergy.com/

Engineering	**Proconics**	South Africa	Proconics has a reputable track record for excellence with over 2 decades of units and a variety of other power technologies for its various clients. We boast strong HV, MV and LV teams that have successfully completed complex brownfields power projects. Proconics provides operators with technically suitable and cost-effective designs, equipment and integration systems for brownfield projects.	Substation automation, UPS Replacement, Statutory Audits	Taru Madangombe, Business Development Manager - Power and Renewables Energy	taru.madangombe@proconics.co.za	http://www.proconics.co.za/
Engineering	**e:Sun Systems**	South Africa	e:sun systems is a subsidiary of the German engineering firm "e:craft systems GmbH" which was founded in the German province of Thüringen. A combination of the skills of industrial installation and electrical engineering together specializing in German Solar Photovoltaic engineering and installation technology.	Solar PV	Michelle Andrews, Managing Director	m.andrews@esun-systems.co.za	http://www.esun-systems.co.za/
Engineering/Mini Grid Design Manufacturers	**Aquanovis**	UK	Aquanovis Limited is an innovator in the field of clean energy generation. The company has developed a proprietary technology to install subterranean hydroelectric generation plants beneath waterfalls and rapids	Mini-Grid, Hydropower, telecommunications transmission	Paul Jankel, CEO	paul.jankel@aquanovis.com	http://www.aquanovis.com/home.html

Investment	**Lions Head Global Partners**	UK	Specialized merchant bank based in London and Nairobi, focusing on emerging markets and Sub-Saharan Africa. Provide financial advisory services across a range of sectors, including agriculture, health care, education, financial intermediation and infrastructure.	Financial valuations, due diligence and deal structuring and market analysis	Leonard Mathu, Executive Director	leonard.mathu@lhgp.com	http://www.lhgp.com/
Investment	**Clean Energy Africa**	South Africa	A core focus of CEA is to Identify, develop and then invest in alternative energy opportunities throughout Sub – Saharan Africa.	Investment in renewable technology, clean energy, mini grids	Egmont Ottermann, Manager	egmont@cleanenergyafrica.co.za	http://cleanenergyafrica.co.za/
Manufacturers	**ART Solar**	South Africa	Locally owned solar panel manufacturing plant considered the largest and most high-tech of its kind in Africa due to its automated Swiss and German equipment. ARTSolar was established by a group of South African entrepreneurs who wanted to take advantage of the growing interest in renewable energy.	Solar PV Manufacturer.	Max Davidson, Management	max@artsolar.net	-
Manufacturers	**Ezylight**	South Africa	Innovative South African company focussed on the sustainable and renewable energy solutions.	Solar lighting, back-up power systems, emergency lighting, solar panels, wind technology, solar hot water, LED light fittings and	Ahmed Ahmed, Founder	ahmed@ezylight.co.za	http://www.ezylight.co.za/

				Solar Street lamps			
Manufacturers	**Setsolar**	South Africa	Assembles, import and distributes a wide range of Solar panels, Charge Controllers, Inverters, Batteries, Cabling, Connectors, Mounting structures and many more.	Solar PV Manufacturing and maintenance	Chris Sierra, National Sales Manager	chris.sierra@setsolar.co.za	http://www.setsolar.co.za/
Manufacturers	**Solaire direct Technologies**	South Africa	SD Direct Pro is the leading trade Only solar service provider in South Africa. With over 21MWp in operation in South Africa and 600MWp worldwide, SD Direct Pro expertise helps you to grow your business in delivering ground-breaking solar energy solutions.	Partner programme, technical support and custom design	Karl Lotter, Technical Manager	klotter@solairetechnologies.com	http://www.solairetechnologies.com/
Manufacturers	**MeshPower**	UK	MeshPower sets up solar panels linked to a secure battery storage unit in the centre of a village called a "base station", typically in a customer's house where free electricity is provided in return for keeping the equipment safe.	Solar PV, Off-grid energy, small village projects.	Lukas Lukoschek, Chief Executive	l.lukoschek@meshpower.co.uk	https://www.meshpower.co.uk/index.html
Manufacturers	**Micro Care**	South Africa	Manufacturer of a range of Pure Sine Wave Bi-directional starting from 300W to 15kW Inverter. In 2016, Microcare launched a range of Three-Phase Pump Controllers, Solar UPS solutions and a 12V Solar Power Supply.	Solar PV components manufacture.	Gareth Burley, Marketing Manager	gareth@microcare.co.za	www.microcare.co.za

Manufacturers	**First National Battery**	South Africa	First National Battery is the leading lead acid battery manufacturer in South Africa, producing over 2.2 million batteries a year. Established in 1931 when the first automotive batteries were produced in East London, South Africa, First National Battery remains at the forefront of battery technology and innovation. The batteries are also exported to over 40 countries worldwide.	Battery manufacture, recycling, product design and project management	Russell Bezuidenhout, Managing Director	russellb@battery.co.za	www.battery.co.za
Manufacturers	**Bosch Projects**	South Africa	In-house engineering consulting expertise covers process, mechanical, structural, civil, electrical, instrumentation engineering, including conceptual and detailed design adding significant value in providing integrated engineering solutions. In addition, services include front end engineering and feasibility studies, project management, construction monitoring, plant management contracts, operations and training.	Solar PV energy harvesting systems, power evacuation and grid connection systems, low, medium and high voltage system design and implementation and power transmission, distribution and substation design and implementation	Butch Carr, Energy Sector Director	carrb@boschprojects.co.za	http://www.boschprojects.co.za/

Manufacturers	**ILB Helios Southern Africa**	South Africa	ILB Helios Group is formed by ten international companies operating in the renewable energy sector. The objective of this joint activity is not only the production and sale of high performance products such as photovoltaic modules, solar cells, flat and tubular collectors, tracking systems, inverters and other products for solar energy, but also providing all kinds of solutions and an appropriate follow up.	Solar PV installation	Patrick Nawa, Director	pnawa@ilbhelios.co.za	http://www.ilb-helios-group.ch/
Manufacturers	**ABB Edenvale**	South Africa	ABB has unmatched expertise in designing and building off-grid and grid-connected microgrids. Our portfolio encompasses the full range of enabling technologies including conventional and renewable power generation, automation, grid stabilization, grid connection, energy storage and intelligent control technology, as well as consulting and services to enable microgrids globally.	Mini Grids, energy storage	Tony Duarte, Sales Manager	tony.duarte@za.abb.com	http://new.abb.com/
Monitoring & Service Providers	**RTC Control Systems**	South Africa	Specialise in assessments, design work, Power Purchase agreements and procurement and construction for solar PV.	Solar PV	Leon Barkhuizen, Managing Director	leon@rtccs.co.za	http://www.rtccs.co.za/
Monitoring & Service Providers	**Off Grid Energy**	UK	We are the leading manufacturer of hybrid power systems – making a positive social and environmental impact around the globe.	Off grid battery providers	Janene Dooler, Commercial & Strategy Developer	janene.dooler@offgrid-energy.co.uk	http://www.offgrid-energy.co.uk/index.php

Monitoring & Service Providers	**AD Solar**	South Africa	Our work includes basic systems that provide solar electricity, for example, to security fencing all the way up to major commercial plants where alternative energy generation forms a major part of an operation's energy supply, e.g. a large distribution centre. AdSolar prides itself as being the foremost supplier of proven alternative power systems in KZN, with clients choosing us as their preferred energy partner in their pursuit to developing energy independence.	Solar PV, energy supply	Carne Curgenven, Group Managing Director	carne@adsolar.co.za	http://www.adsolar.co.za/
Partnership Hub	**arei**	South Africa	Arei's prime objective is to contribute to the creation of an environment which encourages a dynamic growth of the electronic manufacturing industry, at both component and system level, in South Africa	Promotes and encourages ethical business practices, well-trained and professional sales teams, technical support and the availability of inventory to meet planned customer requirements.	Jenny Gooding, Administrator	jenny.gooding@arei.co.za	http://www.arei.co.za/index.htm
Payment Collection System Providers	**Azuri Technologies**	UK	Commercial provider of PayGo solar home systems to rural off-grid communities across sub-Saharan Africa.	PayGo for solar off-grid solar systems.	Simon Bransfield-Garth, CEO	sbg@azuri-technologies.com	http://www.azuri-technologies.com/

Project Developer	**Specialized Solar Systems**	South Africa	Specialise in providing complete off-grid electrification (with optional back-up) to rural and undeveloped communities in South Africa and other African countries	Solar off-grid developments	Albert Monk, General Manager	albert@specializedsolarsystems.co.za	http://www.specializedsolarsystems.co.za/
Project Developer	**Practical Action**	UK	Practical Action is an international non-governmental organisation (NGO) that uses technology to challenge poverty in developing countries.	Mini-Grid, Bioenergy, solar PV, hydro, hybrid, wind	Aaron Leopold, Global Energy Representative	aaron.leopold@practicalaction.oorg.uk	http://practicalaction.org/
Project Developer	**Sustainable Energy Research Group (SERG)**	UK	The Sustainable Energy Research Group (SERG) is part of the Energy and Climate Change Division (ECCD) within the Faculty of Engineering and the Environment at the University of Southampton.	Mini-grids. Stand-alones	AbuBakr Bahaj, Professor of Sustainable Energy	A.S.Bahaj@soton.ac.uk	http://www.energy.soton.ac.uk/2nd-african-mini-grid-summit/
Project Developer	**SOLA Future Energy**	South Africa	Renewable energy development and construction group specialising in solar PV and energy storage in sub-Saharan Africa.	Design and construction of Solar PV	Dom Wills, CEO	info@solarfuture.co.za	http://www.solafuture.co.za/
Project Developer	**CMDET Smart Villages Initiative**	UK	Smart Villages aims to provide policy makers, donors and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries – technological, financial and political – and how they can be overcome.	Mini-Grid, Biofuels, Development, Energy efficiency, Geothermal, Hydro, Solar PV, Wind	Mike Price, Research Associate	mbp27@cam.ac.uk	http://e4sv.org/

Project Developer	**ITPEnergised**	UK	IPEnergised is a world leading renewable energy consultancy firm. We offer technical, engineering and advisory services to public and private sector clients in all aspects of sustainable energy.	Carbon finance, Energy, Environment, Finance/investment, Renewable energy, Rural development	David Fernandez Blanco, Principal Renewable Energy Engineer	david.blanco@itpenergised.com	http://www.itpenergised.com/
Project Developer	**Climate Care**	UK	Works with partners around the world to deliver solar energy programmes to bring access to realisable and renewable solar light to households without reliable electricity.	Solar PV	Tom Morton, Director (Africa)	tom.morton@climatecare.org	https://climatecare.org/
Project Developer	**Akon Lighting**	US	Akon Lighting Africa seeks to provide a concrete response at grass roots level to Africa's energy crisis and lay the foundations for future development. This initiative aims to develop an innovative solar-powered solution that will provide African villages with access to a clean and affordable source of electricity.	Clean energy, micro-grids, incl. in SA	Steven Olikara, Senior Advisor	steven.olikara@millennialaction.org	http://akonlightingafrica.com/
Project Developer	**Kempston Renewables**	South Africa	Kempston Renewable Energy is your best long term partner in the solar energy industry. Born out of a demand for alternative energy, we are geared to provide energy solutions to both commercial and residential clients.	Solar PV, Off-grid energy plus battery bank	Alec Booth	alec.booth@kempston.co.za	http://www.kempstonrenewable.co.za/
Project Developer	**Out of the Green Box**	South Africa	Out The Green Box will work with landowners, project developers, technology providers, regulators, and investors to source and develop renewable energy projects in South Africa and the rest of sub-Saharan Africa	Solar PV, Off-Grid Energy, Battery back ups	Andrew Hugo, Project Engineer	andrew@outthegreenbox.co.za	http://www.outthegreenbox.co.za/

Project Developer	**Specialised Solar Systems**	South Africa	We specialise in providing complete off-grid electrification (with optional back-up) to rural and undeveloped communities in South Africa and other African countries. Our off-grid solar electrification projects provide an effective and renewable energy source that meets the highest safety and design specifications. We focus heavily on the sustainability of our alternative energisation systems - working together with universities, NGOs, local government and, more especially, involving the local communities and their leadership.	Mini grids, grid support	Carlos Smith, Rural Energy Systems Implementation Manager	carlos@specializedsolarsystems.co.za	http://www.specializedsolarsystems.co.za/index.php
Project Developer	**Aurecon**	South Africa	We provide advisory, design, delivery and asset management services on projects across a range of markets, in locations worldwide. These services include 1) Digital advisory and infrastructure advisory 2) Building design, ground engineering design and infrastructure design 3) Programme and project management delivery 4) Asset management and geospatial systems	Power transmission, power generation, infrastructure advisory	Clinton Carter, Technical Director	clinton.carter-brown@aurecongroup.com	http://www.aurecongroup.com/en.aspx
Project Developer	**Urban Earth**	South Africa	Urban Earth provides technical support and strategic consulting advice to help organisations achieve sustainability objectives. This includes strategy development, sustainability research, and stakeholder engagement.	Energy Management	Dereck Morgan, Senior Associate	derek@urbanearth.co.za	http://www.urbanearth.co.za

Project Developer	**Energy In Motion Technologies**	South Africa	The mission of Energy In Motion Technologies is to make a significant contribution in alleviating the plight of energy shortage in Southern Africa. We further aim to play a sizable role in reducing the carbon footprint which contributes to global warming that is threatening our global environment.	Solar PV, Wind power, Energy storage, technology solutions, mini grids	Linda Cele, Managing Director	lindac@energyinmotion.co.za	http://www.energyinmotion.co.za/index.html
Project Developer	**Power X**	South Africa	POWERX buys power from independent power producers and sells the clean power it purchases directly to end users. POWERX acts as a conduit between buyers and sellers of power to stimulate the generation of power in South Africa.	Investment, clean electricity, power generation	Ignus du Toit, Managing Director	ignus@powerx.energy	http://www.powerx.energy/
Project Developer	**Mainstream Renewable Power**	UK	Mainstream Renewable Power is a global renewable energy company established in 2008 to develop, construct and operate wind and solar PV projects in high-growth emerging markets. As at November 2016, it has 9.8 gigawatts in development, 280 megawatts in construction and 524 megawatts delivered into operation safely, on time and on budget.	Solar PV, wind power	Liam Leahy, Development Manager	Liam.Leahy@mainstreamrp.com	http://mainstreamrp.com/

Project Developer	**UVAL**	South Africa	UVAL leverages decades of experience in the consulting engineering industry and its extensive network of engineering resources offering specific skills for specific projects. UVAL relies on world class technology providers with an established African footprint to provide the best technology and the best support in an often challenging environment.	Mini Grids, Consultancy, Engineering	Morten Hald, Executive Director	morten.hald@uval.co.za	http://www.uval.co.za/
Project Developer	**Founders Engineering**	South Africa	Implementation and execution focused company that realizes that project success also hinges on proper up-front development work. We therefore aid in near execution or bankable project finalization and scope definition to take the projects forward.	Solar PV farms &rooftop mounts, mini grids	Reinhardt Barnard, Project Engineer	Reinhardt@foundersengineering.com	http://www.foundersengineering.com/
Project Developer	**Steama.co**	UK	SteamaCo enables convenient buying and selling of off-grid utilities. Our universal smart meter connects any utility asset to the cloud wirelessly.	Mini-grids, solar irrigation pumps, biogas digesters	Dr. Sam Duby, CTO and co-Founder	sam@steama.co	http://steama.co/#connect-the-unconnected
Project Developer	**Energy 4Impact**	UK	Energy 4 Impact supports businesses that provide energy access to off-grid communities.	Mini grid development	Peter Weston, Director of Investment Advisory Services	peter.weston@energy4impact.org	http://www.energy4impact.org/

Project Developer - Large scale	**GlobalEq**	South Africa	Operating in South Africa since 2012 with their head office based in Cape Town, Globeleq South Africa Management Services develops, constructs and manages energy projects as part of the South African government's REIPPP.	Major shareholder in three independent power producing utility projects in South Africa's renewable energy sector, namely Jeffreys Bay Wind Farm, De Aar Solar Power and Droogfontein Solar Power.	Jonathan Hoffman, Senior Business Development Director	jonathan.hoffman@globeleq.com	http://www.globeleq.co.za/
Social Enterprise	**Brighter World Energy**	UK	For every 2,000 UK energy customers that switch to Brighter World Energy, we will install a solar powered micro grid in a village in Africa.	Off-grid installation	Cheryl Lathan, CEO	cheryl@brighterworldenergy.com	https://brighterworldenergy.com/
Training	**SARETEC**	South Africa	Continuous service in the engineering and design of substations, switchgears, UPS	Solar PV Service Training	Sven Pietrangeli, Operations Manager	PietrangeliS@cput.ac.za	https://www.saretec.org.za/