Department for
Business, Energy
& Industrial Strategy

‘KEEPING IT COOL’ :

DEVELOPING SUSTAINABLE BUSINESSES WITH OFF-GRID SOLAR-POWERED PRODUCTIVE USE APPLIANCES IN SOUTH AFRICA’S INFORMAL SETTLEMENTS

Newton Fund

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UKRI Natural Environment Research Council

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HEADLINE ISSUES

- Including local service needs into energy applications in informal settlements is essential for providing clean, safe, and reliable energy solutions. Decentralised forms of renewable energy, like off-grid solar mini-grids, offer opportunities for providing energy to meet local needs (e.g., community lighting or refrigeration) while also building sustainable livelihoods (e.g., setting up a business using solar-powered services).

- Delivering sustainable renewable energy services requires balancing the social, financial, and technical factors to enable replicability and scale. Experimentation and co-learning between utilities and communities is key, and building close working relationships builds trust and enables refinement across the lifetime of the project.

- Necessary actions for government, academics, utilities (e.g., small-scale, city, and national governments), and development organisations include developing policy and practice to support the use of off-grid renewable applications, linking utilities and communities, and developing sustainable finance models to support additional infrastructure and services (e.g., productive use businesses).

SUMMARY

Households in informal settings are often built in precarious locations: residents draw on a range of self-help energy sources (including paraffin, candles, diesel generators, and illegal connections) to meet their energy needs (cooking, heating, cooling, and lighting). Many informal settlements in South Africa do not receive formal grid-based electricity as they are located on unstable ground,[1] private and/or state land, or in infrastructure servitudes.[2] Residents therefore rely on off-grid selfhelp options (e.g., paraffin, charcoal, and candles, as well as diesel generators) to meet their energy needs. As many of these options produce toxic fumes when burnt, the use of these fuels often have long-term implications for individual livelihoods, wellbeing, and community development.[3]

Understanding local energy service needs is critical for developing sustainable and reliable energy solutions in informal settlements. As informal settings differ based on their location, demographics, and access to infrastructure services, it is necessary to understand local needs when implementing electrification applications (e.g., lights, TVs, mobile phone charging, fridges, freezers, or cooking appliances).[4] Designing the provision of energy applications around the desired productive use of energy (e.g., refrigeration, heating, etc.) supports the co-development of sustainable and viable electrification projects, where daily quotas, subsidies, and/or allowances/limits can be matched to community needs.

Delivering renewable energy services tailored to informal settlement communities means thinking outside the box in linking electrification to additional services and infrastructures. Approaches to renewable energy provision, followed by governments and international development aid for example, often focus on the delivery of infrastructural services to meet 'basic' needs: energy, water, sanitation. A step change is required in linking basic service provision to additional services that can deliver change at the local livelihood level. Solar mini-grids can power fridges, which can, in turn, be used for businesses by local entrepreneurs, thus enhancing livelihoods and creating supporting opportunities (e.g., solar towers, on which mini-grids are based, can be used for repeaters, powered by solar, that make community wifi available in what are generally data-poor environments[5]).

Sustainable finance and a long-term project perspective are key to replicability, scale, and sustainability. Solar mini-grid-based energy services (e.g., electricity and refrigeration) require a long-term commitment to the community and to the project to ensure long-term success. Many aid and academic research projects function on 1- to 3-year timelines that are too short for ensuring long-term viability and impact. Longer project timelines, even with small budgetary commitments, can help ground continued commitment to deliver sustainable services.

1 Includes wetlands and dolomitic land.
2 Areas of land owned by the state that cannot be developed as they are earmarked for the provision and maintenance of grid infrastructure. Examples include areas with electricity lines and pylons, or water and sewerage pipes.
3 Contribute to the worsening of respiratory ailments and chronic diseases such as asthma and Chronic Obstructive Pulmonary Disease (COPD).
4 Informal settlements vary greatly in relation to, among other factors, their geographic location, resident demographics, and age.
5 These services can be more reliable than access to the internet via mobile phone and could be more affordable.

ENERGY ACCESS AND USE IN SOUTH AFRICA'S INFORMAL SETTLEMENTS

In 2018, the World Bank estimated 25.6% of South Africa's population lived in informal settlements (World Bank, 2018). Given recent population predictions,[6] it is anticipated that the number of individuals in informal and/or low-income areas will continue to rise in the coming years, notwithstanding the socio-economic impacts of Covid-19. To make the move towards engaging with informal settlements as permanent or semi-permanent features of South Africa's urban landscape, it is essential to view them as places and lived spaces in their own right that are characterised by a highly dynamic and diversified set of infrastructure and service-based needs (Caprotti et al., Forthcoming).

National programmes for infrastructure delivery often focus on overcoming service-based deficits in informal or low-income parts of South Africa, providing a utilitarian service to meet 'basic' infrastructural needs: electricity, water, sanitation, and waste removal (Roy, 2011; Kovacic et al., 2021).[7] As many informal settlements fall outside the remit of national, regional, or city-level electrification projects due to their 'illegal' status[8] or location on precarious ground (e.g., wetlands, dolomitic ground, or in infrastructure servitudes), many informal settlements are unlikely to be upgraded or receive basic access to infrastructure services via the formal 'grid' (via retrofits or grid extensions).

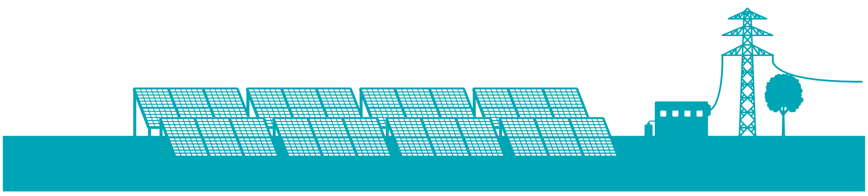
Where municipal governments have identified the need to electrify informal settings as part of their core mandate (e.g., City of Cape Town), their activities are often limited due to land ownership, flooding, and existing grid infrastructures that limit their legal remit or the practical implementation of electricity[9] (City of Cape Town, 2020). This means that while many residents of informal settlements desperately need infrastructure services, as their basic human right, their location precludes them from state-led electrification initiatives (Box 1).

While many residents of informal settlements desperately need infrastructure services, as their basic human right, their location precludes them from state-led electrification initiatives.

To meet energy needs in informal settings, many residents resort to self-help options to access energy services. This includes a range of locally available, or affordable, forms of energy (e.g., paraffin, wood, and plastic) (Jaglin, 2014; Koepke et al., 2021). Studies show residents can draw on grid and non-grid energy options comprised of individual, illegal, and subscribe-retailer energy sources at any one time in Dar es Salaam,[10] Tanzania (Koepke et al., 2021), and grid-based electricity, generators, and off-grid technologies in Accra,[11] Ghana (Silver, 2014).

While self-help energy options (e.g., paraffin, wood, and plastic) can meet very basic energy needs, they are unsafe and unreliable, and create toxic by-products when burned that can have long-lasting health impacts for informal settlement residents (World Health Organization, 2016). The World Health Organization found that the use of solid fuel for cooking caused 4.3 million premature deaths each year in informal and low-income settings, of which 3.8 million were caused by noncommunicable diseases[12] (World Health Organization, 2016). Illegal connections to the grid, often achieved through unsheathed or poorly sheathed cabling running on the ground, were also identified as unsafe, posing a lethal threat to residents, especially children.

Access to unsafe and unreliable energy has knock-on impacts on human livelihoods. For example, insufficient lighting impacts access to current and future educational opportunities and productive enterprises. Women and children most often bear the brunt of the health and safety impacts of fuels burnt indoors for energy[13] (World Health Organization, 2016; Haddad et al., 2021).



6 Urban populations in South Africa are forecasted to reach 70% of the national total by 2030 and up to 80% by 2050 (SEA, 2015, p. 12).
7 Many South African infrastructure programmes follow a free basic allowance that drives the provision of services. In many cases, the provision of services does not meet actual energy needs.
8 Located on private or state-owned land.
9 Households in informal settings cannot be retrofitted with electricity if they are located within 50-year flood lines or are in road, rail, and power line reserves and servitudes (CoCT, 2020, p. 126).
10 Kilakala, Mabwepande, Kariakoo, Msasani, Mikocheni, and Kisutu.
11 Ga Mashie.
12 Including stroke, ischaemic heart disease; lung cancer; and chronic obstructive pulmonary disease (see World Health Organization, 2016).
13 Includes the actual impacts of toxic by-products (World Health Organization, 2016).

ENERGY ACCESS IN QANDU-QANDU, CAPE TOWN

1

Qandu-Qandu is an informal settlement in Khayelitsha, Cape Town (Figure 1). Qandu-Qandu residents are not connected to the national South African energy grid.

- Local planning laws define the settlement as 'illegal' and temporary, thus making it difficult to spend public funds on upgrading its infrastructure services.
- Saturated ground due to naturally occurring wetlands mean that the ground is not suitable for grid infrastructures.
- Existing grid infrastructure (pylons, cables, etc.) predating its development makes it impossible to provide grid infrastructures in parts of the settlement due to fire and electrocution risks associated with low-hanging high-voltage cables.

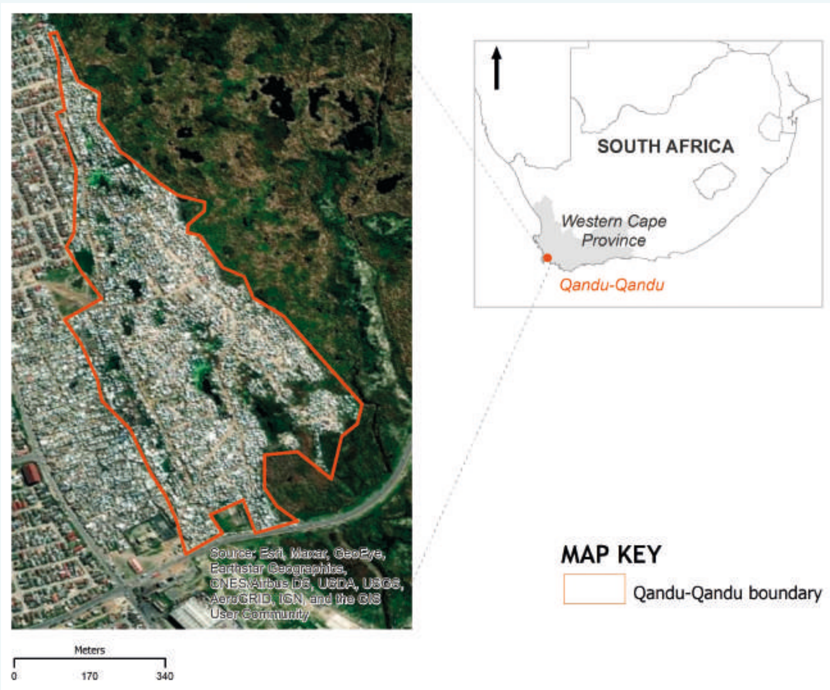
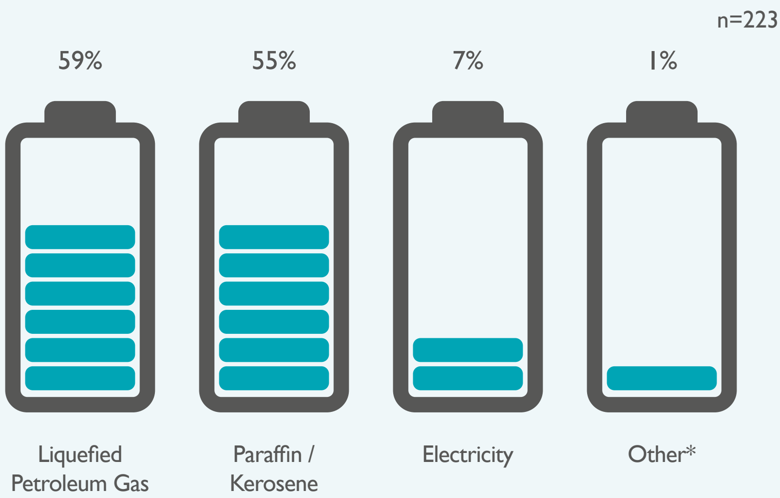


Figure 1: Location of Qandu-Qandu, Cape Town, South Africa (Source: Authors).

Qandu-Qandu residents rely on self-help options to access energy (Figure 2). All these sources carry individual and collective risk, whether it be associated with electrocution or fire (illegal connections), or health concerns (candles, paraffin, diesel, wood, and plastic).



** Candles and rechargable bulbs*

Figure 2: Energy access and use in Qandu-Qandu, Cape Town (Source: Authors).

PRODUCTIVE USES OF ENERGY: PROVIDING SAFE AND RELIABLE BASIC SERVICES FOR LIVELIHOOD DEVELOPMENT

Renewable energy is a viable avenue for (1) delivering energy to meet growing demands in informal settings (IRENA, 2015), and (2) supporting urban resilience (Africa Progress Panel, 2015). As shown in this policy brief (Box 2), it can also present significant opportunities for providing safer and cleaner forms of energy to informal settings, offering additional infrastructure and services for supporting local livelihoods.

While utilitarian service models provide renewable energy services in informal settlements, they do not always meet community needs. Consequently, programmes risk failure as they do not meet the energy needs of residents. An example of this is the Joe Slovo Solar Water Heater project in Cape Town, where energy services did not meet local energy needs, aspirations, contexts, or lifestyles (see Haque et al., 2021).

In terms of working towards boosting the impact and longevity of renewable energy projects in informal settings, the productive uses of energy offer opportunities for delivering energy in ways that respond to real community needs. Productive use refers to the exact service needs of communities and can involve services such as refrigeration, heating, and charging stations.

Developing renewable energy projects around productive uses of energy places the community at the heart of electrification programmes (Croese, 2021), where developing energy solutions around productive uses of energy can further engage with the diversity, taking into account the location, setting, and social structure of informal settlements[17] (Marx & Kelling, 2018; Banks et al., 2020).

Working with communities to develop renewable energy projects offers critical opportunities for testing and experimentation, strengthening project outcomes overall.[8] As communities 'know the context better than anyone else', involving them in the gathering of data supports the building in of replicability, scale, and sustainability to projects (Green Cape, 2020, p. 3), bolstering the social aspects of the project alongside technical, economic, and environmental factors (Caprotti, 2018).

Opportunities to gather data include participatory processes such as workshopping and community mapping (see Green Cape, 2020), and using mobile phones to distribute online surveys (Thrie Energy Collective, n.d.).

2

UMBANE PROJECT – SOLAR MINI-GRIDS FOR CLEAN, ACCESSIBLE, AND SUSTAINABLE ENERGY IN QANDU-QANDU

The UMBANE project (umbane is the Xhosa word for 'electricity') is a joint University of Exeter and University of Cape Town research initiative started in 2021 (funded by the Newton Fund).[14] The project delivered 7 solar mini-grids in Qandu-Qandu, Cape Town, to test renewables-based productive use appliance (solar-powered fridges) businesses.

Each solar mini-grid can serve up to 16 households with clean and safe renewable energy,[15] making them modular and scalable. Each mini-grid is small enough to install in densely populated or difficult-to-reach places such as informal settlements (Figure 3).

Compared to solar home systems that often struggle to meet the higher needs of urban users,[16] solar mini-grids provide enough energy, at 26V DC, to power lighting, TVs, and up to 3 fridges/freezers per mini-grid.

Figure 3: Solar mini-grid setup and connecting wires (Source: Authors).

14 See https://innovativeoffgridenergyservices.weebly.com/umbane.html
15 Making them inherently safe against fire, floods, electrocution, and other dangers as compared to traditional electrical infrastructure.
16 As compared to applications in rural areas.
17 As informal settlements are often developed on abandoned or open tracts of land, they often experience challenges associated with instability (e.g., dolomitic land) and flooding (e.g., wetlands and/or water bodies).
18 Experimentation forms a key component of any successful sustainability project, where it is necessary to overcome uncertainties around the social, technical, and economic aspects of their use (see Castán Broto & Bulkeley, 2013; Swilling, 2014; Cowley & Phillips, 2018).

UMBANE PROJECT PARTNERS

ACADEMIA

Exeter University and the University of Cape Town

ROLE: Guide the overall project approach, gather and analyse project data (qualitative and quantitative), and distil and disseminate findings in a range of outputs (academia, policy, and practice).

PRIVATE SECTOR

Zonke Energy

ROLE: Implement solar mini-grid technology and troubleshoot technical challenges. Develop and refine finance model, including long-term maintenance and customer support.

Thrie Energy Collective

ROLE: Manage project activities and data gathering

Story Room SA

ROLE: Run business development support programme to bolster the socio-economic impact of the project

QANDU-QANDU COMMUNITY

ROLE: Provide insights on local energy needs. Attend business support programme, and provide end-user insights on applicability and use of solar energy and fridges.

ADDRESSING COMMUNITY ENERGY NEEDS USING RENEWABLE ENERGY TECHNOLOGIES

Designing and implementing renewable energy projects to respond to community needs requires a holistic approach. This involves:

1. Incorporating the social needs of the community, through identifying the most desired energy services;
2. Refining technical parameters for supporting community-based needs alongside the operation of mini-grid technology; and
3. Developing sustainable financing options, including incorporating livelihood opportunities to ensure long-term viability and reliable payment for services (Figure 4).

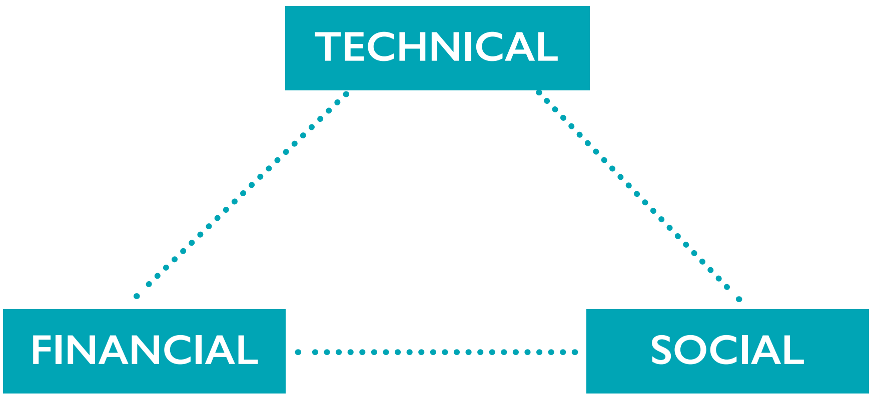


Figure 4: A hollistic approach for developing and implementing renewable energy (Source: Authors).

Placing social needs at the heart of off-grid renewable energy projects

A first step to incorporating a community in an electrification project involves engagement with informal settlement residents. It is critical that engagement is set up as early as possible to support ongoing interactions throughout the lifetime of the project.

Three stages of community engagement are identified, where community inputs prove invaluable to the design, implementation, and long-term use of solar energy throughout the lifetime of a project (Box 3).

Stage 1: DEVELOPMENT [Year 1]

Identify the most desired use of energy and livelihood opportunities that can support the long-term use and sustainability of energy access.

Stage 2: IMPLEMENTATION [Year 1–3]

Continue to engage with the community to refine the technical and financial aspects of solar productive use applications. Find opportunities for supporting the long-term use and sustainability of energy access.

Stage 3: OPERATION AND MAINTENANCE [Year 2 onward]

Ongoing periodic engagement around productive use, technical functioning, and long-term maintenance and operation. This includes agreeing to the roles and responsibilities of the utility and the community beyond the lifetime of manufacturer warranties.

3

ENGAGING A COMMUNITY THROUGHOUT THE LIFETIME OF A SOLAR ELECTRIFICATION PROJECT: *Experiences from Qandu-Qandu*

STAGE 1, YEAR 1

In Qandu-Qandu, community members identified refrigeration as their most desired productive use. Zonke Energy developed a solar package to support energy allowances and limits to provide a solar-powered fridge/freezer (see Box 5).

STAGE 2, YEAR 1

In terms of locating appropriate sites for solar mini-grids, Zonke Energy[19] further engaged with residents to determine community needs for solar energy so they could then place mini-grids to power solar fridges/freezers (Figure 5).[20] Zonke Energy mapped out 10 community zones[21] and digitised them in geographic information software (Figure 6). The final map was used to set up meetings with residents to ascertain interest in solar energy. Solar mini-grid towers were then placed within and between zones in relation to community interest.

STAGES 1–3

During the implementation, operation, and management of the project, Zonke Energy made a call for Qandu-Qandu residents to volunteer to act as 'hosts' for solar mini-grids (Stages 1–2). Hosts agreed to have a solar mini-grid implemented in their yard and were responsible for notifying Zonke Energy of any concerns with the technology and provision of energy (Stage 3).

To support social engagement across all phases of the project, Zonke Energy established a local site office, and hired a community liaison officer, to boost their presence in the community and to respond to concerns or queries regarding the financial or technical aspects of the project.

Figure 5: Solar freezer and electrical setup (Source: Authors).

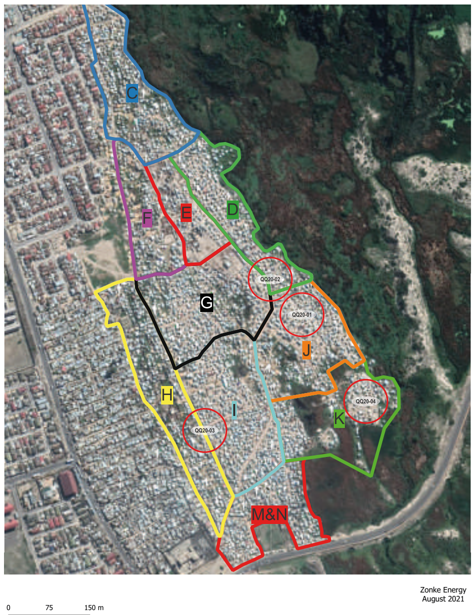


Figure 6: Section map created for Qandu-Qandu to guide engagements with the community. (Source: Authors).

19 Local utility responsible for the implementation of the project.
20 Each mini-grid can power up to 3 fridge/freezers alongside other services such as lighting, TVs, and radios.
21 Boundaries already established informally by residents.

Refining technical parameters to enable clean and safe energy access

While renewable energy technical specificities exist (user manuals and guidelines), the technology has only been used in a handful of informal settlements globally. A key benefit of renewable energy (e.g., solar mini-grids) is that it can be used in densely populated spaces and precarious locations, and requires little space on the ground to both install and operate (Box 4). Therefore, while solar systems can operate in a broad range of settings, the use of available technical specifications requires finetuning (Box 5).

End-user experiences offer avenues for experimentation and co-learning between utilities and community members to refine technical aspects, while also ensuring they are locally relevant (Figure 7). End-user experiences can be included in a range of ways: forums, informal meetings, online or face-to-face surveys, in-depth interviews, or service-based reviews.

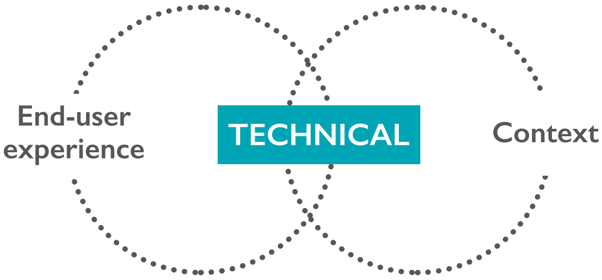


Figure 7: Refining the technical parameters of renewable energy in practice (Source: Authors).

4

REFINING THE TECHNICAL ROLLOUT OF SOLAR MINI-GRIDS IN QANDU-QANDU

Zonke Energy refined their technical approach in at least two ways to support the implementation and use of solar mini-grids in Qandu-Qandu.

LOCATING MINI-GRIDS

As space on the ground is often limited in informal settlements such as Qandu-Qandu, Zonke Energy needed to choose locations where there was enough space to install them. Initially, they selected locations where there was enough space to bring in a small crane to install them. However, given the space limitations,[22] there were very few places in the settlement where there was enough space to house the crane during setup. Over time, they modified their installation process so that they were able to use a light with a winch system, which was more accessible and cost-effective (Figure 8).[23]

Figure 8: Implementing solar mini-grid towers using a light truck and winch system (Source: Authors).

REFINING DAILY ALLOWANCES AND LIMITS FOR FRIDGE USE

Zonke Energy found the actual energy usage of client solar fridges/freezers in practice was far higher than what was outlined in the user manuals. This meant some clients reached their daily energy allowance or limit before the end of the day and their fridge/freezer turned off. Working with their clients, Zonke Energy refined the technical use (e.g., changing the fridge/freezer dials) of the fridge/freezers and client daily allowances to ensure a stable and continuous service.

22 Like many informal settlements, dwellings and supporting structures are located very close to each other, making access difficult.
23 The tower, winch, and light truck need to be in a straight line to install the mini-grids.

Supporting financial sustainability through additional infrastructure and services

Building sustainable autonomous off-grid renewable energy systems requires a sustainable business model for ensuring the long-term viability of clean and reliable energy services. This requires balancing two key aspects: (1) the financial viability of the local utility, and (2) the client's ability to pay (Figure 9).

Continued interaction and communication between utilities and communities over the lifetime of the project enables refinements to costings and modes of provision (i.e., daily allowances/limits, energy packages, rent-to-buy options, and timeframes), thus supporting greater efficiency (Box 5).

Developing additional infrastructure and services can boost the long-term viability of renewable energy projects. Firstly, finding locally relevant financial and/or livelihood opportunities using productive uses of energy (e.g., cooling, heating, etc.) and/or appliances (e.g., fans, fridges/freezers, pumps, and TVs) that enable entrepreneurial activities (e.g., local businesses selling food, cutting hair, sewing clothes, pumping water, etc.) (Box 5). Secondly, it presents opportunities to 'scale up' from one service to multiple linked services, such as community wifi and community cold rooms, providing other avenues for generating income and improving efficiency.

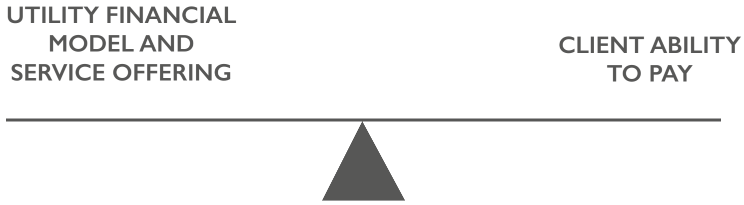
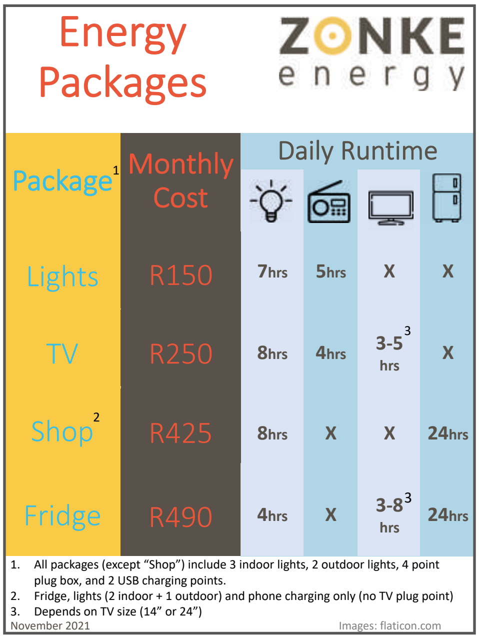


Figure 9: Balancing utility service delivery and community energy needs over time



Energy Packages

ZONKE energy

Package[1]	Monthly Cost	Daily Runtime			
Lights	R150	7hrs	5hrs	X	X
TV	R250	8hrs	4hrs	3-5[3] hrs	X
Shop[2]	R425	8hrs	X	X	24hrs
Fridge	R490	4hrs	X	3-8[3] hrs	24hrs

1. All packages (except "Shop") include 3 indoor lights, 2 outdoor lights, 4 point plug box, and 2 USB charging points.
2. Fridge, lights (2 indoor + 1 outdoor) and phone charging only (no TV plug point)
3. Depends on TV size (14" or 24")

November 2021 Images: flaticon.com

Figure 10: Zonke Energy offer four energy packages (Source: Authors).

5

REFINING SOLAR MINI-GRID PACKAGES IN QANDU-QANDU

Zonke Energy's initial business model included the provision of lights, TVs, and solar fridges/freezers. This was diversified to include a 'shop' package, which enabled clients to generate income to continue to pay for solar mini-grid services (Figure 10). The refinement of solar mini-grid packages was informed by an affordability survey and local business development initiative run by the Umbane project.

AFFORDABILITY SURVEY

Using an affordability and willingness to pay survey, Zonke Energy developed their solar energy package offering, where they used community affordability to refine the overall cost of each of their packages per month. To do this, 17 existing mini-grid clients were asked about their income and willingness to pay for solar energy and this information was used to develop and refine the their package options and costing.

BUSINESS DEVELOPMENT INITIATIVE

To support the financial and long-term viability of the solar mini-grid project in Qandu-Qandu, project partners saw an opportunity for providing business support via Story Room SA. The business development support sessions were held with 21 female entrepreneurs and were broken down into 3 phases (education, coaching, and mentoring) (Figure 11). Business support aimed to enable the development of sustainable businesses using solar-powered fridges and freezers, with Zonke Energy able to develop their service offering to support this. Businesses set up using a solar-powered fridge included shops selling cool drinks, meat, and ice creams, crèches, restaurants, and gyms.

Figure 11: Business development sessions to support the creation of sustainable livelihood opportunities using a solar fridge (Source: Authors).

POLICY RECOMMENDATIONS

In working towards developing sustainable businesses with off-grid solar-powered productive use appliances in South Africa's informal settlements, we recommend the following actions for the stakeholder groups:

National, regional, and city-level governments

- Developing new and/or building on existing policies (e.g., Free Basic Allowance and Alternative Energy policies) to support the use of off-grid renewable energy in informal or low-cost settings (e.g., by identifying target communities, indigent subsidies, rules for interconnecting to the grid, tariff structures).
- Creating avenues for shared communication and learning between government and academics, utilities, and social enterprises to support the generation of new ideas and avenues for funding and implementation (e.g., energy purchase vouchers or subsidies).
- City-level governments can use co-learning between small-scale utilities and community members to refine policy and process around the use of renewable energy services in practice. Successes and failures are particularly important for understanding how locally relevant best practice is developed and used.

Utilities (small scale and national)

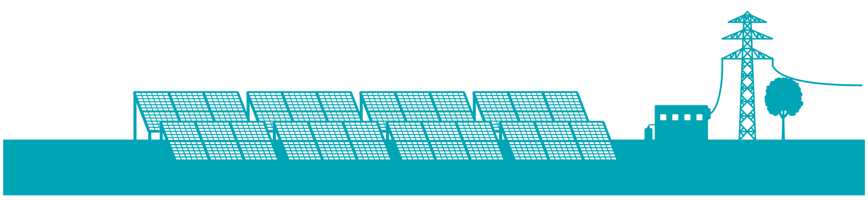
- Utilities can boost the technical and financial sustainability of projects through setting up long-term engagements with communities, where they use community needs as an entry point for developing their service offering.
- Finding ways to communicate with clients is critical (in person or via web-based platforms or apps). As clients pay for a reliable service, setting up strong lines of communication supports troubleshooting and trust-building.
- Finding opportunities to 'scale up' from one service to multiple linked services should form the basis of infrastructure and services projects. Opportunities include the use of repeaters, powered by solar, that make community wifi or community cold rooms.

Development and finance organisations

- Developing locally relevant renewable energy solutions requires understanding the local context, so building activities to understand the geographic location, resident demographics, community needs, and age, among other factors, is important so that these factors can be taken into account to develop relevant and valued energy programmes.
- Skills development to support the implementation, operation, and maintenance of off-grid electrification projects creates livelihood opportunities (e.g., businesses set up using solarpowered fridges/freezers) and should be factored into funding opportunities to create sustainable long-term programmes.
- Initiating funds with longer project timelines, even with small budgetary commitments after the initial project development stage, can help ground continued commitment to deliver continued and sustainable services to and with the community.

Researchers and academics

- Researchers and academics can drive the use of approaches incorporating community needs in electrification programmes.
- Research outputs can be strengthened by finding novel or innovative ways to gather data, or co-learn, together with communities.
- Researchers and academics can also draw on interim findings on the use and development of off-grid electrification programmes to disseminate learnings widely, translating theoretical and practical findings into useable outputs (e.g., technical reports, policy briefs, and practitioner guidelines).
- Reducing the costs of technical components can drive affordability. Technical studies supporting efficiency (using practical learnings) can support the long-term financial viability of off-grid projects.



REFERENCES

Africa Progress Panel. (2015). *Power people planet: Seizing Africa's energy and climate opportunities.* Africa Progress Panel. https://reliefweb.int/sites/reliefweb.int/files/resources/APP_REPORT_2015_FINAL_low1.pdf

Banks, N., Lombard, M., and Mitlin, D. (2020). *Urban informality as a site of critical analysis.* The Journal of Development Studies, 56(2), 223–238. https://doi.org/10.1080/00220388.2019.1577384

Caprotti, F. (2018). *Future cities: Moving from technical to human needs.* Palgrave Communications, 4(1), 35.

Caprotti, F., de Groot, J., Bobbins, K., Mathebula, N., Bulter, C., Moorlach, M., Schloemann, H., Densmore, A., and Finlay, K. (Forthcoming). *Rethinking the off-grid city.* Urban Geography. https://doi.org/doi.org/10.1080/02723638.2022.2036928

Castán Broto, V. and Bulkeley, H. (2013). *Maintaining climate change experiments: Urban political ecology and the everyday reconfiguration of urban infrastructure.* International Journal of Urban and Regional Research, 37(6), 1934–1948. https://doi.org/10.1111/1468-2427.12050

City of Cape Town. (2020). *Directorate executive summary of the service delivery and budget implementation plan 2020/21.* City of Cape Town. https://resource.capetown.gov.za/documentcentre/Documents/City%20strategies,%20plans%20and%20 frameworks/DRAFT_DIRECTORATE_EXECUTIVE_SUMMARIES_AND_SCORECARDS_20_21.pdf

Cowley, R., and Phillips, J. (2018). *What can urban sustainability experiments do?* University of Exeter. https://www.smart-eco-cities.org/wp-content/uploads/2018/02/Event-Report-What-Can-Urban-Sustainability-Experiments-Do.pdf

Croese, S. (2021). *Towards a research agenda for knowledge co-production in Urban Africa. In Marrengane, N. and Croese, S. (Eds) Reframing the Urban Challenge in Africa: Knowledge Co-production from the South (pp. 208–213).* Abingdon, UK, Routledge.

Green Cape. (2020). *Resilient urbanism: The intersection of shared data and inclusive public engagement.* Green Cape. https://www.greencape.co.za/assets/RESILIENT_URBANISM_REPORT_6_7-v2.pdf

Haddad, Z., Williams, K. N., Lewis, J. J., Prats, E.V., and Adair-Rohani, H. (2021). *Expanding data is critical to assessing gendered impacts of household energy use.* BMJ, 375. https://doi.org/10.1136/bmj.n2273

Haque, A. N., Lemanski, C., and de Groot, J. (2021). *Why do low-income urban dwellers reject energy technologies? Exploring the socio-cultural acceptance of solar adoption in Mumbai and Cape Town.* Energy Research & Social Science, 74, 101954. https://doi.org/10.1016/j.erss.2021.101954

IRENA. (2015). *Africa 2030: Roadmap for a renewable energy future.* IRENA. www.irena.org/remap

Jaglin, S. (2014). *Regulating service delivery in Southern Cities: Rethinking urban heterogeneity.* In Parnell, S. and Oldfield, S. (Eds) The Routledge Handbook on Cities of the Global South (pp. 434–458). Abingdon, UK, Routledge. https://doi.org/10.4324/9780203387832.ch37

Koepke, M., Monstadt, J., Pilo', F., and Otsuki, K. (2021). *Rethinking energy transitions in Southern cities: Urban and infrastructural heterogeneity in Dar es Salaam.* Energy Research & Social Science, 74, 101937. https://doi.org/10.1016/j.erss.2021.101937

Kovacic, Z., Musango, J. K., Buyana, K., Ambole, A., Smit, S., Mwau, B., Ogot, M., Lwasa, S., and Brent, A. (2021). *Building capacity towards what? Proposing a framework for the analysis of energy transition governance in the context of urban informality in Sub-Saharan Africa.* Local Environment, 26(3), 364–378. https://doi.org/10.1080/13549839.2020.1849075

Marx, C. and Kelling, E. (2018). *Knowing urban informalities.* Urban Studies, 56(3), 494–509. https://doi.org/10.1177/0042098018770848

Roy, A. (2011). *Slumdog cities: Rethinking subaltern urbanism.* International Journal of Urban and Regional Research, 35(2), 223–238. https://doi.org/10.1111/j.1468-2427.2011.01051.x

SEA. (2015). *State of Energy in South Africa Cities.* Sustainable Energy Africa.https://cityenergy.org.za/uploads/resource_322.pdf

Silver, J. (2014). *Incremental infrastructures: Material improvisation and social collaboration across postcolonial Accra.* Urban Geography, 35(6), 788–804. https://doi.org/10.1080/02723638.2014.933605

Swilling, M. (2014). *Rethinking the science–policy interface in South Africa: Experiments in knowledge coproduction.* South African Journal of Science, 110(5/6), 7. https://doi.org/10.1590/sajs.2014/20130265

Thrie Energy Collective. (n.d.). *Data Huddle.* Thrie Energy Collective.http://www.thrienergycollective.com/#datahuddle

World Bank. (2018). *Population living in slums (% of urban population)–South Africa.* Data Bank. https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS?locations=ZA

World Health Organization. (2016). *Burning opportunity: Clean household energy for health, sustainable development, and wellbeing of women and children.* World Health Organization. https://apps.who.int/iris/handle/10665/204717

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