Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

LOW- AND MIDDLE-INCOME GRID-CONNECTED SOLAR PV APPROACHES IN SOUTH AFRICA: DISCUSSION PAPER

SUMMARY

Low- and middle-income households have not participated in the growing uptake of solar PV small-scale embedded generation (SSEG) systems in South Africa for various reasons, amongst which are affordability and access to finance. While there are several examples of innovative approaches to deploy grid-connected solar PV technologies on low-income households globally, most of them rely on full or partial subsidisation. In South Africa, such initiatives are rare, and where PV is implemented, the target is generally unelectrified households. Currently, the business case for solar PV SSEG system implementation is not convincing for households and for municipalities without subsidisation. At the same time, the business case for subsidies is weak given the social and economic benefits of alternative social investments programmes. There are, however, options such as decentralised PV installations with storage located at distributor depots in low-income areas, which hold potential benefits for communities and municipalities. These require further investigation. Also, with constantly decreasing PV prices and rising electricity tariffs, the financial case is changing fast. The workshop undertaken in November 2017 with representatives from local and national government, the research community, the utility industry, and other organisations, revealed that the PV industry players are interested in further developing this area. This includes piloting some initiatives to find solutions that could be mass-replicated to benefit lower-income households. Coordination and sharing the lessons among these players is important going forward.

SETTING THE SCENE

CONTEXT

Following the global acceleration of renewable energy implementation and the decentralisation trend of energy generation options, solar PV has become increasingly cost-effective – including in South Africa. Over the recent years, there has been a fast growth in the number of **solar PV small-scale embedded generation (SSEG) systems** installed in the residential sector in South Africa; however, this has largely been limited to urban upper-middle and high-income households. The majority of the electrified low-income and middle-income urban households throughout the country remain reliant on electricity provided either by Eskom or by the local municipality, with some use of alternative energy sources such as paraffin, wood, and candles.

As the uptake of solar PV SSEG among the upper-middle-income and high-income households grows, the municipal revenue from the sale of electricity may decline. Unless municipalities design appropriate tariffs to mitigate the potential loss in revenue, their ability to cross-subsidise lower-income households could weaken.

The renewable energy transition agenda is not simply about technology change, but also equitable access to energy and economic opportunity within the energy sector. In South Africa, distributed renewable energy may offer an opportunity to hedge against above-inflation electricity tariff hikes as well as lead to socio-economic developmental benefits such as green economy growth and the creation of jobs in low- and middle-income communities. Having said this, affordability remains a central issue when dealing with low-income households. Municipalities are making significant headway accommodating SSEG systems with commercial and industrial customers as well as higher-income residential SSEG applications. While associated regulatory, tariff, and technical issues are now better understood and dealt with among municipalities, extending such rollout into the lower-income residential sector in a sustainable manner presents some challenges – both from the distributor's side as well as from the household side.

There is a need for a more in-depth investigation into business models for grid-connected PV SSEG targeting low- and middle-income households as well as an

URBAN-ECON Development Economists | SEA SUSTAINABLE ENERGY AFRICA | SUSTAINABILITY INSTITUTE innovation lab exploration of the socio-economic benefits of such a rollout to clarify the appropriateness and potential mechanisms for engaging in this sector.

This paper serves to stimulate the discussions around this topic and provides an insight into some of the opportunities as well as challenges that exist. It is based on detailed financial modelling, case study assessment, and implementation analysis work (please engage with the contacts at the end of the paper for more information).

TARGET GROUPS

For the purpose of this study, low- and middle-income households are defined as households falling within Living Standard Measure (LSM) groups of 3 to 5 and LSM 6 and 7, respectively. Very low-income households falling within LSM group 1-2 are excluded from the analyses due to being shielded from electricity tariff hikes; they qualify for Free Basic Electricity and generally have small electricity consumption levels.

Low-income HH profile: LSM 3-5 (2016)

Home ownership	• 54% of HH own a house • 25% of HH rent
Housing type	• 47% live in free standing houses • 26% live in informal dwellings • 85.7% of dwellings electrified
Electricity usage	• 225 - 318 kWh per month • Max winter demand - 0.88 kW • 2kWp PV SSEG appropriate
Cost of solar PV system	• Av HH monthly income = R3 046 • 2kW solar PV system = R40 000 • 1.5 X HH annual income
Access to finance	• Qualifying credit (unsec): R11 400 • Qualifying credit (sec): R10 600

Sources: Eskom, Credit Bureau, Stats SA

Low-income households earn just over R3 000 per month on average. While salaries represent the most common source of income, almost a third of this group rely on social grants. Just over half of these households own a dwelling, which largely comprise free-standing houses. Most households in this group have access to electricity and use it to power a few lights, a stove (which often is used for heating and not only cooking), a fridge, a kettle, and a cell phone charger. Installing a 2kWp solar PV SSEG system would cost the household approximately R40 000 at current prices, which would require financing. Due to the low-income levels of this group and limited ownership of assets, they would be unlikely to secure the necessary loan from financial institutions.

Middle-income HH profile: LSM 6-7 (2016)

Home ownership	• 60% of HH own a house • 25% of HH rent
Housing type	• 75% live in free-standing houses • 8% live in informal dwellings • 99.6% of dwellings electrified
Electricity usage	• 429 - 599 kWh per month • Max winter demand – 01.63 kW • 3kWp SSEG PV appropriate
Cost of solar PV system	• Av HH monthly income = R7 911 • 3kW solar PV system = R60 000 • 0.6 HH annual income
Access to finance	• Qualifying credit (unsec): R16 700 • Qualifying credit (sec): R39 200

Sources: Eskom, Credit Bureau, Stats SA

Middle-income households are better off than low-income households, earning R6 000 per month on average and up to R12 000. They generally have improved security of tenure and greater access to electricity. Middle-income households consume twice as much electricity as low-income households. While middle-income households earn more than twice the average monthly income of low-middle households, largely due to higher employment rates, the majority would still be unable to qualify for the loan necessary to purchase a system.

It is clear that there are a number of barriers that low- and middle-income households would face to obtain PV SSEG systems. The cost of solar PV and access to finance are among the most prominent of these. These market segments will not develop under the same incentives as the upper-middle and high-income target markets and require innovative approaches and solutions.

LESSONS LEARNED FROM CASE STUDY ANALYSIS

A review of the international and domestic case studies undertaken revealed a wide variety of models and approaches used to deploy solar PV systems among low-income households:

Internationally, these initiatives target electrified communities and aim to address challenges specific to the country, region, or community, be it:

- The need to reduce the government burden of paying electricity subsidies over the long term;
- Finding a solution to electricity shortages and rising electricity costs;
- Improving the green profile of the area;
- Responding to a sluggish growth of the solar PV industry; or
- Supporting economic inclusion.

The range of approaches used to fund the initiatives varied significantly and included innovative solutions such as:

- Repurposing of electricity subsidies, where government subsidies are used to co-finance the purchase and installation of the SSEG systems (e.g. Mexico and Tunisia)
- On-bill loan recovery, which reduces the administrative burden and provides for payment guarantees (e.g. Tunisia)
- Low-interest long-term loans from development financial institutions and green banks (e.g. Mexico)
- Feed-in-tariffs and net-metering credits (e.g. India, Tunisia, and the USA)
- Bulk purchases aimed at achieving economies of scale and reducing the initial costs of capital (e.g. Mexico and China)
- Funding by utilities as part of their green initiatives and social programmes (e.g. the USA)

Most of the initiatives, however, relied on partial or full subsidisation. In instances where households were responsible for payment, the repayments were generally lower than electricity bills prior to the installation of the systems, which assisted in achieving a greater buy-in among them. While some initiatives aimed to provide systems that would enable self-sufficiency, others allowed for credits or income on excess electricity fed into the grid.

In **South Africa**, cases of deployment of SSEG systems among low-income households are scarce. In most instances, solar PV is used to address current shortcomings in the electrification of households (i.e. in unelectrified or highly grid-constrained areas). Such initiatives are generally championed by the municipalities or non-governmental organisations (NGOs) on a case-by-case basis and are seldom integrated into any broad approach targeting low-income households. The case studies covered indicate that crowdfunding, grant funding, and municipal funding are some of the most prominent means of financing solar PV systems.

There has been limited progress made in SSEG implementation among low-income households in South Africa. The challenges faced in this regard by these households and the government priorities designed to respond to these challenges have clearly not yet established a strong enough market for wider deployment of solar PV SSEG within these target groups. This demands a more focused investigation into the business case and other socio-economic benefits for both households and municipalities.

MODELLING EXERCISE IN BRIEF

In order to investigate a business case for households and municipalities, a preliminary analysis was done to explore the potential impact of a grid-connected solar PV SSEG installation on a low-income household's annual electricity costs and on the municipality's income. This was done by developing a spreadsheet model, the purpose of which was as follows:

a) To examine the influence of a range of assumptions (variables) on the finances of the household and the municipality

b) To identify any scenarios (sets of variables) in which the combined impact on these household and municipal finances, summed at present value over a specified number of years, is sufficient to cover the upfront costs of the PV installation

The analysis used the 2017/2018 municipal and Eskom tariffs, together with a year of hourly solar electricity generation potential (per Wp installed) for a range of locations in South Africa. "Typical" hourly electricity demand profiles for low-income households were generated based on data sourced from a low-income household study. All the data were analysed over a variable finance term (typically 15-20 years) to determine how much money the household could save each year and what the impact on municipal revenues would be (compared to the business as usual (BAU) case, without a SSEG system). Although a shorter repayment period may be more realistic, the cumulative annual savings (from avoided electricity purchases) are typically only sufficient to pay off the cost of the hardware after 15 years or longer. The modelled 15 to 20-year assumption might, however, be feasible if the financing is tied into an existing or new home-loan facility since such facilities often run for the same period or longer.

The range of variables in the model included the average monthly household electricity consumption; the annual escalation (above consumer price index - CPI) of tariffs and the tariffs themselves (including feed-in tariffs and SSEG fixed charges); the cost of capital (above CPI); the size and cost (per Wp installed) of PV hardware; the use (or not) of electricity storage by the municipality and the cost of storage; and the use (or not) of timed electricity consumption by the household (i.e. for water heating).

BUSINESS CASE FOR HOUSEHOLDS

From a perspective of low- and middle-income households, the modelling exercise revealed the following:

- With very favourable conditions (i.e. high solar output, cheap long-term financing, attractive feed-in tariffs, indefinite and high grid-electricity tariff escalations above CPI, ideal roof-orientations), there is potential for a financial break-even over 15 or 20 years for a household consuming 350-550kWh/month and installing a 2kWp system. Conversely the required SSEG tariff levels for household break-even would be minimally adverse for the municipality (compared to BAU revenues)[1]. However, incentives for mid- and low-income households to opt into such a "break-even" proposition would need to include immediate financial benefits for the household (i.e. savings on their electricity bill from the first month). This, in turn, would make the financing of the scheme more expensive due to a longer repayment period, since a portion of the savings would go to the household's pocket rather than going entirely to paying off the cost of the hardware. Therefore, an attractive and viable financial proposition for households is likely to need significant grant subsidisation of the upfront cost of the hardware. This raises the question as to whether this is the most cost-effective way to ensure that low-income households and communities benefit – both financially and socio-economically – from the "future-proofing" potential of solar PV SSEG systems.
- A larger rooftop PV SSEG system (e.g. 3.5kWp which would effectively make the household a net generator) combined with special tariffs can improve the financial viability of the investment, but it would require very innovative financing and a robust partnership contract between the municipality and the household.
- The general trend emerging from the preliminary modelling is that the financial case for low- and middle-income households is precarious at best.

[1] It should be noted that profitability of the BAU scenario for the municipality is increasing each year because the model assumes that the escalation of the municipality's tariff tracks Eskom's tariff increases. This means that the municipality is making a bigger real margin each year.

This is, however, based on a large number of assumptions, which in practice will vary in different circumstances and over time. For example, the model assumes an installed cost of PV at ±R20/Wp However, if costs continue to drop significantly, as they have in the past decade, then the prospects for low- and middle-income households should be reviewed.

BUSINESS CASE FOR MUNICIPALITIES

The analysis of the results from a municipal perspective highlighted the following:

- By setting SSEG tariffs to appropriate levels, municipalities can ensure that they do not lose revenue (off a business as usual scenario) via middle- and low-income household SSEG rollout programmes. However, such a tariff would need to be set carefully to not be punitive for low- and middle-income households.
- To protect revenue while still providing an attractive financial offering to such households remains a challenge: For each kWh of self-generated consumption by a customer, the municipality loses revenue, and yet the municipality is typically required to buy back the consumer's surplus generation at precisely the time when demand is low and Eskom electricity is relatively cheap. Thus, the municipality is very limited in how much it can pay for feed-in units, unless this can be subsidised by a third party and motivated by other objectives such as climate change targets or industry development.
- Notwithstanding the potential for accessing grants or subsidies to help kick-start a take up of PV SSEG by low- and middle-income households, it is questionable whether targeting individual households as beneficiaries of such subsidies is the most cost-effective and equitable approach. To clarify this case would require further exploration.

The case for municipalities to invest and support a large-scale rollout of rooftop PV SSEG among low- and middle-income households, without third party support, appears weak at this stage. However, the municipal business case is likely to be improved, to some extent, by using storage to reduce purchases of Eskom electricity in winter peak-demand periods. It should be noted, though, that the current cost of storage (on a cost per stored kWh basis) remains high, and while these costs are predicted to drop significantly over the next 5-10 years, any investment in storage would require a plan that makes continuous and full-capacity use of a large-scale (not individual household) storage facility throughout the year. This, in turn, means that a storage facility would need to serve more than just the avoidance of peak Eskom tariffs. The financial case would also need to serve other objectives such as avoiding grid-upgrade costs in constrained areas. Therefore, while SSEG systems with large-scale storage is a potentially attractive proposition under certain assumptions, it requires further investigation, particularly in relation to its use in areas where the distribution grid capacity constrains demand.

IDENTIFIED OPPORTUNITIES

In general, the investigation into the accelerated deployment of solar PV SSEG systems among low- and middle-income households, inclusive of the inputs from a range of stakeholders, indicates that it is not easy to make a financial case for embarking on the rollout of rooftop solar PV SSEG in these target markets, considering both the household and the municipal perspectives. Subsidies would be required, as has also been seen in the majority of international case studies. However, any subsidisation would need to be justified through broader socio-economic motivating factors such as industry stimulus, carbon reduction targets, power price stabilisation and local job creation. Where the subsidy would be raised within the system requires thought. And even then, it would be important to determine whether the allocation of subsidies for the accelerated rollout of solar PV SSEG among low- and middle-income households would be the most cost-effective and equitable way to generate socio-economic benefits for these communities, or whether greater societal benefits could be achieved through alternative implementation models. For example, the same socio-economic benefits could potentially be achieved more cost-effectively and equitably by developing centralised but localised PV plants, rather than funding individual household installations. The financial returns could still be passed on to the target communities via electricity tariff reductions or other innovative means.

While the financial case may change in the coming years, particularly if the price of PV panels decreases markedly and pure market-based approaches become more likely, currently there appears to be little reason to focus on schemes that involve solar PV SSEG systems on roofs of individual low- and middle-income household dwellings that are already connected to the grid without normal supply constraints. There are also additional concerns around equipment security, reverse-feed safety, and maintenance and metering demands on municipal staff, among others. These sentiments were expressed by participants of the workshop held in November 2017, which was attended by representatives from local and national government, research institutions, the utility sector, non-governmental organisations, and other interested parties.

The more promising areas for further exploration, which were also highlighted at the workshop, revolve around implementing community-level (rather than individual household) solar PV systems (e.g. local solar farms) coupled with storage in local distribution areas, especially where the grid is constrained. Importantly, such systems can still create socio-economic benefits for the community. The use of larger SSEG systems on rooftops may also hold promise if suitable financing and ownership models can be implemented. These are discussed further below.

OPPORTUNITY 1: EMBEDDED SOLAR PV 'FARMS' AND STORAGE INSTALLATIONS IN LOCAL DISTRIBUTION AREAS

Instead of installing a grid-tied solar PV system on each household, a municipal-owned PV system is rather installed at the local electricity depot, together with storage. The municipality installs, operates, and maintains the system, which is in a secure enclosure. The use of storage can improve the municipal financial case for such a project and is of particular benefit where the grid is constrained (i.e. unable to meet peak loads). The availability of storage will also benefit the households by improving power availability over peak times. In addition, the existence of such PV systems on the municipal grid can hedge against future increases in national generation prices.

Advantages/Pros

- ✓ Potential to collaborate with the private sector to overcome capacity constraints
- ✓ Security of PV equipment is improved
- ✓ Installation and maintenance costs are reduced
- ✓ Maintenance consistency
- ✓ Training and local job creation potential (system operation, maintenance)
- ✓ Local business stimulus (e.g. if combined with a small business hub)
- ✓ Grid constraints reduced; upgrades deferred
- ✓ Local shareholding schemes could be explored
- ✓ The potential for centrally raised finance for a number of such installations across the municipal distribution areas could be explored (at lower risk than household financing and therefore lower cost of capital)
- ✓ Can help stabilise electricity prices for the municipality and customers (in the face of potentially fast rising national grid-sourced power prices)
- ✓ More equitable distribution of financial and socio-economic benefits to the local community

Disadvantages/Cons

- ⚠ Municipalities do not have experience with such installations
- ⚠ Municipal capacity to operate such a plant is not in place
- ⚠ Local benefits may not be direct (individual households may not see a financial gain)

While such a system may not financially benefit the local community directly, local jobs to operate and maintain the installation could be created, and a small-business and/or public services hub (preferably with daytime peaking loads) could be encouraged near the site. In addition, schemes that enable local shareholding could be explored to provide more direct benefits to target communities. Such schemes are being considered by some cities and the private sector and involve establishing a company, which invests in PV projects and allocates dividends according to set procedures. Mechanisms to include low-income households require further consideration, but may include loan schemes payed off via dividends.

There may be opportunities for several such local PV 'farms' to be pooled to facilitate more attractive financing and possibly attract financing from development finance institutions (DFIs) or donor support.

Further modelling and analysis is necessary to clarify the feasibility of different approaches for such installations, including undertaking a comparison of costs and benefits with alternatives such as larger scale municipal generation (e.g. comparing ten 100kWp systems with one 1MWp system). Regulatory clarity is also required.

OPPORTUNITY 2: SOLAR PV ON APARTMENT BLOCKS

There may be a case for installing solar PV SSEG on low- and mid-income apartment blocks around cities. These may be municipally owned social or affordable housing projects or privately-owned dwellings with some form of residents' association or a body corporate. As pressure to densify mounts, the incidence of such housing types will increase, providing numerous opportunities for such SSEG systems.

SSEG systems on apartment blocks also have the potential for reduced installation and maintenance costs compared to individual household systems, can stabilise electricity costs for residents, and can help cities reduce their carbon emissions. In addition, in line with densification strategies and climate commitments, cities may be able to offer incentives to developers (such as removing height restrictions) to install costlier but low carbon PV energy systems. The financial case and ownership mechanisms need to, however, be further explored.

Advantages/Pros

- ✓ Reduced installation and maintenance costs
- ✓ Support stabilisation of electricity costs for households (as national grid prices increase)
- ✓ Maintenance consistency
- ✓ Potential local job creation (operation and maintenance)
- ✓ Carbon reduction for municipality
- ✓ Could be paired with storage in grid-constrained areas
- ✓ Improved security of infrastructure

Disadvantages/Cons

- ⚠ Financial and ownership model untested
- ⚠ Requires adequately orientated roof-spaces (limiting feasibility for existing buildings)

OTHER OPPORTUNITIES

Other opportunities that may hold promise for the future include the following:

- Ongoing significant reductions in PV panel prices may open up opportunities for direct market-driven SSEG implementation in low- to middle-income areas in the future. In this case, the only enabling requirement from the municipality would be an appropriate SSEG fixed charge that is not punitive for low- and middle-income households (which is the case in many municipalities at the moment). Understanding the implications for municipal distributors, amongst others, is important.
- Larger solar PV SSEG systems on rooftops of low to middle-income household dwellings (such that they become net-generators) could open up opportunities for more direct benefits for such households, with carefully designed tariffs and appropriate ownership and financing schemes.
- With fast-decreasing storage costs, distributors across the world are looking at integrating such storage into grids optimally (independently of SSEG considerations). One of the most obvious areas for including storage is in grid-constrained areas and various players, including Eskom, are

already looking into the role of storage in this regard.

- Providing solar PV installations as a first-phase electrification scheme under the national housing policy for "phased *in-situ* informal settlement upgrading" is also another potentially viable opportunity to create a greater deployment of solar PV among low- and middle-income households. Smaller (400-800Wp) installations would provide a subsidised "free-basic" service (50-100Wh/month) for eligible indigent households and would be installed "grid-ready" for subsequent connection to the grid, as the second phase of upgrading. Technically, the PV system would initially have battery storage (per household or shared in clusters for better efficiency) and a "grid-ready" inverter that provides AC power. Later, when each household is upgraded to a grid connection, the PV panels would be retained but the storage component would be decommissioned (since the grid then becomes the "store"). There are precedents where the Free Basic Electricity (FBE) subsidy has been used to support the delivery and maintenance of off-grid PV electricity to unelectrified informal settlements. However, some policy development would be required to integrate this idea into a longer-term programme of incremental *in-situ* upgrading. In-line with the broader housing objectives, the PV-panels themselves could be integrated into the roof component of a robust, basic dwelling super-structure (e.g. four pillars and a roof).
- Greenfield developments that are off the Eskom transmission grid and may not be connected in the medium term provide interesting sites within which to explore SSEG and mini-grid options.

RECOMMENDATIONS

RECOMMENDATION 1: FURTHER DEVELOP THE FINANCIAL AND SOCIO-ECONOMIC CASE FOR PV 'FARM' AND STORAGE INSTALLATIONS IN LOCAL DISTRIBUTION DEPOTS

This option presents a range of advantages, including economies of scale (compared with SSEG on household rooftops), such as reduced operating and maintenance costs, stabilisation of electricity costs, and local community benefits. The financial case needs to be further developed, as does the implementation mechanism, including the potential for community shareholding or ownership. In addition, the potential socio-economic benefits need to be maximised in the implementation approach. Suitable financing sources and mechanisms need to be clarified.

RECOMMENDATION 2: FURTHER EXPLORE THE IMPLEMENTATION OF SSEG ON LOW TO MIDDLE-INCOME APARTMENT BLOCKS

With the increasing numbers of such apartment blocks in cities, the potential for rooftop SSEG systems to benefit both the municipality and residents holds promise. The financial case, socio-economic benefits, implementation mechanisms, ownership models, and potential financing sources should be further explored.

RECOMMENDATION 3: PERIODICALLY EVALUATE THE FEASIBILITY OF SSEG ON LOW TO MIDDLE-INCOME HOUSEHOLD ROOFTOPS

As PV prices drop and national grid power prices rise, the financial case for such systems could change significantly. This includes the feasibility of installing over-specified SSEG systems on rooftops (i.e. such households becoming net generators). A periodic re-evaluation of the costs and benefits of such implementation should be undertaken.

RECOMMENDATION 4: PERIODICALLY DRAW TOGETHER THE WORK OF THE MANY STAKEHOLDERS ACTIVE IN THIS AREA

The stakeholders working in areas relevant to SSEG in the low-income sector include GreenCape (exploring implementation mechanisms and financing options which are appropriate for this sector), the CSIR, Eskom, SEA and SAPVIA. In addition, a number of municipalities are actively looking at such rollout mechanisms and feasibility, including undertaking pilot projects. These include eThekwini, the City of Johannesburg (City Power low-income SSEG pilot), the Nelson Mandela Bay Metro, and the City of Cape Town. It would be useful for these and other relevant players to share experience and coordinate activities periodically.

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