An alternative to higher energy tariffs: Extracting unused capacity from small-scale embedded solar

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Small-scale embedded solar (SSES) is already widespread in South Africa, driven by declining photovoltaic (PV) costs, rising electricity tariffs and grid instability. Nevertheless, the further expansion of SSES is constrained by its affordability and disincentives for energy trading. Real-time data from a 6.5 kWp PV with an 8/10 kWh battery were used to evaluate the techno-economic performance of SSES, focusing on the economic rationale for bidirectional metering and prosumer integration. It is shown that the levelised cost of energy is 75% higher than the cost of grid-based electricity. An important contributor to the high cost is the extent of unused generation capacity (50%). Scenario modelling shows that if this excess energy were sold to the grid, electricity distributors would realise significant revenue gains, fully justifying their initial subsidy of the metering and certification costs. This study concludes that enabling prosumer participation through municipality-funded bidirectional metering would stimulate SSES registration and partially offset the need for future tariff increases, offering a cost-effective pathway toward a more inclusive and sustainable energy transition in South Africa.

Significance:

- Eskom and local authorities are foregoing a strategic opportunity to profit from low-cost SSES energy.
- SSES is an expensive option for homeowners; the levelised cost of energy is 75% higher than the cost of grid-based electricity.
- A major barrier to authorised interconnection and energy trading is the additional cost of registration and bidirectional meters.
- The benefit to cost ratio of interconnection for electricity distributors is 5.2:1.
- Eskom and municipalities should subsidise these costs to drive energy affordability and resilience.

Introduction

Despite favourable climatic conditions, the initial installation of solar photovoltaic systems in South Africa began slowly due to extensive grid connection and low-cost electricity. Nearly 90% of households have access to grid-delivered electricity[1] and, historically, electricity prices have been low relative to those in other countries[2].

However, small-scale embedded solar (SSES) is now widespread, with nearly 3.4 GW of installed capacity as of the end of the third quarter in 2023, of which at least 1.54 GW has been installed in the major metropolitan areas.[3]

The rapid uptake of SSES in South Africa has been driven by main three factors: the falling price of solar energy globally[4], the rising cost of grid-based electricity[5] and major instability in the national energy system resulting in frequent loadshedding and interruptions to supply[6].

Many of these SSES systems are designed for winter conditions, when solar irradiation is at its lowest and the solar panel must be able to meet the daily energy demand of the household, agricultural, industrial or commercial site for which it has been designed. Under summer conditions, however, these systems are overdesigned, resulting in large amounts of excess generation capacity which cannot be used unless the system is equipped with bidirectional metering and other interconnection capabilities.

Such a facility, shown diagrammatically in Figure 1, allows the energy consumer to become a supplier and a consumer, referred to as a 'prosumer', implying that the owner of the SSES system can both sell electricity to the

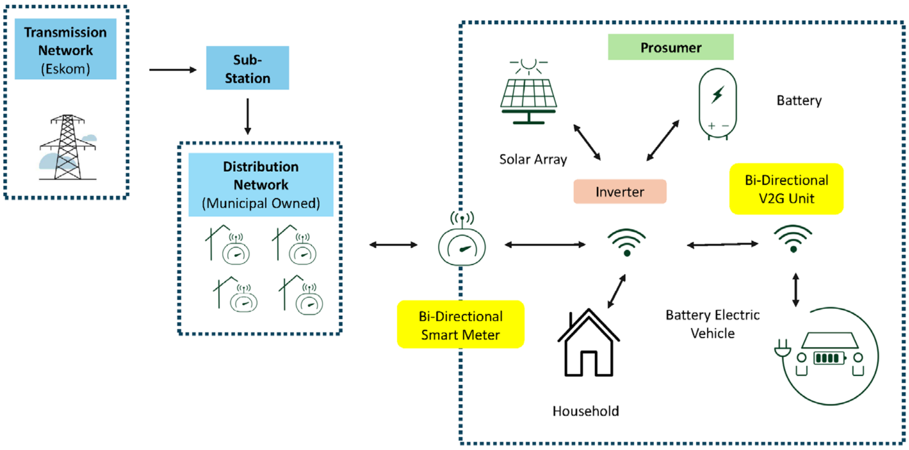

Figure 1: Standard configuration of grid-tied small-scale embedded solar.

grid and purchase energy when the behind-the-meter resources are not available. Prosumer relationships are already widely used within many countries but have been slow to materialise in South Africa.

This article provides a brief review of the literature on SSES systems and their interconnection, and the economics of rooftop solar. I then describe the structure of the techno-economic model that was used to explore the issue of affordability and economic return to both SSES owners and electricity distributors, and how the primary data were collected, following which the results of the modelling are presented and discussed. Finally, the implications thereof for energy regulators and electricity distributors are outlined.

Literature review

Small-scale embedded solar in South Africa

SSES is a subset of small-scale embedded generation, where the latter refers to small-scale electricity generation systems connected to the grid at a residential, commercial or industrial site, typically with a capacity below 1 MW. Small-scale embedded generation may deploy a variety of energy technologies, including photovoltaics (PV), wind turbines, micro-hydro, biomass, biogas, natural gas or liquid fuels.

SSES has emerged as a major component of small-scale embedded generation, driven in South Africa by the three factors already mentioned (decreasing costs of PV, rising cost of grid-based energy and unreliable supply). Other contributing factors, in South Africa and elsewhere, include lower costs of battery storage[7], greater modularity of PV components which allow systems to scale linearly[8], widespread social acceptance[9,10], policy incentives[5,11] and the development of smart grid integration technologies[12].

Estimates for the total installed capacity of PV systems in South Africa vary. The South African Photovoltaic Industry Association (SAPVIA) reports that the total capacity, including utility-scale installations, was 5.7 GWp (p refers to peak power and is the rated output of a PV panel under maximum solar irradiation) at the end of the first quarter of 2023, of which 3.4 GW is SSES.[3] However, the actual number of systems and total capacity could be significantly higher due to unregistered installations.[3]

Costs of embedded solar

Surprisingly, as of the end of 2024, there were few published studies of the levelised cost of energy (LCOE) for SSES in South Africa, and how this compares to the cost of grid-based electricity (GBE). Klever[14] reports that, for a 15 kWp grid-tied system with battery electric storage, the investment costs range from ZAR20000/kWp to ZAR29 000/kWp, and the LCOE values from ZAR1.4/kWh to ZAR1.8/kWh (all values in nominal 2018 ZAR). Klever[14] also noted that the LCOE values are all higher than the GBE values, resulting in a negative net present value.

Other studies have looked at utility-scale solar, or rooftop solar systems without storage, but the values are mostly incorrectly calculated or incomparable.[5,15-17] The main conclusion of the few relevant studies which have been published is that LCOE values for SSES systems which meet the minimum standards in respect of regulatory compliance and reliability, exceed the cost of GBE.[14]

In an attempt to stimulate investment by private consumers in energy generation, some South African municipalities offer feed-in tariffs for small-scale embedded generation.[18] For instance, the City of Cape Town provides a feed-in tariff of ZAR1.173/kWh for both residential and commercial systems up to 1 MW.[19] These incentives can enhance the economic viability of solar installations by providing additional revenue streams for system owners, but, more importantly, provide a low-cost source of electricity for municipalities and Eskom itself, a potential co-benefit which is further explored later in this article.

In summary, the emergence of SSES raises several important questions for all stakeholders in energy systems, including consumers, prosumers, utility companies, regulatory agencies, policymakers and governments. By its very nature, SSES leads to the weakening of publicly accessible energy infrastructure, as the systems provide localised energy generation and reduce the demand for centralised systems. Previous publications have noted that SSES challenges the market structure of electricity distribution in South Africa and have urged the development of a coherent policy that would at least attempt to allow co-benefits in the ongoing evolution of the electricity system.[13,20]

The goal of economic co-benefits, not previously reported in the literature, is the intent of the analysis as reported in this article. In the next section, the overall research approach, the structure of the LCOE model and the design of the experimental equipment are presented in more detail.

Research methodology

The research method for this study is based on a techno-economic modelling approach using the LCOE framework, as described in the following subsection. Techno-economic modelling is a widely applied analytical tool to investigate the feasibility of emerging technologies such as V2G.[21] At its core, the methodology involves quantifying technical parameters (such as energy efficiency, conversion rates, resource inputs and system lifetimes) and translating these parameters into cashflows, investment requirements and potential returns under different scenarios using financial calculations such as internal rate of return, net present value and annual equivalence. This combination of both technical and economic analysis allows researchers and entrepreneurs to bridge the gap between purely technical assessments and abstract economic models, providing a framework that captures both engineering realities and market dynamics.

Although useful, engineering and finance are not the only considerations in understanding and negotiating or driving processes of change. Indeed, techno-economic models have been accused of being calculative agencies intent on their own replication.[22] In other words, a model is not an abstract or objective reflection of the techno-economic merits of a technology – it can itself become the means through which a predetermined perspective of a novel technology is perpetuated, and any necessary socio-technical transitions are resisted.[23,24] These limitations are acknowledged and respected, and, in response, the discussion of the model results concludes with a brief reference to the limitations of the economic incentives, and what else may be required to develop prosumer energy markets.

Construction of the techno-economic model

The model is based on the techno-economic method of levelised cost of energy (LCOE).[25] The assumptions, steps and algorithms of LCOE have been widely reported[26,27] and are not repeated in this publication, except to note the following:

- The cost of the capital items (panels, battery, inverter, phase controller and balance of plant) are actual values from the purchase of the system as specified in Table 3.
- The financial calculations are all based on real 2024 South African rands (ZAR), noting that LCOE cannot deal with inflation in the model.
- The (real) discount rate for the LCOE calculation is assumed at 8%; the value excludes inflation (see Park[28] for a full description of the distinction between real and nominal interest rates).
- The levelised cost calculation as used in this study may be more accurately described as the levelised cost of delivery, because it is based on delivered energy to the site after losses associated with the inverter/battery cycle, referred to as the roundtrip inefficiency.[29]
- Operations and maintenance costs are entered at ZAR205/kw/year.[30]
- A 20-year project lifetime is used for the analysis and no allowance has been made for replacement of any of the capital items within this time period.
- Actual data on decreases in PV panel efficiency over their lifetime, although reported in the literature[31], have not been included as no primary data are available over an extended period from the site.
- Values for GBE were obtained from actual utility bills for the site at which the SSES was located and are listed in Table 1.

Table 1: Costs for grid-based connection

Cost component	Unit	Cost
Network capacity charge	ZAR/year	2699
Unit cost (<600 kWh/month)	ZAR/kWh	2.824
Unit cost (>600 kWh/month)	ZAR/kWh	4.541

Source: Eskom utility bills

Equipment design

The energy output of a solar system depends on factors such as geographical location, panel orientation and local climate conditions. In South Africa, a well-optimised residential solar PV system can produce between 1500 and 1800 kWh per kW per year in the northern parts of the country. Thus, a 5 kW system might generate between 7500 and 9000 kWh annually. For the Western Cape, which is further south and has long periods of cloud cover, the equivalent values are 6000 to 7500 kWh per year.

The system, used in this study, was designed to meet the daily energy requirements for a three-bedroomed household with the main energy needs being air conditioners, a borehole pump and space heaters in winter, but no water heating as most of the hot water needs are covered by a solar water heater. Total usage for this configuration is about 400 kWh per month in summer (November to February) and 1000 kWh per month in winter (July to September), giving a total of 7500 kWh per year. The maximum demand during the day in winter is about 20 kWh. Based on these parameters and the location of the site (in the Western Cape Province), 12 panels of the 555 W Canadian Solar HiKu6 Mono PERC were specified.

The design of the battery system was based on the single design parameter of meeting the summer overnight usage, which is about 0.6 kWh per hour for the period 18:00 to 08:00, in other words about 6–7 kWh/night. Given that it is not advisable to deplete the battery beyond 35% on a regular basis, the specified battery size was then 10 kWh.

However, this method for the battery specification ignores an important parameter for SSES, namely the desired level of system reliability. Renewable energy is an intermittent and variable resource. Decentralised SSES energy systems completely independent of the grid must provide sufficient local storage to combat periods of low or zero solar power, so that demand can continue to be met without any interruption in supply. However total independence without any supply failure is non-viable. The size of the necessary storage to cover long periods of poor solar insolation is simply too large to be economically justifiable.

As a result, systems are designed according to an estimated level of reliability, or what the literature refers to as the fraction of demand served (FDS).[32] For small-scale embedded generation systems within sub-Saharan Africa, it is reported that the cost of energy is lowest when a FDS value of 90% is used, at which point the LCOE is about USD0.4/kWh (ZAR8/kWh). Higher levels of FDS are possible but the costs increase logarithmically thereafter.[32] A system operating at 90% FDS typically has a PV ratio of about 6 kWp to 8 kWh storage, but this ratio is heavily dependent on the profile of night vs day consumption, winter vs summer consumption and daily variability in solar insolation.

Primary data were extracted from a single photovoltaic system located in the Western Cape, South Africa, with the specifications as indicated in Table 2.

The actual costs for the SSES system are given in Table 3. It is noted that the costs do not include the costs of a directional meter and its registration/installation. The total installed cost equates to ZAR33 000/kW, which is lower than the international benchmark costs[18] but similar to those from other studies for South Africa[15].

Data collection

The system was monitored continuously over the period of the study, with data recorded every minute. Hourly data records were then downloaded for the entire period, 1 January 2024 to 31 December 2024. The hourly records were averaged over the period of each week (Week One extending from the 00:00 on 1 January to 24:00 on 7 January, etc.) to produce 24-hour profiles for each day of the week and for each week of the year. In other words, the records were combined into 1248 data points, allowing comparisons between the weeks rather than the days of the year.

Table 2: Specifications of the photovoltaic (PV) system used in this study

Component	Unit	Value	Description
PV panel	W	545	Canadian Solar HiKu6 Mono PERC
Total PV capacity	kW	6.540	12 panels in fixed mounting
Maximum power point tracking (MPPT)	V	450 V, 100 A max	Victron MPPT RS 450/100 48 V
Inverter	V	48 V / 6.4 kW	Victron Multiplus-II 48/8000/110-100 230 V
Battery	kWh kW	8 (80%) 10	Freedom Won LiTE Home 10/8 Max power 10 kW, energy 8 kWh @ 80% depth of discharge

Table 3: Capital costs for the small-scale embedded solar system used in this study

Component	Number	Cost (ZAR)
Photovoltaic panels	12	27 500
Battery	1	53 000
Inverter	1	21 000
Maximum power point tracking	1	52 500
Balance of plant		43 000
Installation		18 000
Total		**215 000**

Source: Actual costs in June 2023

The downloaded records included the total energy demand (D_T), solar power generated (S), the solar irradiance (G) and the energy consumption from the electricity grid (E_G), and were processed using the following calculations:

Energy supplied to the battery and the inverter, $D_B = D_T - S - E_G$

Energy supplied from the battery to the household, $D_H = D_T - S - D_L$

where D_L is the energy consumed by the inverter and the battery (energy losses). If we define the inverter/battery efficiency as η_B, we can calculate the losses and efficiency as follows:

$$D_L = \sum D_B - \sum D_H \qquad \text{Equation 1}$$

$$\eta_B = 1 - \frac{D_L}{D_T} \qquad \text{Equation 2}$$

Over the whole year, the net energy supplied from the SSES to the household is then

$$D_H = \eta_B . D_T \qquad \text{Equation 3}$$

Using the solar irradiance and the panel efficiency, it is also possible to calculate the potential solar generation (S_P) as:

$$S_P = \mathit{Irradiance} * \mathit{Panel\ Efficiency} * \mathit{Conversion\ Factor} \qquad \text{Equation 4}$$

Then:

$$\mathit{Unused\ Solar},\ S_U = S_P - S \qquad \text{Equation 5}$$

$$\mathit{Overall\ SSES\ Efficiency},\ \eta_{SSES} = \frac{S}{S_P} \qquad \text{Equation 6}$$

The conversion factor is temperature dependent and hence not constant. Empirical observation yielded values of 0.0039 kW/(W/m^2) and 0.0052 kW/(W/m^2) in summer and winter, respectively.

Results

Solar efficiency

Based on the irradiance data and the conversion factor, it was calculated that the theoretical maximum panel efficiency at the site for the study was 17.5%, somewhat less than the value from the panel's specification sheet of 21.6%.

Furthermore, at least 54% of the available energy from the panel was not used, giving a value for the overall SSES efficiency as 46%. The extent of the unused electricity during the year is shown clearly in Figure 2. In the winter peak (weeks 20 to 36), when supply is lowest and demand is highest, most of the available solar is used. However, for the remainder of the year, supply exceeds demand.

The analysis for this single site is not unusual. For most SSES systems, capacity utilisation in the summer months is less than 50% because the systems are designed for the winter months.

There is also another important factor for owners of SSES and electricity distributors that is not apparent from Figure 2, namely the time of use consumption. Even though all of the winter solar generation is used by the household ($S_U = 0$), not all the household energy needs are supplied by solar. Indeed, as shown in Figure 3, during the winter months, as much as 60% of the total demand cannot be supplied by the SSES system. The typical pattern is that the weak winter sun can meet the electricity needs of the household during daylight hours and recharge the battery, but the latter is quickly discharged in the peak evening period for heating and cooking.

This difference between the summer and winter profiles can be clearly illustrated using the daily supply and demand profile, as shown in Figure 4. Peak winter maxima are only 40% of the summer maximum, and even in winter there is a component of unused solar because use of electricity before the evening peak is typically low.

Levelised cost of electricity

The consumption data now allow the calculation of LCOE values for SSES vs GBE according to the daily and seasonal patterns of solar energy generation and electricity consumption. Using the capacity factor of 46%, an energy loss factor of 8.4% in the battery/inverter conversion process and the maximum panel efficiency of 17.5%, as previously calculated, the LCOE for electricity supplied by the SSES is ZAR5.63/kWh vs the GBE unit cost of about ZAR2.96/kWh. It is apparent that the cost of SSES is higher than the cost of energy obtained from the national utility or municipality.

A similar result is obtained when we compare the annual costs of the two options, as shown in Table 4. The SSES cost is about 75% higher than that of GBE, which is a surprising result given that other analysis has shown that PV is less expensive than GBE – in other words, SSES delivers a positive return on investment.[18] Furthermore, this analysis applies to a system which has a 71% FDS value. Should higher levels of behind-the-meter power reliability be required, the system cost would increase logarithmically[32], making SSES even less affordable.

In summary, peace of mind and energy independence come at a cost. For households for which peak electricity demand generally falls in the early mornings or late evenings, when solar insolation is at its weakest or even non-existent, the rationale for SSES is fragile. This perspective, however, overlooks other benefits of SSES, including the positive environmental impact through lower carbon emissions, especially in South Africa with its carbon-intensive electricity system. Further growth of SSES is necessary and prudent but will not happen without incentives to support household-level investment in behind-the-meter solutions. In the next section, the use of incentives, and how these can simultaneously deliver significant revenue to municipalities, is discussed.

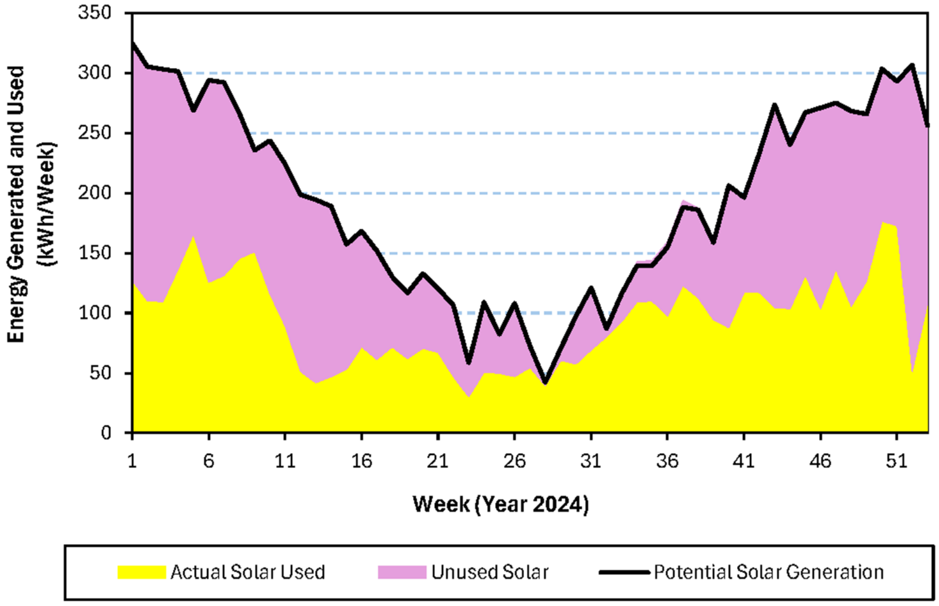

Figure 2: Potential solar generation and used/unused solar during 2024.

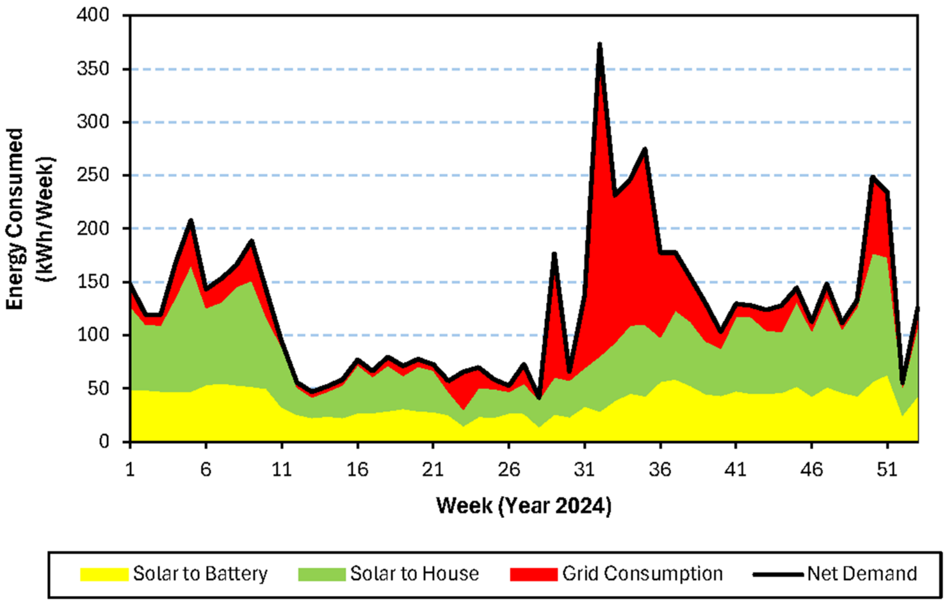

Figure 3: Grid consumption, solar use and net demand during the year.

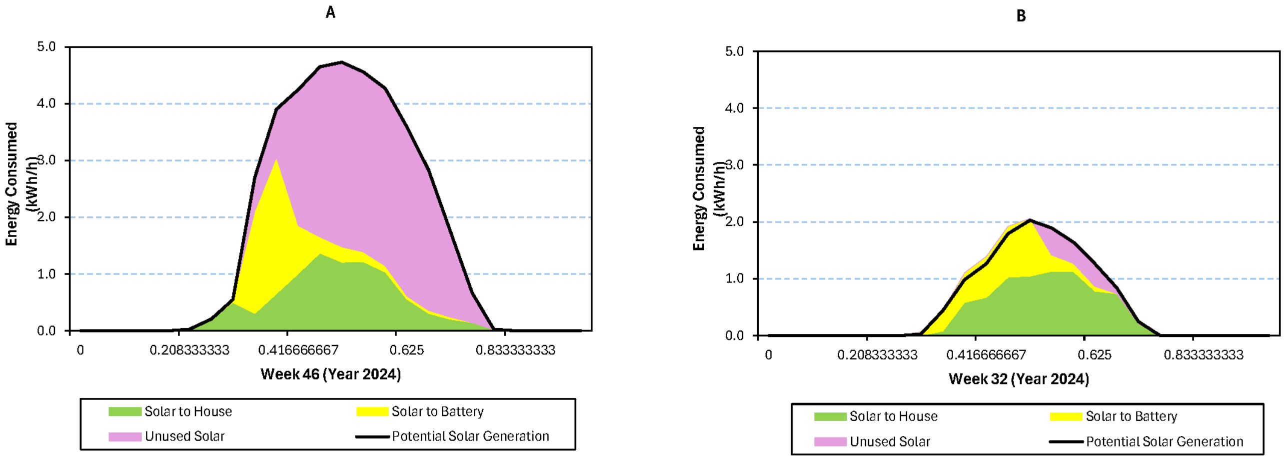

Figure 4: Daily profiles of solar supply and use for (A) summer and (B) winter.

Table 4: Comparison of small-scale embedded solar (SSES) and grid-based electricity (GBE) consumption and costs for the case study

Comparison	Consumption SSES (kWh)	Consumption GBE (kWh)	Cost SSES (ZAR)	Cost Eskom (ZAR)
Grid	1701	5828	7501	17 553
Solar	4127	0	23 239	0
Total	**5828**	**5828**	**30 740**	**17 553**

Discussion

As has been shown here, overdesign of SSES systems results in excess capacity, typically about 50% of the available energy output, which could be usefully deployed into the national grid, and the LCOE for such systems is 70% higher than that for GBE. Both results indicate that SSES as a consumer option is more expensive, leading to the inevitable conclusion that the rationale for household SSES investment cannot be an economic one. Instead, such choices are driven by the need for reliable electricity supply within the context of high levels of load shedding in South Africa over the recent past[6], and possibly reducing the indirect household-linked carbon emissions through the use of Eskom power.

Higher capacity utilisation would reduce the LCOE, but this would only be possible if the excess energy could be supplied to the grid. For instance, if the total available energy could be used and is purchased at its cost of production, the net LCOE, which we call the breakeven cost, would be ZAR2.53/kWh.

In practice, such an option is not available. Many municipalities do indeed offer feed-in tariffs but these range from ZAR0.32/kWh to ZAR1.3/kWh, with the average being ZAR0.87/kWh, the latter equivalent to 34% of the breakeven cost.[3] For the SSES system used in this study, the net impact of the average feed-in tariff is a reduction in the LCOE to ZAR4.56/kWh, from which it is calculated that the premium for the privilege of (some) energy independence is 54%.

The low level of the export or feed-in tariff is insufficient to incentivise greater investment in SSES.[5] Yet such an investment is highly desirable from a number of perspectives. Ignoring for the moment any potential benefits to the household, municipalities could improve their margins by purchasing excess solar energy from SSES prosumers and reselling the electricity to their customer base. Exit prices vary somewhat but the average value (ZAR0.87/kWh) is about 29% of the average retail

Table 5: Benefit to cost calculation of small-scale embedded solar (SSES) based on data for the City of Cape Town

Component	Unit	Value	Reference
Benefit calculation			
SSES unused solar energy	% of total	50%	This study
Exit price (feed-in tariff)	ZAR/kWh	1.0595	City of Cape Town[34]
Retail price	ZAR/kWh	3.00	City of Cape Town[34]
Eskom wholesale price	ZAR/kWh	2.00	City of Cape Town[34]
Panel efficiency	%	17.5%	This study
Unregistered solar capacity	MW	100	Dippenaar and Bekker[18]
Unused energy	GWh/year	153.3	This study
Purchase value	ZAR million	162.4	
Eskom purchase value	ZAR million	306.6	
Resale value	ZAR million	459.9	
Additional gross earnings	ZAR million	144.2	
Cost calculation			
Connection meter	ZAR	6036	City of Cape Town[35]
Certification of SSES by engineer or qualified electrician	ZAR	11 448	Dippenaar and Bekker[18]
Average SSES size	kW	10	This study
Number of meters		20 000	
Cost of meters and installation	ZAR million/year	35 (5 years)	
Benefit to cost ratio		**5.2:1**	

price (ZAR3/kWh) and provides sufficient incentive for municipalities to establish and grow their prosumer base.

The growth of interconnected SSES systems selling energy to the grid at a price highly advantageous to distributors is, however, not only a question of encouraging future investment. There are already many thousands of existing SSES systems not yet registered and equipped with bidirectional metering, many of which are potential energy suppliers. Indeed, it is estimated that about 50% of the installed SSES capacity is not registered and not compliant.[18] By accessing this resource, municipalities would be able to almost immediately boost their margins on the sale of electricity.

The problem is that the responsibility for registration and compliance presently lies with the prospective prosumer. Although the costs are variable between municipalities, two of the major components are the cost of the birectional meter and the cost of certification, values for which are given in Table 5. Typically, the combined cost can reach ZAR17 500 or higher[18], which deters prosumers from accessing the benefits of selling their excess power, and restricts the profit potential for municipalities.

The net benefit for distributors can be easily illustrated by considering the single example of the City of Cape Town, which implemented feed-in tariffs some years ago and is probably the furthest advanced in South Africa. Registered SESS systems in Cape Town amount to about 100 MW[33], but total capacity is estimated at 200 MW[18], from which it is clear that an additional 100 MW of capacity is available. Using the panel efficiency value of 17.5% as obtained in this study, it is calculated that 153 GWh per year of unused SSES energy could be accessed, at a cost of ZAR162 million (the City's feed-in tariff is ZAR1.0595/kWh), but with a retail value of ZAR460 million, delivering gross earnings of ZAR297 million.

In practice, the full value of these earnings would not be realised because the resale of SSES energy would replace the energy that the City is already procuring from Eskom. The actual additional revenue is then the difference between the sale of Eskom vs SSES energy. According to the City of Cape Town[34], the average wholesale price from Eskom is ZAR2/kWh, from which the additional margin to the City is calculated at ZAR144 million.

We now need to consider the meter and compliance costs in order to calculate the benefit to cost ratio, having made the argument that the City should be covering these items. Using the most recent meter price of ZAR6043 and compliance certification of ZAR11 500, and assuming the average SSES size is 10 kW and the maximum number of new connections per year is 2000, the annual worth of the additional costs of new connections to the City of Cape Town is calculated at ZAR20.8 million vs the annual worth of the additional gross earnings from SSES energy trading of ZAR107 million. The input values and results of these calculations are summarised in Table 5.

In other words, the net benefit to cost ratio for the City is 5.2:1, supporting the argument that electricity distributors have the most to gain from operational SSES interconnection and should be paying for the interconnection costs.

This analysis illustrates that Eskom and the municipalities could extract considerable value from unused SSES capacity. However, building the market for energy trading between distributors and prosumers will require more than offers to install bidirectional meters; these organisations will also need to address issues of trust and transparency.[36] It will require a customer-focused campaign to explain the benefits of trading for both parties.

Conclusion

The study has considered the techno-economics of SSES systems for both homeowners and electricity distributors in South Africa. Two important results have emerged from the analysis. Firstly, it is shown that the LCOE for a standard configuration, as used in this study, is 75% higher than that for GBE. In other words, homeowners have opted for SSES for reasons of energy security rather than cost. For those households which can afford the premium, reliability of supply overrides any additional energy cost.

Secondly, SSES systems at the household level are generally sized to deliver sufficient energy to match average demand under winter conditions (low sunlight intensity and shorter daylight hours), and, as a result, have on average about 50% unused capacity (excess to demand), particularly during the summer months. This excess capacity could be a valuable source of energy for Eskom and the municipalities, which have struggled to meet electricity demand due to supply constraints. In Cape Town alone, it is estimated that 153 GWh could be available to the municipality, which, if fully traded, would generate a net trading profit of ZAR144 million.

However, the additional energy and revenue source is presently underutilised because homeowners are disincentivised from prosumption. To participate in the market, they are compelled to incur the costs and face the bureaucratic barriers of installing the necessary bidirectional meters. As a result, fewer than half of present SSES installations are registered and certified as required by the regulatory environment, and it is clear that the prosumer base in South Africa will remain dormant unless the distributors agree to absorb the meter costs.

There is a compelling economic reason that they should do so. Using a standard cost/benefit analysis and data for the City of Cape Town, it was shown here that the benefits exceed the costs by fivefold. Distributors will also benefit through more resilient electricity systems (diversity of supply), lower grid emission factors and lower energy losses. Opponents of SSES argue that encouraging SSES will allow more customers to achieve energy independence and reduce municipal revenues.[37] However, the level of investment which is necessary to achieve total independence (FDS greater than 99%) is uneconomical. The optimal FDS level is about 85%, meaning that prosumers will always be dependent on the grid and grid-connected SSES is the only viable, and indeed sensible, approach.

The present context for the planning, governance and development of the electricity system in South Africa and other countries in the region is the need for universal access, reliability, affordability and carbon neutrality. The results of this analysis show that a simple initiative to be taken by the distributors, namely installing birectional meters at their cost, could partially address at least two of these important factors. Extracting unused capacity from existing SSES will reduce their carbon emissions and costs. Supporting the expansion of a cohort of prosumers could partially offset the need to further raise energy tariffs, which have increased at rates higher than inflation over a long period.[38]

Finally, it is also noted that this study is limited by its use of only a single SSES system in a single location within South Africa. The results could be strengthened by further studies across a wider range of geographical areas and using different system configurations. For instance, the use case in this study of a domestic residence in the Western Cape has a high disparity between user demand and solar generation, and winter/summer fluctuations.

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Data availability

The data supporting the results of this study are available upon request to the corresponding author.

Declarations

I have no competing interests to declare. I have no AI or LLM use to declare.

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