(MODELLING) THE FINANCIAL CASE FOR ROOFTOP SOLAR PV IN LOW- AND MID-INCOME HOUSEHOLDS IN SOUTH AFRICA

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SUMMARY

- This report describes, in detail, a spreadsheet model that evaluates the impact on municipal revenue and household electricity costs if a household invests in a grid-tied rooftop photovoltaic (PV) system.
- The model is intended for use as a ***broad policy making tool*** to evaluate trends and emerging opportunities for investments in rooftop PV systems for low- and mid-income households. The model is not intended as a detailed simulator for project implementation purposes.
- A range of variables in the model (such as the rate of future tariff escalations, cost of PV, cost of debt, etc.) can be adjusted to ***find the conditions under which the PV investment could save on net costs for the household and, at-least, be revenue-neutral for the municipality***.
- The model was used to assess these impacts for low- and mid-income households in Cape Town:
  - Based on 2019/2020 tariffs, the model shows that ***low-income households*** that currently benefit from the maximum electricity subsidies (free electricity units and low first-tier unit charges) ***would be worse off if they invested in a rooftop PV system***. The main reason is that ***there is no provision for special low-income Small-Scale Embedded Generation (SSEG) tariffs***.
  - If electricity tariffs continue to escalate significantly above inflation, and if the cost of PV hardware continues to drop, then ***mid-income households may be able to make net electricity savings*** (if they are able to access specially-structured, long-term debt-finance for a PV system).
- The results of the model suggest that municipalities would be able to support low- and mid-income household investments in PV systems ***without losing revenue*** by designing ***modestly discounted SSEG tariffs*** for these households. Importantly, a proposed "Domestic Life-Line SSEG" tariff should not be seen as an additional subsidy cost for the municipality but rather as a transfer of part or all of the existing subsidisation that eligible low-income households receive under their current "Domestic Life-Line" (non SSEG) tariff.
- The table below illustrates the influence of the model's main variables on household energy costs and on municipal revenue:

Household (HH) invests in rooftop PV: Impact on household's costs and municipal revenue		
Household Costs	**Change in Variable**	**Municipal Revenue**
+ve*	**Increase size of rooftop PV system**	**+ve**
+ve	**Increase household consumption**	**-ve**
+ve	**Implement household load-shifting** (eg mid-day water heating)	**-ve**
+ve	**Higher annual tariff escalations**	**-ve**
+ve	**Reduce cost of PV hardware**	-
+ve	**Reduce household cost of debt** (for a PV hardware loan)	-
+ve	**Increase loan period for PV hardware**	-
+ve	**Increase level of SSEG tariff subsidy** (for eligible low- and mid-income households)	**-ve**

* "+ve" = positive and "-ve" = negative. These trends are relative to the baseline case (ie a household with a fixed consumption behaviour and without a PV system); Although the model shows that both the household and the municipality are generally better off (in the long term) with a larger system - regardless of consumption, the current regulations restrict net monthly exporting. However, this may change under the 'Just Transition' to renewables, as provided for in South Africa's new Integrated Resource Plan (IRP).[1]

[1] Department of Energy, 2019: Integrated Resource Plan (IRP2019). Pretoria, South Africa. https://www.dmr.gov.za/Portals/0/Resources/INTEGRATED%20RESOURCE%20PLAN%202019/DoE%20IRP%202019__October%202019.pdf?ver=2019-10-18-170552-007

INTRODUCTION

In recognition of the fact that low- and middle-income households (LIHH & MIHH) have not participated in the growing uptake of rooftop solar PV (small-scale embedded generation 'SSEG') in South Africa, a preliminary study was undertaken to explore possible solutions to the myriad barriers facing these households. A spreadsheet model was developed to assess potential long-term electricity-cost savings if households were able to access affordable loans for grid-tied rooftop PV systems. The model calculates whether or not these cumulative savings would be sufficient to cover loan repayments, based on current electricity tariffs. A range of variables and assumptions in the model (including tariffs and household demand profiles) can be adjusted in order to test the impact of these variables on financial viability.

This report:

a) provides a detailed description of the model (including recent improvements to functionality), and an explanation on how to use the model;
b) summarises preliminary findings from the model (including updates based on more recent tariffs);
c) identifies areas of potential which could improve the financial case for LIHH & MIHH without unduly prejudicing municipal income or requiring significant subsidisation.

DESCRIPTION OF THE MODEL

The most recent version of the model: '*Low-Income PV SSEG (CoCT)*' has been developed for the Cape Town context (using regional PV electricity data and Cape Town electricity tariffs) but it is adaptable for other municipalities[2].

The model compares household electricity costs for two scenarios called 'Without SSEG' (without a rooftop PV system, i.e. the default) and 'With SSEG' (with a rooftop PV system). The model assumes that the cost of the PV installation is financed by a loan with an adjustable repayment period of 1 – 20 years, fixed instalments, and an adjustable interest rate. A full year of actual solar data for Cape Town (in 15-minute intervals) is used to calculate how much electricity would be generated from a PV array of any size. This PV supply profile is overlaid with the (adjustable) seasonal demand profiles in order to calculate the hourly units of self-consumption, export ('feed-in'), and municipal supply – for every hour in the year. These three flows of electricity translate to billing charges determined by the municipal- and Eskom-tariffs. Running this calculation for each year over a loan-period, using assumed tariff escalations, produces cumulative savings or losses for the household and for the municipality (compared to the default 'Without SSEG' scenario), and the final results indicate whether the investment in the PV system could be financially viable or not (i.e. whether it is more financially attractive than simply buying all electricity from the municipality). Of course, once the PV loan has been repaid, then the household will enjoy significant ongoing savings. But this future benefit is not factored into the model which only looks for a break-even during the loan term.

The basic steps in the model are therefore as follows:

1. **Calculate the 'Without SSEG' scenario:** The monthly municipal supply costs and household consumption costs (without a rooftop PV system) are calculated for a full year: 'YEAR 1' (based on

[2] The model can be applied to other municipalities (with similar tariff structures to Cape Town) by importing solar data for that region and entering the applicable tariffs. Cape Town was chosen as a conservative test case due to the relatively lower solar resource compared to other regions in the country. The model is available here: https://www.sseg.org.za/wp-content/uploads/2019/10/Low-Income-PV-SSEG-Model.xlsm.

typical energy consumption patterns[3], and on the municipality's actual electricity tariffs in a given year).

2. **Calculate the 'With SSEG' scenario:** The supply and consumption costs are calculated for the same household in YEAR 1, but with a rooftop PV system (where the daily solar power generation is modelled based on actual solar insolation data from the region).
3. **Calculate the difference between 'With SSEG' versus 'Without SSEG' in YEAR 1:** The difference shows either a savings or increased expenditure ('loss') for the household and either a revenue gain or revenue reduction ('loss') for the municipality.
4. **Calculate the difference for *all* years over the chosen loan period:** Based on assumed future annual tariff escalations, the savings, gains or losses for each year are combined to identify the overall viability of the PV investment for the chosen loan period and interest rate.
5. **Assess Viability:** The basic assumption is that these combined savings, gains and losses must at least break-even by the end of the loan period in order for the investment to be viable.
6. **Test variables:** The model incorporates a number of variables that allow one to explore the impact of these variables on the viability of the investment and to identify opportunities to adjust tariffs and/or consumption patterns in a way that improves the investment-case without prejudicing municipal revenue (compared to the default scenario).

HOW TO USE THE MODEL

The Excel spreadsheet model comprises 4 sheets:

1. **'Analysis'**

   This sheet contains all the calculations described above as well as the main table where variables and assumptions[4] can be adjusted as shown below. (In the next section, a more detailed explanation of each variable is provided.)

#	VARIABLES/ASSUMPTIONS	SELECT
1	PV installation size (Wp):	3,000
2	Average monthly HH consumption (kWh)	300
3	Time-controlled Water Heating?	n
4	With Centralised Storage?	n
5	Cost of Storage (cents/kWh) 2017	154
6	Installed cost of PV (R/Wp)	R15
7	Municipal Savings per kVA avoided during peak	R11.20
8	VAT Rate	15.0%
9	Annual PV Degradation Rate	0.7%
10	PV Hardware Maintenance & Insurance/month	R60
11	Annual Inflation: Consumer Price Index (CPI)	4.5%
12	Loan Interest Rate above CPI	4.5%
13	PV Hardware Loan Term (yrs)	15
14	Free Basic Electricity (FBE) subsidy included?	n
15	Discount on Fixed SSEG charge	0.0%

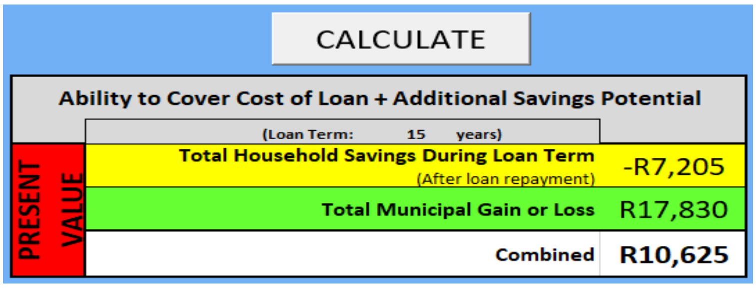
TARIFF VARIABLES		
Tarrif YEAR	2019/2020	
Tariff Escalation Rates (above CPI)		
Up to YEAR	Eskom	Munic
5	5.0%	5.0%
10	4.0%	4.0%
thereafter	3.0%	3.0%

-> ANNUAL LOAN REPAYMENTS	R5,477

[3] 'Typical' hourly electricity demand profiles for low-income households were generated based on data sourced from a low-income household study in a number Cape Town areas (Masiphumelele, Langa N2 Gateway, Joe Slovo) conducted by Sustainable Energy Africa (SEA). For the full study contact SEA at info@sustainable.org.za.

[4] Many of the sample variables and assumptions in the model (such as PV cost, insurance, etc) are for indicative purposes only. The main purpose of the model is as a broad policy tool to test and identify trends and opportunities that may improve the PV investment case (now or in the near future). Any specific project proposal would require detailed research into the context-specific value of these variables.

Once the desired variables have been entered, the 'CALCULATE' button is clicked to produce the net present value of savings, gains or losses for the household and the municipality, as shown below[5].



2. **'Household Demand'**
   This sheet contains 24-hour demand profiles for a 'summer' season (October – April) and 'winter' season (May – September). The profiles are generated (and are adjustable) by modelling the time of use (in hourly increments) and the power-rating of a range of appliances used by the household during the day. The profiles in the current model emulate the actual consumption patterns of a number of low-income households in Cape Town that participated in an energy study (see examples of actual profiles to the right of the 'Household Demand' sheet). The demand profiles can be scaled up or down by adjusting the average monthly total consumption (a variable in the 'Analysis' sheet).

3. **'Tariffs'**
   This sheet contains the Eskom Megaflex tariffs for the budget years 2017/2018 to 2019/2020, and the Cape Town Domestic Lifeline, Domestic, and SSEG tariffs for the same years[6]. The sheet also provides for the future entry of the 2020/2021 tariffs as well as a 'Test Case' municipal tariff table in which variations on the actual tariffs can be entered (see bottom right of 'Tariffs' sheet). The desired tariff-year is selected in the main variables table in the 'Analysis' sheet.

4. **'PV Electricity'**
   This sheet contains the full year of generated PV electricity for the Cape Peninsula (in 15-minute intervals). The source data (from the CSIR) was captured in 2012 using PV panels to measure the actual generation of MWh per MWp of installed capacity. There are no adjustable variables in this sheet. However, the data can be swapped out for a different region[7]. It should be noted that the PV electricity data is based on the results of optimised test conditions, and so the results of the model should be used for indicative purposes only[8].

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[5] The 'Combined' result should be used as a rough indicator of whether or not the investment in the system will be net positive or negative (for the household and municipality together). If it is positive, then there is scope for shifting the benefit to the party that takes the risk on the investment. If it is negative, then it is not an investible proposition unless other financial, social or economic benefits and contributions are factored in.

[6] The city's 'Home User' tariff (for properties valued above R1mil) is not incorporated in the current version of the model.

[7] The following locations were evaluated by the CSIR and the data is available: Johannesburg, Nigel, Westrand, Vaal Triangle, Newcastle, Pinetown, Empangeni, West Coast, Peninsula, Southern Cape, East London, Port Elizabeth, Karoo, Waterberg, Polokwane, Warmbad, Rustenburg, Welkom, Bloemfontein, Highveld North, Highveld South, Pretoria, Carletonville, Kimberley, Ladysmith, Lowveld, Namaqualand. Data obtainable from CSIR Energy Centre. ('MW per MWp' data – i.e. MW generated per MWp of PV capacity installed).

[8] The household's actual electricity yield from an installed PV system will depend on a number of factors apart from local irradiation: shading, microclimate, cleanliness of the panel, orientation and design, component-choice and resultant losses, as well as the quality and regularity of maintenance will all have a significant impact on yield. Thus, the actual yield is unlikely to match that from the optimised test conditions which produced the model's source data (in 2012). However, with each year, advancing hardware innovations and ongoing cost-competitiveness should increasingly off-set the short-fall between 'optimised' and actual generation.

Model Variables		Where and How to Adjust the Variable		
Variable	**Description**	**Sheet**	**TABLE & Variable #, Name**	**Select/Enter**
Tariffs: ALL	Municipal: Cape Town 'Domestic', 'Domestic Lifeline' and 'SSEG' Electricity Tariffs; Eskom: Time-Of-Use (TOU) Megaflex Local Authority Tariff (for Cape Town – i.e. Transmission Zone >900km & Voltage > 132kV). • Option to choose the YEAR 1 tariffs (from 2017/2018 to 2019/2020, with provision to add the 2020/2021 tariffs in future) • Option to choose annual escalation rates (above CPI inflation) for Eskom and Municipal Tariffs	*Analysis*	TARIFF VARIABLES	**Select:** Tariff Year from drop-down list **Enter: %** escalations (separately for Eskom and for Municipality and for each period. Note: the periods can also be adjusted)
Tariffs: Municipal Domestic ('Without SSEG' Case)	Inclined Block Tariff (IBT). Two-tier structure with adjustable unit prices and threshold. • Option to choose between the 'Domestic' tariff (for property values between R400k and R1mil) and the 'Domestic Lifeline' tariff with the Indigent Free Basic Electricity Subsidy (for property values below R400k).	*Analysis*	VARIABLES/ASSUMPTIONS #14 *Free Basic Electricity (FBE) subsidy included?*	**Enter:** Y or N
Tariffs: Municipal SSEG ('With SSEG' Case)	Two-tier IBT for consumption; a fixed monthly SSEG fee; a fixed per-unit feed-in-tariff ('FIT' or 'Export Tariff')[9]. • Option to change the SSEG tariffs in order to test the impact on PV investment viability. (The corresponding Eskom Tariff is the 2019/2020 Megaflex)	*Tariffs*	TEST CASE (in 'Cape Town Municipal Tariffs' section – below Eskom tariffs)	**Enter:** test-case tariffs for 'With SSEG' and 'Export Tariff'
Size of PV System	• Option to input any PV system size Although any system size can be entered in the model, a pop-up message will warn the user if the size will result in net exporting of electricity to the municipality - which is currently disallowed by the regulations [10].	*Analysis*	VARIABLES/ASSUMPTIONS #1 *PV installation Size (Wp)*	**Enter:** Size in Wp
Household Electricity Consumption	Modelled on the actual consumption patterns of low-income households in Cape Town. Different profiles for Winter (May-October) and Summer (October- April) • Option to adjust household consumption: enter average monthly household consumption for the year (in kWh). Note: The resultant monthly consumption is higher in 'winter' versus 'summer', averaging out at the chosen units/month. • Option to adjust hourly consumption (by appliance – e.g. kettle, fridge, lights, etc.). The resultant demand profile is automatically scaled to match the chosen monthly consumption.	*Analysis* *Household Demand*	VARIABLES/ASSUMPTIONS #2 *Average monthly HH consumption (kWh)* HOUSEHOLD DEMAND PROFILES – unshaded tables for summer and winter[11]	**Enter**: units/month (kWh) **Enter:** units: Wh consumed (per hour, per appliance)

[9] This SSEG tariff structure is common to many other municipalities e.g. Tshwane & Johannesburg, amongst others.
[10] Since the purpose of the model is to explore the impact of (current and future) trends in tariffs and regulations that may improve (or prejudice) the case for low-income access to PV, the allowable PV sizes in the model are not restricted by the current regulatory framework (which does not allow for net exporting). With the recent publication of South Africa's new Integrated Resource Plan (IRP) in 2019, the call for a 'Just Transition' to renewables may see a relaxing of net-export restrictions (which are arguably prejudicial towards lower consuming households since it forces them to limit the size of their system to a point where the 'Balance of System' costs are disproportionately large compared to that of a higher consuming household that can have a larger system).
[11] For the purposes of modelling consumption patterns, 'summer' is October to April, 'winter' is May to September. (i.e. this does not correspond to the 'LOW' and 'HI' seasons for the Eskom TOU tariffs).

Model Variables (cont.)		How to adjust Variable		
Variable	**Description**	**Sheet**	**TABLE & Variable #,Name**	**Select/Enter**
Household Electricity Consumption	Modelled on the actual consumption patterns of low-income households in Cape Town. Different profiles for Winter (May-October) and Summer (October- April) • Option to adjust household consumption: enter average monthly household consumption for the year (in kWh). Note: The resultant monthly consumption is higher in 'winter' versus 'summer', averaging out at the chosen units/month. • Option to adjust hourly consumption (by appliance – e.g. kettle, fridge, lights, etc.). The resultant demand profile is automatically scaled to match the chosen monthly consumption.	*Analysis* *Household Demand*	VARIABLES/ASSUMPTIONS #2 *Average monthly HH consumption (kWh)* HOUSEHOLD DEMAND PROFILES – unshaded tables for summer and winter[12]	**Enter**: units/month (kWh) **Enter**: units: Wh consumed (per hour, per appliance)
Demand-management (load shifting):	• Option to select 'timed water heating' (i.e. heating water during day-light hours) – increasing percentage of self-consumption from the PV supply. This can act as a proxy for shifting other loads such as washing machines, cooling, refrigeration, etc.	*Analysis*	VARIABLES/ASSUMPTIONS #3 *Time-controlled Water Heating?*	**Enter:** Y or N
Energy Storage	• Option to model the storage of feed-in electricity by the municipality using a centralised storage facility – costed on a per-unit of stored energy basis. • Option to adjust the cost of stored energy. This is the Levelised Cost of Storage (LCOS) per unit. The model's simple logic of storage is that units will be stored if the municipality can save on the cost of supply (including the cost of storage) by selling-on the stored units in the subsequent 24hours during a peak-demand period. The model assesses each unit of feed-in energy from the PV system. Only those feed-in units that satisfy the following condition are stored: The Eskom tariff at the time of feed-in must be less than the highest Eskom TOU tariff (within the next 24 hours) MINUS the storage-cost/unit. If this condition is not met, the model simply assumes that the feed-in units are sold on immediately without first being stored.[13]	*Analysis*	VARIABLES/ASSUMPTIONS #4 *With Centralised Storage?* #5 *Cost of Storage (cents/kWh)*	**Enter:** Y or N **Enter:** R/kWh stored
Municipal Savings from Peak-shaving	If the storage option is selected, then the model calculates the average peak Eskom demand (in units) that is averted across the year which translates to a reduced monthly Transmission Network Charge for the municipality.[14] • Option to adjust Eskom's Transmission Network Charge (currently set at 2019/2020 rate, and assumed to escalate annually in-line with other tariffs)	*Analysis*	VARIABLES/ASSUMPTIONS #7 *Municipal Savings per kVA avoided during Peak*	**Enter:** R/kVA/month

[12] For the purposes of modelling consumption patterns, 'summer' is October to April, 'winter' is May to September. (i.e. this does not correspond to the 'LOW' and 'HI' seasons for the Eskom TOU tariffs).
[13] The model assumes that there will be a demand for all feed-in units – whether stored or sold-on immediately. This assumption may not hold if there was a significant up-take of PV SSEG within the municipality.
[14] The 'peak-shaving' effect is very limited, and the modelling of this effect is simplified.

Model Variables (cont.)		How to adjust Variable		
Variable	**Description**	**Sheet**	**TABLE & Variable #,Name**	**Select/Enter**
Cost of Installed Rooftop PV	• Option to adjust total hardware and installation cost (R/Wp) The working assumption is that the hardware and installation costs can be minimised through a relatively high volume, multi-household pilot. The hardware would need to include a smart meter.	*Analysis*	VARIABLES/ASSUMPTIONS #6 *Installed cost of PV (R/Wp)*	**Enter:** R/Wp (installed)
VAT Rate	• Option to change VAT rate	*Analysis*	VARIABLES/ASSUMPTIONS #8 *Vat Rate*	**Enter:** VAT%
PV Panel Degradation Rate	• Option to adjust degradation rate	*Analysis*	VAVARIABLES/ASSUMPTIONS #9 *Annual PV Degradation Rate*	**Enter:** % degradation per year
Hardware Maintenance & Insurance	• Option to adjust monthly maintenance and insurance costs This monthly cost escalates annually with CPI inflation.	*Analysis*	VAVARIABLES/ASSUMPTIONS #10 *PV Hardware Maintenance & Insurance/month*	**Enter:** R/month
Inflation Rate[15]	• Option to adjust CPI The CPI rate is fixed for all years but the tariff escalations are variable.	*Analysis*	VAVARIABLES/ASSUMPTIONS #11 *Annual Inflation: Consumer Price Index (CPI)*	**Enter:** % CPI
Lending Rate	• Option to adjust loan interest rate The PV hardware loan interest rate <u>should exclude the CPI component</u> (which the model adds back as necessary).	*Analysis*	VAVARIABLES/ASSUMPTIONS #12 *Loan Interest Rate above CPI*	**Enter:** % interest (above CPI)
Loan Term	• Option to adjust loan period from 1- 20 years	*Analysis*	VAVARIABLES/ASSUMPTIONS #13 *PV Hardware Loan Term (yrs.)*	**Enter:** # years
Fixed SSEG Charge Discount	• Option to enter a discount on the standard fixed monthly SSEG fee There is currently no municipal discount on the fixed fee for low- or mid-income households. The discount option is included in the model to test the idea of an SSEG tariff that retains some subsidy benefit for households that are eligible for the 'Domestic Lifeline' tariff (which includes lower unit charges and free basic units). Most municipalities in SA are still in the early stages of developing their SSEG policies and tariffs and there is still wide variability amongst them. Apart from the IBT and FIT structure used by Cape Town, other tariffs that have been implemented by other municipalities include 'Time-Of-Use' and 'Net-Metering', or combinations. These tariff structures have not yet been modelled in this study.	*Analysis*	VAVARIABLES/ASSUMPTIONS #15) *Discount on Fixed SSEG charge*	**Enter:** % discount

[15] Average annual inflation (Consumer Price Index 'CPI') has ranged between 4.0 and 6.6 over the past 10 years.

KEY FINDINGS

An earlier version of the model looked at Tshwane and Johannesburg municipalities as well as Cape Town, using the 2017/2018 tariffs. The general findings were as follows:

- In almost all cases the model predicted that the **municipalities would generate significantly more income compared to the default 'without SSEG' scenario**.
- Conversely, the **households were typically unable to break-even by the end of any feasible loan repayment period** - even if extended to 20 years.
- This generally poor financial case was **most pronounced for low-income households** who already benefit from tariff subsidisation at the lowest consumption levels (typically < 350kWh/month).

The primary reason for these findings is that the SSEG tariffs for all three municipalities (comprising high fixed monthly charges and relatively low feed-in tariffs) did not translate to net savings for the household once they had also made loan repayments on the PV hardware. This was the case even when households consumed up to 33% less municipal electricity (by shifting any hot water heating to day-time, using PV power). The lack of financial viability persisted even when modelling relatively high tariff escalations rates (5% above CPI) over the entire loan-repayment period.

Since there is no equivalent 'low-income' SSEG tariff for households that are currently eligible for tariff subsidisation, it still makes more sense for them to simply use 100% municipal energy at the subsidised tariffs[16].

The most recent version of the model (using the 2019/2020 tariffs, and focussing on Cape Town), shows:

- **Modest improvements for households in the above general findings** (i.e. compared to the 2017/2018 model) – owing to the latest higher costs of municipal electricity and ongoing reductions in PV costs.
- **Opportunities for municipalities to develop special low-income SSEG tariffs which are revenue- or cost-neutral for the municipality** but which allow low-income households to retain some subsidy benefit while investing in PV. (In particular, the model shows that a theoretical 'domestic life-line SSEG' tariff, with a reduced or waived fixed charge makes the financial case for the household more viable).

Overall, however, under current conditions and tariffs, the study suggests that the business case for SSEG in low-income households remains marginal, and given the practicalities and risks involved in implementation, does not appear to represent an immediate opportunity for either these households or the municipality.

On the following page a set of 'starting point' variables and corresponding results shows a very poor outcome for the household (but a significant income gain for the municipality over the loan period). Below this, a different scenario is shown in which all the variables have been adjusted. This scenario produces a more promising result for the (higher consuming) household and a neutral outcome for the municipality. The cumulative contribution of each variable is tabulated and detailed on the subsequent page. The purpose of this exercise is to illustrate the areas where there may be

[16] Households that qualify for subsidised electricity do, however, carry the risk that their eligibility may fall away based on the municipality's targeting rules which are adjusted from time to time. (See Section: *Exploring Pilot Opportunities*).

opportunities to improve the investment case for low- to mid-income households. The potential for a more optimum set of parameters to be applied should be the subject of periodic future reviews.

Non-viable Conditions (Base-Case)

(Net-negative outcome for household; high net gain for municipality)

#	VARIABLES/ASSUMPTIONS	SELECT
1	PV installation size (Wp):	2,500
2	Average monthly HH consumption (kWh)	250
3	Time-controlled Water Heating?	n
4	With Centralised Storage?	n
5	Cost of Storage (cents/kWh) 2017	154
6	Installed cost of PV (R/Wp)	R15
7	Municipal Savings per kVA avoided during peak	R11.20
8	VAT Rate	15.0%
9	Annual PV Degradation Rate	0.7%
10	PV Hardware Maintenance & Insurance/month	R60
11	Annual Inflation: Consumer Price Index (CPI)	4.5%
12	Loan Interest Rate above CPI	4.5%
13	PV Hardware Loan Term (yrs)	15
14	Free Basic Electricity (FBE) subsidy included?	y
15	Discount on Fixed SSEG charge	0.0%

TARIFF VARIABLES		
Tarrif YEAR	2019/2020	
Tariff Escalation Rates (above CPI)		
Up to YEAR	Eskom	Munic
5	5.0%	5.0%
10	4.0%	4.0%
thereafter	3.0%	3.0%

-> ANNUAL LOAN REPAYMENTS R4,564

Ability to Cover Cost of Loan + Additional Savings Potential		
	(Loan Term: 15 years)	
PRESENT VALUE	Total Household Savings During Loan Term (After loan repayment)	-R61,375
	Total Municipal Gain or Loss	R61,441
	Combined	R67

Viable Conditions

(Meaningful positive outcome for household; neutral outcome for municipality)

#	VARIABLES/ASSUMPTIONS	SELECT
1	PV installation size (Wp):	3,500
2	Average monthly HH consumption (kWh)	350
3	Time-controlled Water Heating?	y
4	With Centralised Storage?	n
5	Cost of Storage (cents/kWh) 2017	154
6	Installed cost of PV (R/Wp)	R14
7	Municipal Savings per kVA avoided during peak	R11.20
8	VAT Rate	15.0%
9	Annual PV Degradation Rate	0.5%
10	PV Hardware Maintenance & Insurance/month	R50
11	Annual Inflation: Consumer Price Index (CPI)	4.5%
12	Loan Interest Rate above CPI	4.5%
13	PV Hardware Loan Term (yrs)	17
14	Free Basic Electricity (FBE) subsidy included?	n
15	Discount on Fixed SSEG charge	10.0%

TARIFF VARIABLES		
Tarrif YEAR	2019/2020	
Tariff Escalation Rates (above CPI)		
Up to YEAR	Eskom	Munic
5	5.0%	5.0%
10	4.0%	4.0%
thereafter	3.0%	3.0%

-> ANNUAL LOAN REPAYMENTS R5,638

Ability to Cover Cost of Loan + Additional Savings Potential		
	(Loan Term: 17 years)	
PRESENT VALUE	Total Household Savings During Loan Term (After loan repayment)	R39,645
	Total Municipal Gain or Loss	R352
	Combined	R39,996

Scale of impact of variables on financial viability (indicative examples)[17]				
Variable	**Changes (Additive)**	**Household Saving/Loss**	**Municipal Gain/Loss**	**Comment**
Base Case		-R61,375	R61,441	(See table of base-case variables above)
Monthly Units	250 -> 350	-R68,691	R68,231	The household case worsens if all other variables remain the same. However, the incremental improvements below are reliant on the larger monthly consumption (350kWh or more).
Size of System	2500 -> 3500Wp	-R64,838	R71,438	Although a larger system requires a bigger loan, this result shows that more installed PV capacity (more exported units to the municipality) benefits both the household *and* the municipality. (see Footnote #9)
Mid-Day Water Heating	OFF - > ON	-R37,912	R48,819	The significant improvement is helped not only by more self-consumption but also because the use of municipal electricity drops below the 250kWh threshold allowing the household to get 60 free units. (This is particular to the City of Cape Town's FBE tariff structure, and it would rely on the city honouring the FBE subsidy for eligible households even if they move to the SSEG tariff.)
Cost of PV/Wp	R15 -> R14	-R33,131	R48,819	Further research is required on accurate prices (for installed systems) in South Africa as well as the potential for further price reductions for bulk buying.
Annual PV Degradation Rate	0.7% -> 0.5%	-R31,821	R48,900	Degradation rates of up to 1% are also possible.
Maintenance and Insurance	R60 -> R50	-R30,021	R48,900	Further research is required on maintenance and insurance costs, as well as scope for cheaper group insurance.
Loan Period	15 -> 17 years	-R24,108	R55,789	By linking the loan to a longer-term home loan or to the municipality's rates bill, it would be possible to extend the loan period to improve the financial viability of the investment. However, in the current model the fixed loan repayments mean that the household would be 'out of pocket' in the early years of the loan (compared to the 'Without SSEG' scenario). A special loan facility - with incremental loan repayments - could be structured to address this problem.
Level of Tariff Subsidy	'Domestic Lifeline' (with 25 free units) -> 'Domestic'	**R34,579**	R4,757	In Cape Town, eligibility for FBE and the 'Domestic Lifeline' tariff is based on property value (≤ R400,000). If the property valuation moves above this threshold, the household is then subject to the standard 'Domestic' tariff resulting in significantly higher electricity costs. In this case a rooftop PV system could help the household to make significant savings.
Reduced Fixed SSEG Fee	0% -> 10% discount	**R39,645**	R352	There is currently no 'low-income' SSEG tariff. However, a modest discount on the fixed fee component of the tariff - for eligible low-income households - can improve the household's investment case for the PV system while still protecting municipal income.
Bulk Storage	No -> Yes	**R39,645**	**R23,590**	This result (showing a significant improvement for the municipality) assumes that bulk storage is available and can provide a Levelised Cost of Storage (LCOS) of R1.54/kWh. This is based on (un-confirmed) figures for Vanadium Redux Flow Batteries. However, this technology is not yet widely available. Also, the LCOS is based on 100% daily cycling through-out the year, whereas at current storage costs (and feed-in tariffs) it would only be worth storing electricity from domestic PV systems during the winter. The battery facility would therefore also need to receive imports from other, cheaper sources throughout the year in order to be financially viable.

[17] We have not shown the impact of changes to CPI or loan interest rate since this is self-explanatory. Also, the higher the Eskom and Municipal tariff-escalations, the more viable the investment case for the household.

PROMISING FUTURE OPPORTUNITIES

One of the more useful outcomes of the modelling exercise is that it has revealed a number of factors that might in future contribute to an increasingly attractive investment case for low-income rooftop PV systems. These factors include:

1. **Escalating Eskom tariffs** well above inflation for the foreseeable future;
2. **Fundamental changes in municipal tariff structures** enabled by Smart Meters so that municipalities can offer Time-Of-Use (TOU) tariffs to domestic end-users (in alignment with their input costs of supply)[18];
3. **PV affordability** Ongoing competition in the Rooftop PV industry (internationally, at R&D level, and locally, as more installers and suppliers enter the market) and resultant cost reductions in PV infrastructure;
4. **Innovative Capital Financing Schemes:**
   a) Tying the hardware loan into a home-loan facility (since the lifespan of a well-maintained modern rooftop PV system is in excess of 25 years),
   b) Government-funded financing such as Property Assessed Clean Energy (PACE);
5. **Storage**
   As revealed in the basic modelling of a bulk municipal storage facility, there is no realistic financial case when relying on savings from tariff arbitrage alone (for current tariffs), since the current figures for Levelised Cost of Storage (LCOS) using, for example, a large Vanadium Redux Flow Battery (VRFB) [19] only make storage financially attractive during winter week-days when the difference between the peak and off-peak Eskom rates is higher than the LCOS. Furthermore, this kind of battery technology is not yet fully developed. However, as storage costs inevitably come down[20] the differential between peak and off-peak rates even in the low demand season will eventually be higher than the cost of storage and this will make investing in bulk storage more feasible. There are also other potential benefits to localised storage which may translate to savings, such as frequency regulation, spinning reserves, demand response and demand charge mitigation[21];
6. **Centralisation (Apartment Blocks)**
   Collective schemes to exploit economies of scale, aggregate demand profiles (in order to ensure more self-consumption), maximise efficiencies, reduce project risks and provide larger-scale investment opportunities. The Appendix provides a basic summary of a study conducted by South South North (SSN) on the financial case for bulk PV arrays in a large-scale low-income housing project in Cape Town. An earlier version of the *Low-Income PV SSEG* model was used for this investigation.

[18] Nelson Mandela Bay and George Municipality offer domestic TOU for both feed-in and supply – this is considered good practice.

[19] The draft IRP 2018 did not acknowledge batteries in the generation mix to 2050. However Eskom is testing VRFBs as a possible alternative to concentrated solar power storage. The World Bank has recently announced a major battery energy storage programme that will mobilise $5bn and 17,500 MWh of storage in developing countries, including South Africa (which has a particular competitive advantage with respect to VRFBs due to rich Vanadium deposits.) https://www.businesslive.co.za/bd/opinion/2019-03-21-vanadium-powered-batteries-waiting-to-rescue-eskom/.

[20] Bushvled Minerals cites research (by Navigant Research) that CAPEX Flow Battery costs will almost halve between 2018 and 2023. http://www.bushveldminerals.com/wp-content/uploads/2018/11/Energy-Storage-Vanadium-Redox-Flow-Batteries-101.pdf.

[21] https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

GAPS IN KNOWLEDGE

The following areas require further research:

1. **Hardware pricing:** Understanding the expected cost reductions in coming years (in South Africa) for PV panels, Balance of System (grid-tied) costs and installation costs.

2. **Eskom Tariff escalation** scenarios for South Africa in the coming decade.

3. **Financing**: Exploring in more depth what work is being done to create financing products and mechanisms that are suitable for low-income households and enable them to enjoy immediate savings (instead of waiting for a breakeven point some years after installation).

4. **Identify possible pilot sites:** Find those municipalities which are more receptive to the idea of:
    a. encouraging (via supportive SSEG tariff policies) a vibrant local industry in domestic rooftop solar PV installations;
    b. **designing appropriate special SSEG tariffs for low-income households** (for example waiving the fixed-charge component) to ensure that they are able to participate in the emerging opportunities to invest in 'green assets' but still retain their benefits of subsidised tariffs (without resulting in additional costs or losses for the municipality over-and-above its existing costs of subsidisation[22]).

    In particular, pilot opportunities are more likely in municipalities that are prepared to implement balanced Time-of-Use Tariffs for supply and feed-in without onerous fixed charges and willing to retain subsidies for low-consuming households and free-basic units for eligible low-income households.[23]

5. **Smart-meter technology:** pricing, capabilities, future developments, and exploring impactful demand-side management strategies to maximise energy efficiency and self-consumption of solar electricity.

6. **Storage:** Notwithstanding the stated limitations (notably LCOS) of current battery technology in producing savings from shifting load for municipalities, there are other potential utility benefits claimed for batteries (voltage and frequency regulation, inter-seasonal and seasonal storage, augmenting supply in areas of constrained grid). Further work is required to understand how these potential ancillary benefits could translate to avoided costs of supply and management, and whether or not there are circumstances particular to low-income residential areas (such as constrained grids) where such benefits could improve the financial case for rooftop PV installations – for both the household and the municipality.

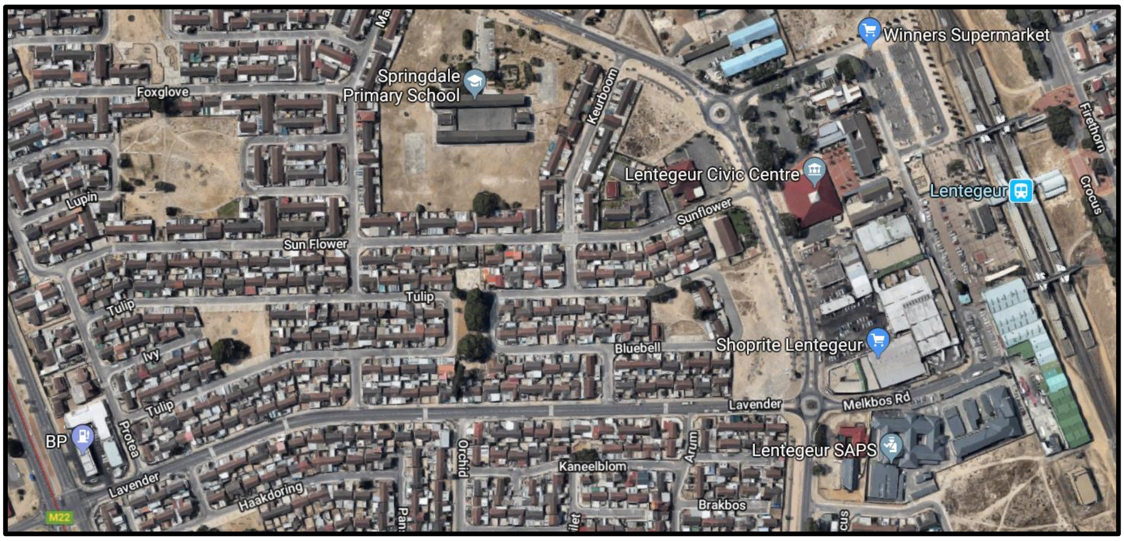
[22] Section 74(2c&e) of the ***The Municipal Systems Act*** **(2000)** mandates the subsidisation of poor households.
[23] An example was Nelson Mandela Bay where their SSEG tariff includes TOU for both supply and feed-in and includes a low fixed charge (R60 per month in 2019). A separate indigent SSEG tariff where eligible households continue to receive free-basic electricity would further support LIHH towards a viable solar PV business case.

EXPLORING PILOT OPPORTUNITIES

It is beyond the scope of this study to investigate comprehensive proposals for pilot projects. However, the modelling exercise has revealed those factors that could advance the financial feasibility of PV installations for low- to mid-income households. For example, the opportunities to exploit economies of scale through centralised systems for apartment blocks have been considered for the Cape Town 'Southern Corridor' planning process (see Appendix). For individual (lower-income) households, the sweet-spot appears to be in those suburbs where most households just miss the eligibility threshold for any free basic units or a subsidised 'domestic lifeline' tariff (in terms of the Cape Town tariff nomenclature). In Cape Town, eligibility for these subsidies is based on municipal property valuations. Currently the threshold is R400,000. Those households with property values just above this threshold have a more compelling financial case for a rooftop PV system (subject to affordable, long-terms loans, and modest SSEG tariff subsidisation).

An example is the suburb of Lentegeur in Mitchells Plain. A general scan of the Cape Town Property Valuation Role shows that many of the houses in this area are in the range R350k – R500k, and so many of these families will not be eligible for the domestic lifeline tariff (which means that even if they manage to consume only 250kWh or less a month, they would be paying R572 per month on electricity compared to R262 if their property were valued under R400k.

A suburb like this could be a candidate for a pilot programme, with a roll-out of sufficient size to minimise hardware and installation costs and possibly aggregate maintenance and insurance costs. The layout of the streets in the area is in a predominantly east-west direction meaning that the majority of houses have suitable north-facing roofs. Also, as shown in the satellite image of the western half of Lentegeur (below) there are a large number of municipal and other public buildings immediately to the east of this area (Civic Centre, Sub-council offices, Police Station, School, etc). A group of these public buildings and services that operate during the day could agree to take up any spare electricity generated from the domestic panels at a rate lower than what they buy from the municipality in a wheeling contract. There is of course a valid argument for rather investing in larger, municipal-owned PV systems on these public buildings (simpler, more cost-efficient, lower risk, etc). But with that approach, the opportunity for lower-income households to invest in green assets and engage more actively in the green economy is lost. There are presumably many areas such as this in Cape Town which could be suitable candidates for piloting, but considerably more work would be required to establish a robust business case for this idea.



West Lentegeur – a possible site for a LIHH/MIHH rooftop PV pilot

APPENDIX

BULK CENTRALISED PV SSEG – LOW-INCOME APARTMENTS: PRE-FEASIBILITY

One for the opportunities identified in the first report for the *GiZ-funded Low-Income SSEG Project*[24] was the possibility of enhancing financial viability via the economy-of-scale of larger installations coupled with aggregated demand profiles of a group of low-income households, for example in social housing projects or apartment blocks. This opportunity was subsequently explored as part of a large-scale sustainable housing proposal for the Kosovo informal settlement in Cape Town (±8000 apartment-style units), commissioned by the Western Cape Government: A pre-feasibility study was undertaken by South South North (SSN) to explore the financial viability of installing up to 20MWp of Solar PV on the communal rooftops of the proposed apartments. An adapted version of the *Low-Income PV SSEG (CoCT)* model was used to test the business case for a Public-Private-Partnership with the City of Cape Town in which the private investor would finance and own the PV infrastructure and generate a rental return covered by each household from savings in electricity bills.

The preliminary results showed that aggregating the demand from individual households as well as including some non-domestic (day-time) users (<10% of total annual demand) could enable up to 36% local consumption (compared to typically lower levels, predicted by the same model for individual households with similar demand profiles and monthly consumption of 250kWh). Without incorporating energy efficiency or demand-side management (such as solar water heaters or gas-cooking), the investigation found that a private investor in a distributed rooftop system (totalling 20MWp) could generate an Internal Rate Return (IRR) of 9% (or up to 14% if the investment were made via a tax efficient Section 12J structure).

A key factor that contributes to this more positive case compared to individual households is that the apartment model assumed a significantly reduced fixed monthly SSEG tariff (R25 versus R343). The argument for a lower fixed tariff for low-income households has already been made in this report, but there is as yet no municipality in South Africa that offers such income-dependent tariffs for SSEG. Nevertheless, when this idea was presented by SSN to various departments at the City of Cape Town (including Electricity, Energy and Human Settlements) the idea was reportedly positively received.

Other proposed benefits of such a programme include improved mechanisms to incentivise payment, fraud detection, local job-creation, value-added services, and the stimulation of regional green economy "allowing the COCT to fulfil its service delivery mandate and realise decentralised energy while harnessing private sector expertise to ensure the low carbon energy solution is funded and delivered". [25]

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[24] Urban-Econ, SEA, Sustainability Institute, 2018: Low-and middle-income grid connected solar PV approaches in South Africa: Discussion paper, https://www.sseg.org.za/wp-content/uploads/2018/12/discussion-paper.pdf.

[25] SSN, Planet Capital Energy and Carbon Trust, 2018: 'Pre-Feasibility Study for A Low-Carbon Energy Solution for the Development of the Kosovo Informal Settlement in the Southern Corridor Integrated Human Settlements Programme, Western Cape, South Africa', http://southsouthnorth.org/wp-content/uploads/Philippi-Low-Carbon-Energy-Solution_19-June-2018.pdf.

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