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How to stimulate the South African rooftop PV market without putting municipalities' financial stability at risk

A Net Feed-in Tariff proposal

June 2015

Document Reference Number:
CSIR/02400/Renewable Energy/IR/2015/0002/A

Authors Contact Details: Prof Dr Tobias Bischof-Niemz, Centre Manager: Energy, CSIR, TBischofNiemz@csir.co.za, +27 83 403 1108

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Executive Summary

Due to drastically reduced prices for Photovoltaic (PV) systems and significantly increased electricity tariffs in the last five years, embedded PV generators are now attractive for many electricity customers in South Africa as a supplement to their main electricity supply. But embedded PV is not only attractive for individual electricity customers; it is also a cost-competitive new-build option in South Africa for the power system as a whole and a supplement to the fleet of new large, central power generators.

At the same time, the South African power system is currently under severe constraints, with several controlled load shedding events in late 2014 and during the first months of 2015. Embedded PV fulfils the requirements to address the electricity crisis that South Africa is currently facing in three dimensions: First, it is cheap with effective tariff payments of 0.8-0.9 R/kWh required to stimulate the market; second, it can be implemented fast, because of the distributed nature many thousands of projects can start implementing at the same time; third, it can be significant, with estimated 500-1,000 MW of annual new-build capacity that could be ramped up quickly.

That is a system view. A large uptake though without any countermeasures will put the financial stability of electricity distributors (municipalities and Eskom)[1] at risk, because self-consumed PV energy reduces the sales and therefore gross-margins of distributors, which they need to cover their fixed cost of building, operating and maintaining the distribution grid, as well as cost of metering and billing.

The CSIR Energy Centre therefore developed a Net Feed-in Tariff (NETFIT) concept in which electricity distributors are made financially indifferent to embedded PV, and in which the business case for the PV owner is de-risked at the same time. The concept differs from the also widely known "net metering" approach in the sense that it stimulates embedded PV as part of the overall power-generation fleet, regardless of what the specific load at the customer's site is, and it compensates municipalities financially for the portion of the fixed grid cost of electricity distributors that they cannot recover from electricity sales anymore due to self-consumed PV electricity.

The NETFIT concept is estimated to lead to no net costs to the system compared to alternative new-build options.

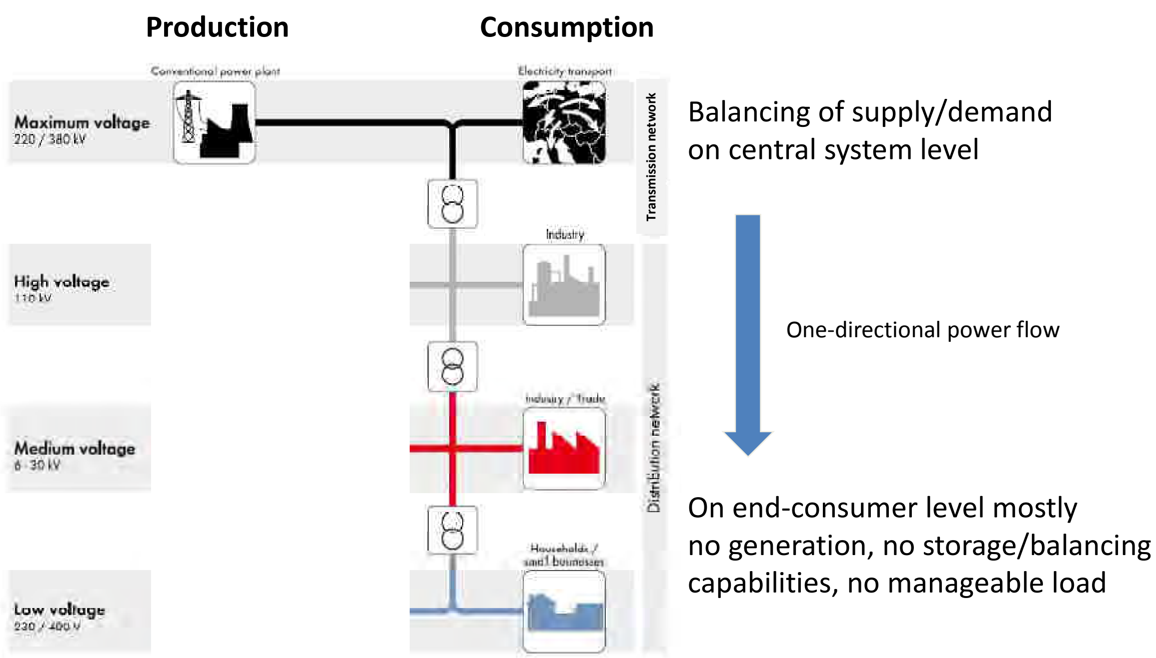
[1] Whenever the term "electricity distributor" is used in this document, it refers to the holder of an electricity distribution license, which can be either a municipality or Eskom Distribution

1 Introduction and Background

What is embedded PV?

In Figure 1, the principle architecture of today's power system is shown. The different voltage levels comprise of maximum and high voltage, medium voltage and low voltage. Historically, on production (i.e. electricity generation) side generators are only located at maximum voltage level, whereas on consumption side loads can be found on all voltage levels. International exchange typically happens at maximum voltage, large industries are connected at high voltage, smaller industry and commercial/trade businesses typically tap into the medium voltage level, whereas households and smaller business are connected at low voltage.

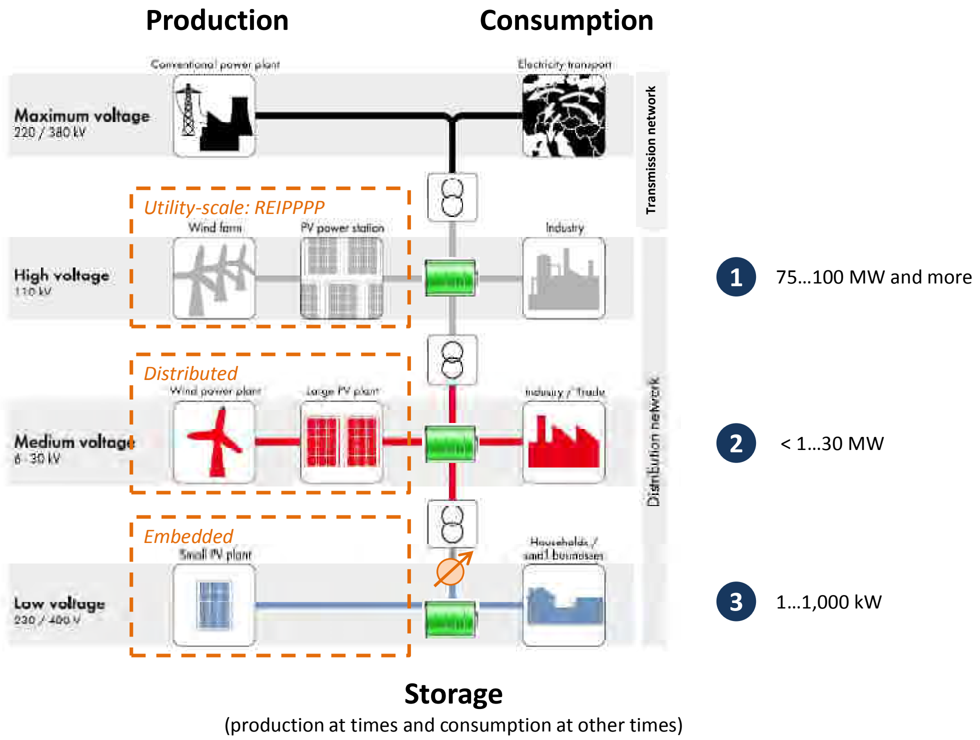
This was and still is the power-system architecture for most large power systems globally. Because generators are located on highest voltage level only, the power flow is one directional from maximum voltage to low voltage. Balancing of supply and demand typically happens on central system level and is done by the power-generation fleet. On end-consumer level, there are generally speaking no generation, storage/balancing capabilities and no manageable loads.



Sources: SMA; CSIR analysis

Figure 1: Today's power-system architecture

In the future power system however, the production side will be more diverse, with power generators being distributed across the interconnected electricity grid on all different voltage levels, from high to low voltage (refer to Figure 2). That is due to the nature of renewable power generators (in this example focus lies on solar PV and wind power generators), because they are inherently smaller in size than conventional power generators and they follow the resource (sun and wind), which is generally wider spread across the country than fossil fuels are (which are more point-resources as opposed to renewables, which are area-resources).



Sources: SMA; CSIR analysis

Figure 2: Power-system architecture with a high solar PV and wind penetration

From a technical perspective, this distributed nature of renewables implies that the power grid has to cope with bi-directional power flows, because generators are now located at low- and medium-voltage levels, pushing power back into the grid, potentially even back from low-voltage to medium-voltage, or even up to high-voltage level . With relatively small investments into the distribution grid, these changes are manageable. Protection systems in substations that potentially prevent reverse power flows need to be revisited, and the voltage level along low-voltage distribution lines needs to be carefully managed, for example by mandating low-voltage connected solar PV generators to produce reactive power if otherwise the voltage level cannot be controlled. These technical challenges however have all been solved and can be managed, as the example Germany has shown, where approx. 2.5 solar PV modules are installed per inhabitant across the country, most of them embedded and on low-voltage level.

In this future power-system architecture, energy storage (which essentially is a technology that is at times a load and at other times a power generator) will play a role in balancing supply and demand instantaneously and managing imbalances on different voltage levels. It is important to note though that the inherent volatility of solar PV and wind supply is most cost-efficiently managed in the following sequencing of events:

1) Widespread spatial aggregation of both solar PV and wind leads to significant reduction of short- and medium-term volatility of both power sources (i.e. spatial distribution of solar PV and wind generators across the country and region, all connected to the same interconnected grid). This is generally speaking the easiest and cheapest way of reducing fluctuations of solar- and wind-based power generation.
2) Remaining fluctuations can be managed by flexible conventional power generators (e.g. gas-fired engines, gas turbines, combined-cycle gas turbines, pumped storage). These generators are both technically flexible (fast ramp rates, good grey- and black-start capability, low min-load requirements), as well as economically flexible in the sense that their cost structure is capital-light and more fuel-heavy.
3) In the next stage of absorbing volatility from solar PV and wind, one would bring flexible, non-essential (i.e. dispatchable / shiftable) loads into the picture.
4) As an additional mean to manage fluctuations or in cases with very high penetration of renewables and related "overshoots" of supply, energy storage in form of batteries will be a viable option. At the moment however, it is still the most expensive of all the mentioned means to manage volatility from renewables power supply. The business case for batteries today lies in provision of system services, for example balancing power to deal with short-term imbalances of supply and demand, or for managing local grid congestion problems, or for peak-shaving for commercial/industrial customers. Batteries will also play a role in the residential market; however the market forces to drive this segment are different from those of a pure system-optimising central planner.

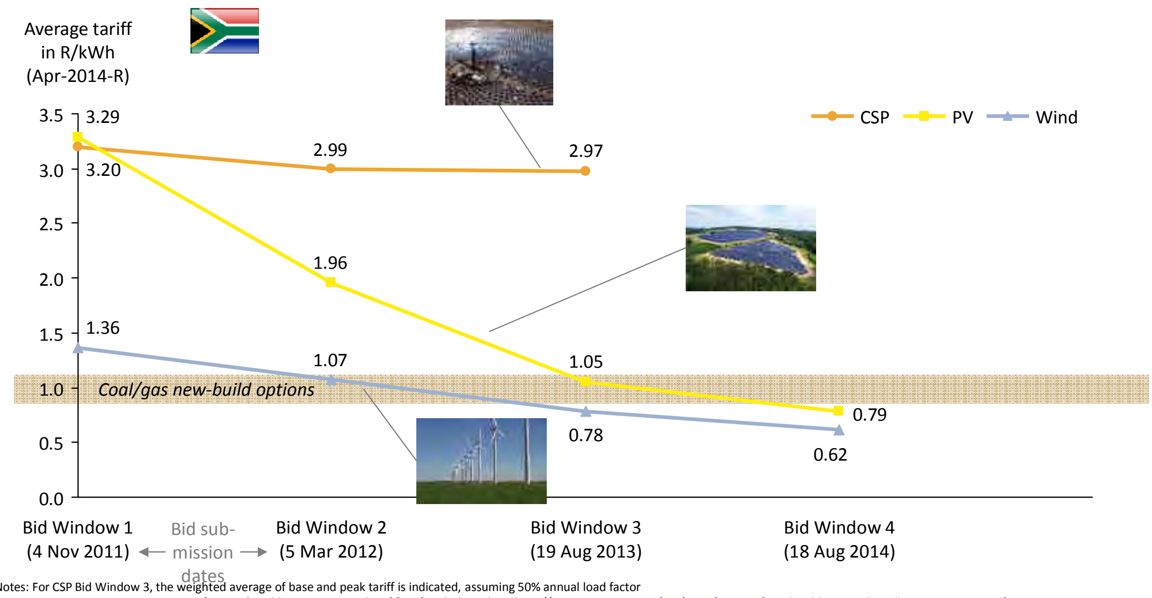
In short, the technical solutions to integrate embedded generators into the system are in principle existing. The commercial / accounting perspective seems to be more challenging than the pure technical one. Because embedded generators are per definition installed behind a customer's meter, and because the operation of the distribution grid (the wires) is done by the same entity that sales electricity to the end customers (the "electricity distributor"), any kWh of electricity from an embedded PV installation that is self-consumed behind a customer's meter reduces the sales volume of the electricity distributor, therefore reduces its gross margin and therefore reduces its ability to cover the fixed costs of running the distribution grid and selling electricity to its customers.

This is a challenge for any integrated electricity distributor anywhere in the world, regardless of its efficiency, its business model, its approach to marketing and sales. What is important to note however is that from a power-system perspective, embedded generators (like solar PV) play exactly the same role as any other power generator: they feed electricity into the "electricity pool", which is the interconnected power system. The facts that they happen to be connected at low-voltage level and behind a meter are immaterial for their ability to form part of the power-generation fleet in the country.

Grid and wholesale parity: Embedded PV generators in South Africa are cost competitive today

Massive cost reductions in Photovoltaic (PV) module and system prices during the last five years combined with increasing electricity tariffs make residential and commercial PV systems cost competitive to grid power in South Africa today. Residential PV systems of an installed module capacity of a few kWp (kilowatt peak) in size cost less than R 100,000 for the turnkey installation of the system and thus became affordable for many residential customers. The lifetime energy costs of such systems are in the order of R 0.8-0.9 per kWh. That compared to residential electricity tariffs (without VAT) reaching 1.2-1.4 R/kWh creates a huge incentive for residential customers to install PV systems on their roofs and supplementing their grid supply.

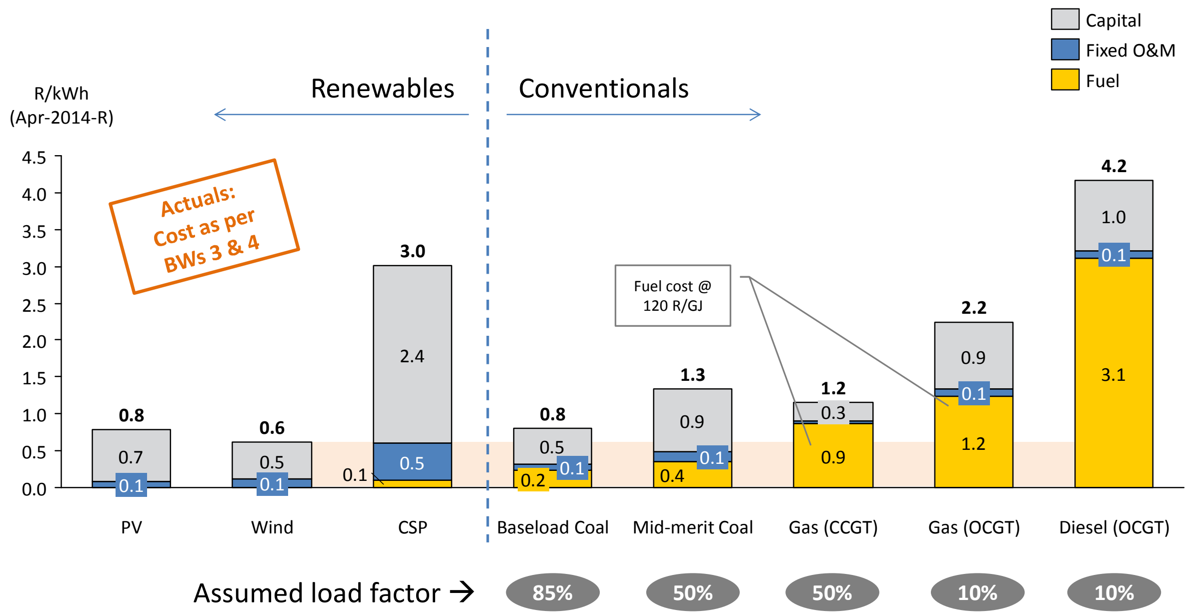
This is the view of an individual electricity customer who compares the LCOE of a PV system with the retail energy tariff in R/kWh. From a power system perspective, the costs of PV (LCOE) need to be compared with the cost of alternative new-build options. Figure 3 shows the results of the first four Bid Windows of the Department of Energy's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Especially the costs of PV to the power system in form of the tariffs that have to be paid to the IPPs decreased sharply by more than 75% from Bid Window 1 (R3.29 per kWh) to Bid Window 4, less than three years later (R0.79 per kWh).



Notes: For CSP Bid Window 3, the weighted average of base and peak tariff is indicated, assuming 50% annual load factor
Sources: StatsSA on CPI; Department of Energy's publications on results of first four bid windows http://www.energy.gov.za/IPP/List-of-IPP-Preferred-Bidders-Window-three-04Nov2013.pdf; http://www.energy.gov.za/IPP/Renewables_IPP_ProcurementProgram_WindowTwoAnnouncement_21May2012.pptx; http://www.ipprenewables.co.za/gong/widget/file/download/id/279; CSIR analysis

Figure 3: Results of the first four Bid Windows of the Department of Energy's procurement programme for solar and wind Independent Power Producers (IPPs)

Comparing these results of the REIPPPP with the costs of alternative new-build options as highlighted in Figure 4 shows the competitiveness of both wind and solar PV in the South African power market.



Assumption: Typical full-load hours per generator assumed (92% for nuclear, 85% for coal, 50% for CCGT, 10% for OCGT). Changing full-load hours for conventionals drastically changes the fixed cost components per kWh (lower full-load hours → higher capital costs and fixed O&M costs per MWh); average efficiency for CCGT = 50%, average efficiency for OCGT = 35%

Source: IRP Update; REIPPPP outcomes; CSIR analysis

Figure 4: Cost comparison of alternative new-build options for the South African power system

This is the power-system view on very large-scale individual projects of the REIPPPP (individual PV projects are up to 75 MW in size, covering several 100s of ha of land). An additional aspect of embedded PV of a few kW to a few MW in size is that the ownership base is typically quite different to that of large utility-scale PV projects of multi-MW-size. Residential customers typically have a lower return expectation on their investment than large companies. Lower return expectation (i.e. lower Weighted Average Cost of Capital – WACC) in a capital-intensive investment like solar PV however has a direct and very strong effect on the resulting "Levelised Cost of Energy" (LCOE). This is illustrated in Figure 5.

Even if a small solar PV installation costs more per installed kW than a large utility-scale one, the lower WACC can compensate that and lead to a similar LCOE for both types of installations. In other words, a private individual would accept the same tariff payment in R/kWh as a large independent power producer, despite the fact that his investment cost per installed kW might be higher. From system perspective, the tariff that needs to be paid out per kWh however is the only relevant measure for the cost of a power generator.

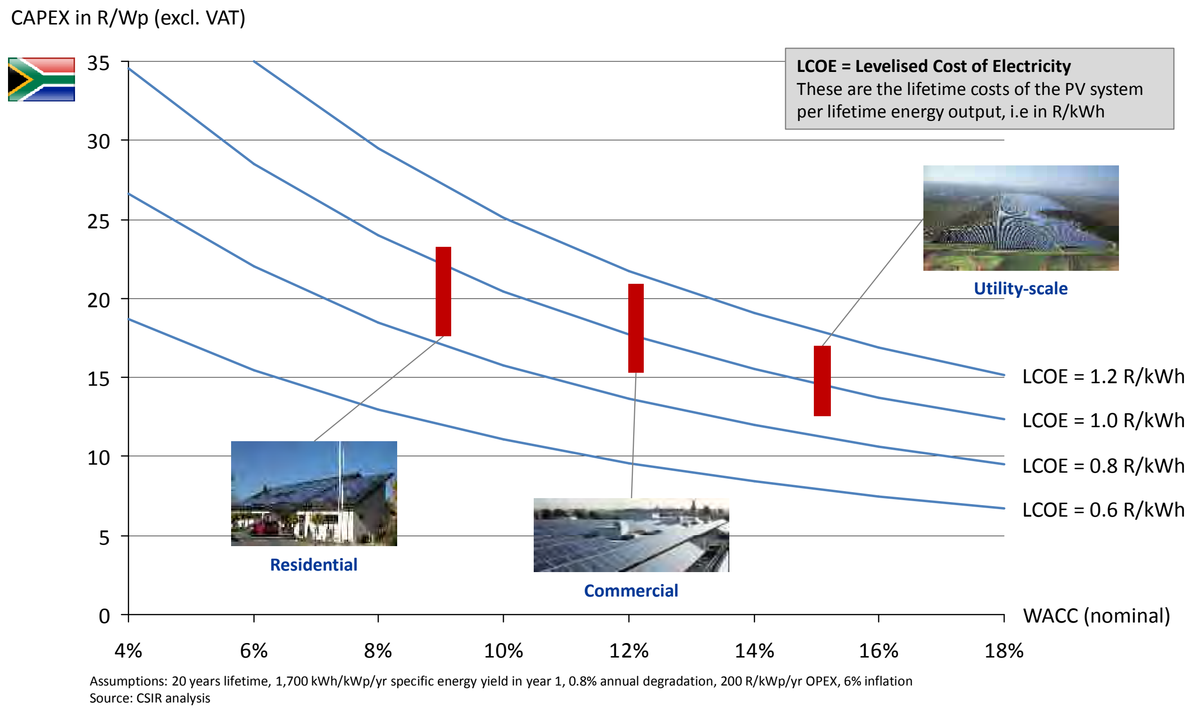
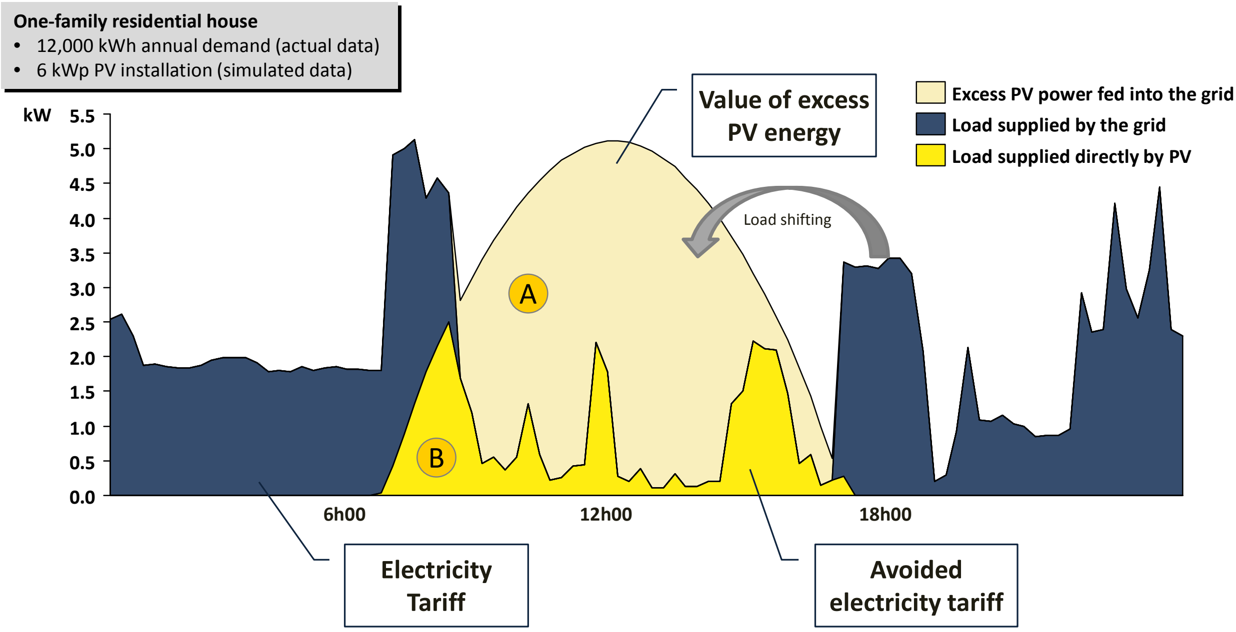


Figure 5: Higher CAPEX of residential or commercial PV can be (partly) compensated by lower cost of capital for residential home owners

The Integrated Resource Plan 2010 (IRP 2010) plans for 8.4 GW of installed PV capacity by 2030. Where that capacity is installed – in utility-scale only, in residential-scale only or, ideally, as a mix of both – is irrelevant from an IRP perspective. Hence, if embedded PV can be installed at the same or similar tariff as compared to large utility-scale projects, there is a clear reason to mix both markets.

The main reason for a still slow uptake from the residential and commercial customers despite the attractive cost base of PV is the uncertainty of the business case "self-consumption" of PV energy. This is illustrated in Figure 6, where the residential load does not match instantaneously the PV supply.



Source: CSIR analysis

Figure 6: Typical daily load profile of a residential household in winter, overlaid with a typical generation profile of a simulated 6 kWp PV installation

The PV systems have a lifetime of 25 years and more, while certainty about the own energy demand, load profile and electricity tariffs for most electricity customers only exists for the next few years. But certainty about both the off-take and the tariff paid for PV-generated energy is required for a business case that is purely capital; PV systems are high in upfront costs and have very low running costs.

In this sense, PV systems are comparable to a fixed-deposit savings account, where the money invested is locked away for many years and the benefits are reaped in form of interest (here: energy production from the PV asset). For any fixed-deposit-type of investment, high investment security is a necessary condition in order to bring the investor-acceptable return down. In the case of the fixed-deposit savings account this means certainty about the interest rate, in the case of a PV investment this means certainty about off-take and about the payable tariff (in other words: the achievable revenues).

From a power-system perspective, small PV installations are not only in the same lifetime cost range per kWh as large-scale ground-mounted PV installations in the multi-MWp-range, they are also cost competitive to conventional new-build options (e.g. coal and gas) and can therefore, if stimulated correctly, cost-efficiently contribute to the new capacities that are required in the South African power system in the short- , medium- and long-term.

2 Business case considerations for different stakeholders

2.1 Municipalities

Concern: municipalities' financial stability is at risk with an uncoordinated uptake of PV

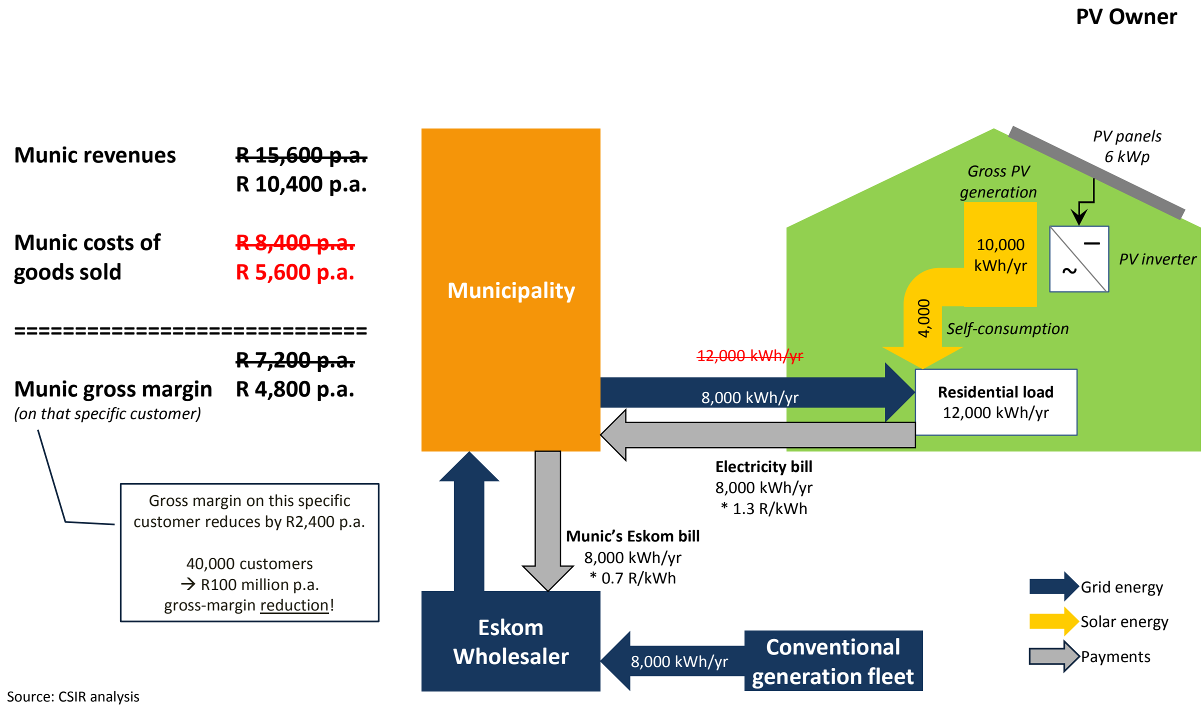
Electricity distributors (municipalities and Eskom Distribution) fund the fixed costs associated with expanding, operating and maintaining the distribution grid through their electricity sales. The tariff that is charged on the (variable) energy consumption (R/kWh) contains a certain portion to cover these fixed grid costs. At the same time, the residential tariff structure is typically such that high-consuming customers pay more per kWh than lower-consuming customers. This is a form of electricity-internal subsidisation.

Because PV is most attractive for those customers that pay the highest tariffs and consume the highest amounts of energy, which are generally well-paying premium customers from municipalities'/Eskom's perspective, there is a huge risk for municipalities/Eskom to lose out on electricity revenues due to self-consumption of PV-generated energy on the site of the electricity customer.

This is illustratively demonstrated in Figure 7, where an assumed PV system of 6 kWp in size is installed at a customer's premise, where the customer has a load of 12,000 kWh/yr. The residential customer in this case is able to consume 40% of the annually produced PV energy of 10,000 kWh/yr directly on site (PV self-consumption). These 4,000 kWh/yr supply the residential load as an alternative supplier to the municipality and therefore municipality sales are reduced by this amount (down from 12,000 kWh/yr to now 8,000 kWh/yr). This effects the municipality's revenues (sales volume times average tariff), but, more importantly, it reduces the municipality's gross margin. The gross margin is the difference between revenues from electricity sales minus the costs of goods sold, which is the amount of money the municipality has to pay to Eskom in order to buy the re-distributed electricity in the first place.

This gross margin on the assumed individual customer was R8,400 per year, and it has to cover all municipality fixed costs (building, maintaining, operating the distribution grid, metering and billing, etc.). With self-consumed PV energy reducing the sales volume by 4,000 kWh/yr, the municipality now makes only R4,800 per year in gross margin on that specific customer. The loss of R2,400 per year in gross margin must be compensated from somewhere – without external intervention it will have to be compensated through increasing the general tariffs for all customers.

This loss in gross margin due to self-consumed PV energy is a threat to the electricity distributors.



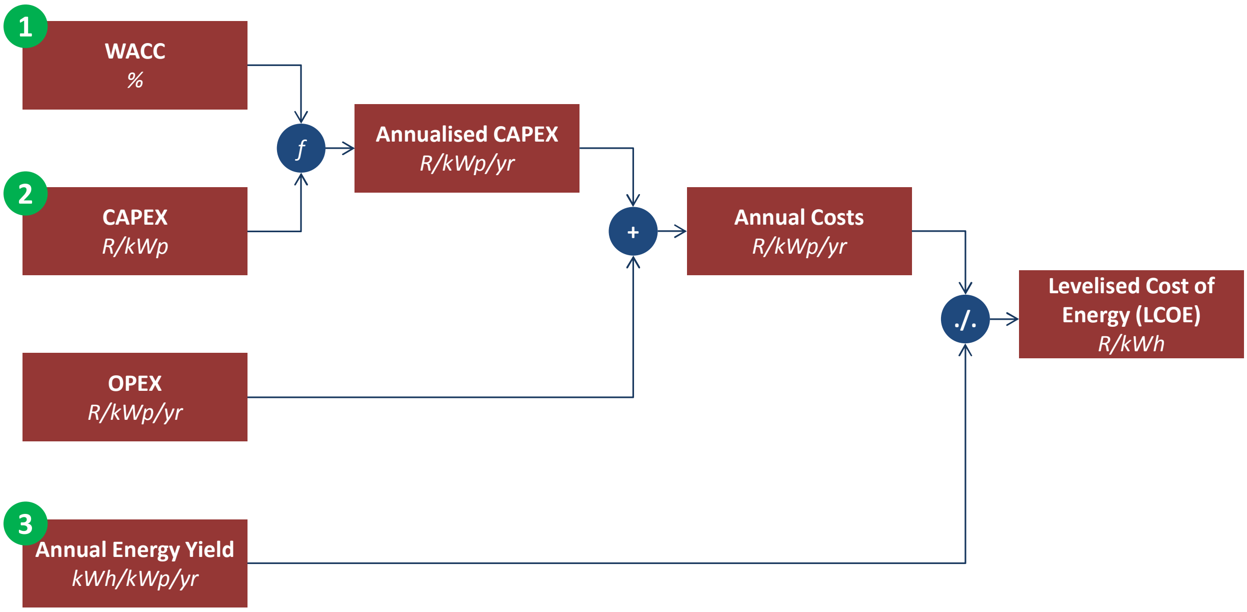
Source: CSIR analysis

Figure 7: Reduction of municipality's gross margins due to self-consumed energy of a behind-the-meter PV system

2.2 Solar PV investors

Solar PV business case

As mentioned before, the nature of a solar PV investment is similar to a fixed-deposit savings account. The business case has three fundamental drivers: First, the cost of capital; second, the capital spent to install the PV system; third, the annual energy yield. The operational costs to maintain the PV system are, compared to the upfront capital investment, relatively small and not a significant cost driver. This is shown in Figure 8.



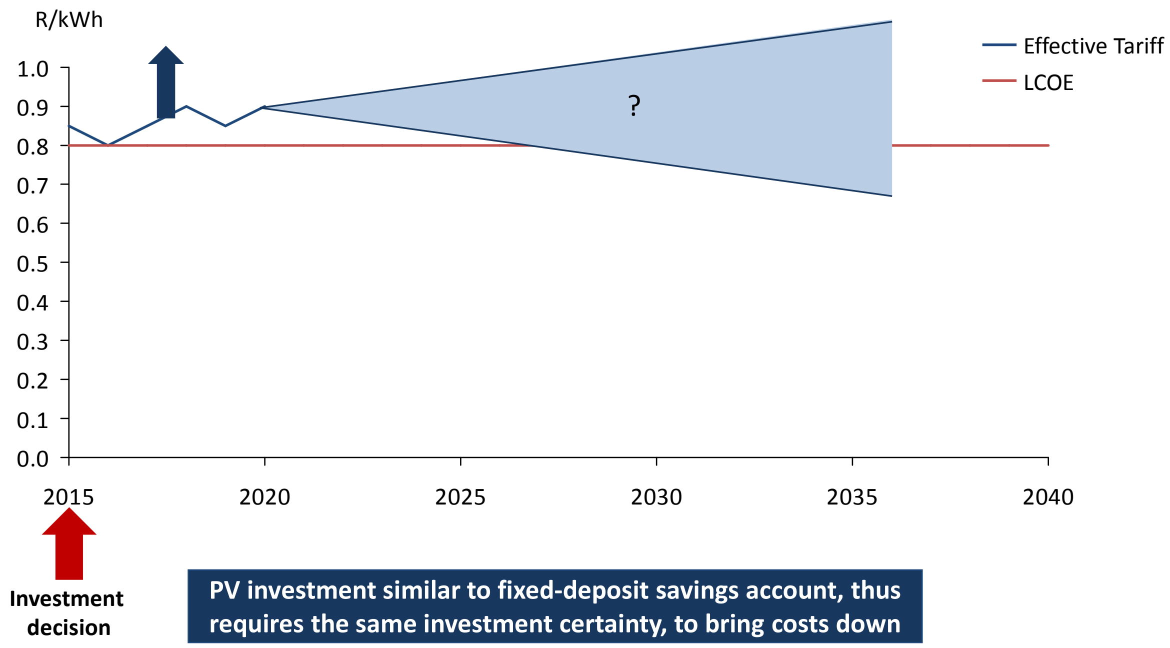
Note: Without inflation, i.e. In real terms; LCOE = Levelised Cost of Energy = discounted total lifetime cost of the PV installation divided by discounted total lifetime energy yield of PV installation
Sources: CSIR analysis

Figure 8: Cost drivers for a solar PV system

In other words, once the decision for the investment is made and implemented, there is almost nothing that the investor can do to improve the business case:

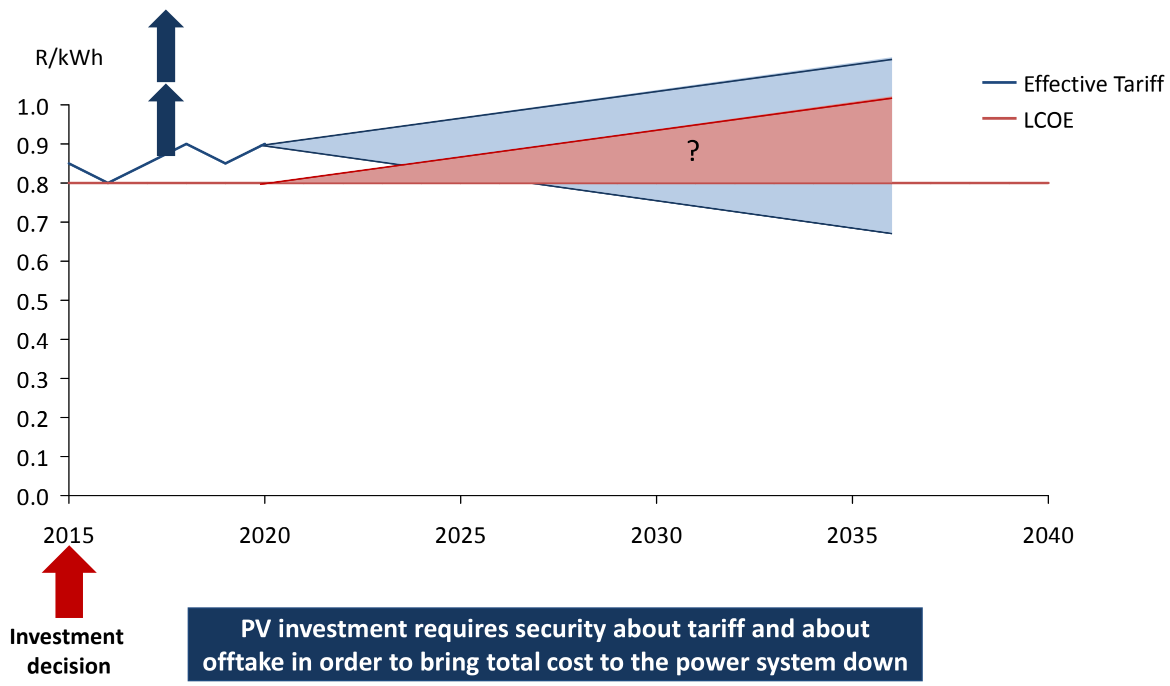
- Location: determines the amount of solar radiation → fixed
- Technology choice: determines the efficiency of converting sunlight into electricity → fixed
- Design of the installation: determines losses → fixed
- Capital investment: is done → therefore fixed
- Cost of capital: unlikely to be re-negotiable → fixed

Any uncertainty about the future off-take (ability to monetise the energy produced from the PV system) and/or the future value of the energy produced, i.e. the tariff, will therefore inevitably lead to a higher required initial compensation to the PV investor than theoretically necessary. This is illustrated in Figure 9 and Figure 10. Uncertainty about future level of the effective tariff (or better: the effective future value of the PV energy per energy unit) will increase the required initial tariff level at the time of the investment decision. Similarly will uncertainty about the off-take (can the PV energy be utilised fully or not?) increase the Levelised Cost of Energy (LCOE) in R/kWh and therefore additionally increase the required initial tariff level at the time of investment decision. The problem here is that this higher-than-necessary initial compensation will create future windfall profits for the PV owner and therefore increase the total cost to the power system (and thus to all electricity consumers).



Note: Without inflation, i.e. In real terms; LCOE = Levelised Cost of Energy = discounted total lifetime cost of the PV installation divided by discounted total lifetime energy yield of PV installation
Sources: CSIR analysis

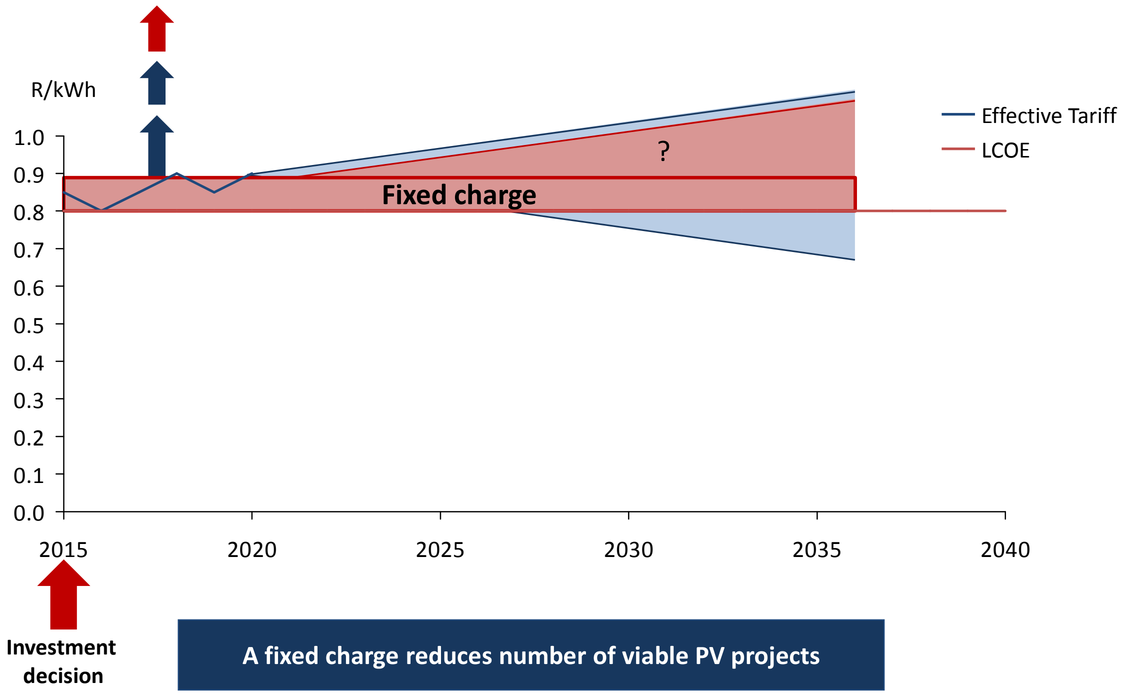
Figure 9: Effect of uncertainty about the tariff (or better: effective value of PV energy) to the required initial tariff level



Note: Without inflation, i.e. In real terms; LCOE = Levelised Cost of Energy = discounted total lifetime cost of the PV installation divided by discounted total lifetime energy yield of PV installation
Sources: CSIR analysis

Figure 10: Effect of uncertainty about the off-take (can all PV energy be monetised?) to the required initial tariff level

If in addition a fixed monthly charge is introduced to be paid by the PV owner, this will effectively increase the LCOE by the level of the fixed charge. Investments into PV might still happen, but only if the effective tariff is higher by the amount of the fixed charge. The introduction of a fixed charge therefore reduces the number of viable PV projects.

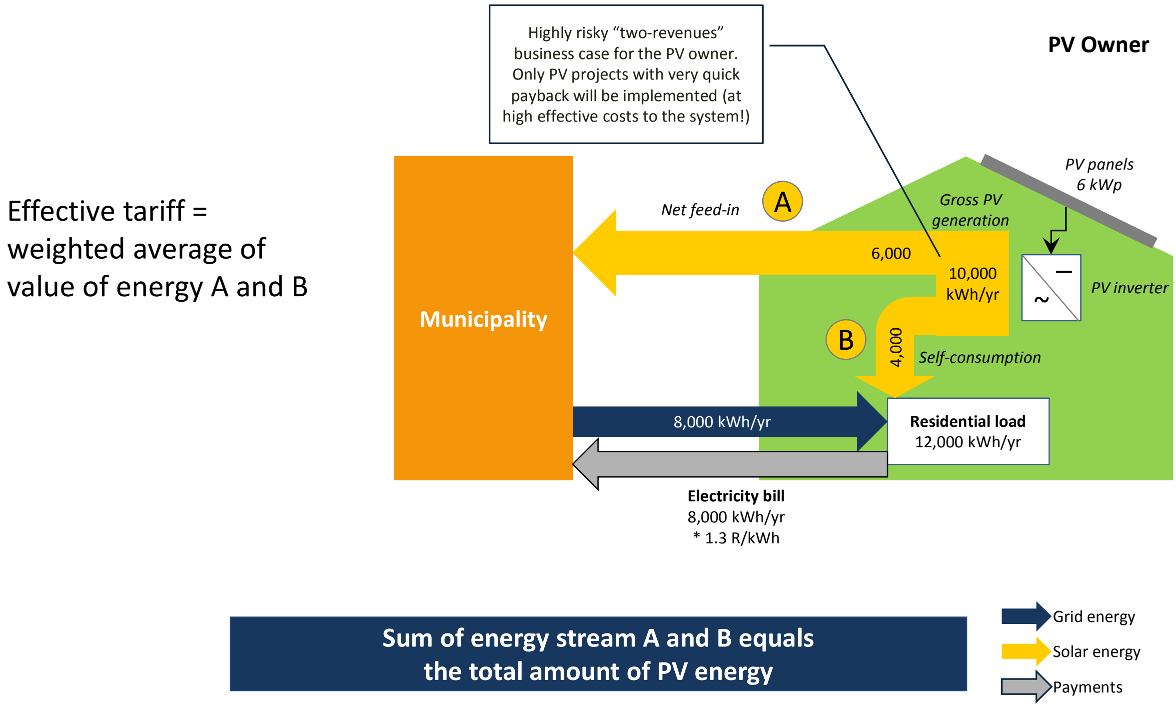


Note: Without inflation, i.e. In real terms; LCOE = Levelised Cost of Energy = discounted total lifetime cost of the PV installation divided by discounted total lifetime energy yield of PV installation
Sources: CSIR analysis

Figure 11: Effect of introduction of a fixed charge for the PV business case

This logic of required certainty about both tariff and off-take in order to bring the costs down is always true, whether the PV system is in front or behind a customer's meter. In case of an embedded PV system however (i.e. behind a customer's meter), it becomes a bit more tricky, because the PV owner will look at two revenue streams with different risk profile: One is the value that is generated by feeding excess PV energy (energy A) back into the grid, the second one is the value from reducing the own electricity bill by self-consuming the other part of the PV energy (energy B).

Figure 12 illustrates the current situation in which the PV owner faces a two-revenue-stream business case with two uncertain revenue streams, while the municipality loses gross margins without any mean to compensate for it.



Source: CSIR analysis

Figure 12: Two-revenue-stream business case for the owner of an embedded PV generator

The effective tariff for the PV owner is the weighted average of the value of energy A (per unit) and of energy B (per unit). Whether explicitly (actually having calculated this effective tariff) or implicitly (having a "feeling" about the effective tariff), the PV owner will always base the investment decision on this effective tariff.

Revenue stream B here is always uncertain, because first, the PV owner does not know what the load profile will be over the lifetime of the PV asset of 25 years. The load profile however determines how much PV energy can actually be self-consumed. Second, the PV owner does not know what the own electricity tariff will be over the lifetime of the PV asset. The avoided electricity tariff however determines the value per self-consumed PV unit.

Thus, from a perspective of the power system, one needs to reduce the uncertainty of revenue stream A in order to give the mixed calculation of the PV owner an acceptable risk-return profile. In a net metering approach however, revenue stream A is just as uncertain as revenue stream B. Hence, only PV systems with a very high effective tariff will be implemented, which in return means that the power system overcompensates these systems, and the total system costs increase unnecessarily.

3 Current situation and approach to embedded PV

An "under-the-radar" uptake of the embedded PV market must be avoided – pro-active stimulation of this market is the better approach

Doing nothing or trying to avoid embedded generators is not an option! Because of the financial attractiveness, even if not all PV energy can be consumed directly on site, some commercial and residential customers will install PV regardless of any regulatory scheme. The problem with this is that highest-value customers with high consumption and highest tariffs will do it first. They will therefore opt out of the cross-subsidisation mechanism. That will lead as a mathematical reality directly to increasing electricity tariffs for poorer customers.

From a system perspective, the biggest concern about such an "under-the-radar" embedded PV market is that there is no control over the magnitude of the development, and, even worse, no knowledge about the magnitude of the development. An assumed 1 million high-income households that install 6 kWp of PV each "under the radar", and another 20,000 commercial properties that install 200 kWp each, would already make a total of 10 GWp of installed PV capacity (or two Medupis). The system operator cannot safely manage the system with such large amounts of embedded PV installed "under the radar", the grid operators would have to fear large numbers of technically non-compliant PV installations, which pose safety risks to their workers, and the municipalities would go bankrupt. It is therefore advisable to embrace the development, stimulate the embedded PV market such that the South African power system and economy get the most benefits out of it.

3.1 Net metering

Net metering: the current approach of municipalities and Eskom to deal with the situation

Many municipalities have realised this threat and the South African Local Government Association (SALGA) has taken on the task to develop a so called net metering proposal for municipalities' customers in order to give some structure to the embedded PV market. A number of individual municipalities are quite advanced in their planning or have already implemented net metering schemes (Cape Town, CityPower, eThekwini, etc.). Similarly, Eskom has started working on tariffs that allow customers to feed energy back into the grid and get compensated for it – which in essence is also a net metering approach.

However, the fundamental problem of the funding source for the embedded PV market is not addressed in net metering schemes. The costs of embedded PV generators in form of lost revenues (better: lost gross margins) in a net metering scheme affect the municipalities' / Eskom's bottom line. This can only be fully avoided if the net metering scheme is designed financially unattractive for the PV owner – which in return might lead again to an "under-the-radar" development.

Many municipalities design their net metering scheme with the introduction of a fixed monthly charge for customers that want to connect an embedded PV system. This fixed charge is meant to compensate for lost gross margins. The problem however remains: a fixed charge makes the business case from the perspective of the PV owner unattractive.

3.2 NERSA's consultation paper on embedded generators

The National Energy Regulator of South Africa (NERSA) has seen the need for action in the embedded generators space and has published a consultation paper on "Small Scale Embedded Generation Regulatory Rules". NERSA has held a public hearing and the final results of the process are expected to be published soon. It is applaudable that NERSA has taken on the lead to give structure to the embedded PV market. That will give guidance to municipalities and Eskom in terms of what tariffs they can and should charge / pay to embedded generators. A much needed financial compensation for electricity distributors for lost gross margins is however outside of the mandate of the regulator and would have to be addressed on policymaking level.

3.3 Technical requirements and enablers

Small-scale embedded generators are not new to Distribution System Operators (DSOs) globally. Bayernwerk, a DSO that owns and operates most parts of Bavaria's distribution grid in Germany, has 250,000 embedded generators connected to its grid, most of which are solar PV. That makes Bayernwerk the DSO globally with by far the highest penetration with embedded PV globally. Bi-directional power flow and power flowing from low-voltage backwards to medium-voltage level are common practice.

In South Africa however, not all norms and standards are in place yet to allow the same level of penetration with embedded PV – which technically is similarly possible as it is in Germany.

Of particular interest in the wiring code for embedded generators (South African National Standards, SANS 10142-3), which is currently in the drafting and approval process with the South African Bureau of Standards (SABS). This wiring code will inform electricians on how to install an embedded generator and what safety practices to follow. It is important to have this document approved and published as soon as possible. However, since the approval process for such a standard takes some time, it would be advisable to draft and finalise a non-binding Implementation Guide as an interim measure that can be used by electricians and electricity distributors to design, install and accept PV installations. This Implementation Guide should be along the lines of the current draft of SANS 10142-3 and it should be stated clearly that if SANS 10142-3, once final, is more stringent in certain dimensions than the Implementation Guide, that then SANS 10142-3 will prevail and existing installations might have to be upgraded accordingly.

3.4 Fixed charges for embedded PV generators

Many municipalities propose the introduction of fixed charges for embedded generators in order to protect themselves against the losses in gross margins. The downsides of a fixed charge however are:

- The associated reduction of energy charge in R/kWh disincentivises energy efficiency

- It pushes customers faster into off-grid, because a) a fixed charge is a guaranteed “payment” from an off-grid business case perspective, and b) the associated lower energy charges make the on-grid PV business case worse
- The business case for embedded PV gets worse and therefore the power system as a whole cannot reap the full benefits of inexpensive energy from embedded PV

From a power-system perspective, it is therefore advisable not to introduce an additional fixed charge for embedded generators, but rather support electricity distributors centrally to cover their lost margins.

3.5 Size limitations for embedded generators

The current regulatory approach to embedded generators is to limit their size in such a way that the behind-the-meter generator does not produce more energy during a year than what the related electricity customer consumes.

Customers with embedded generators should be able to become net energy producers over an annual cycle, as well as net cash receivers. If that is not implemented and the size of the PV installation is limited to the onsite load / annual electricity bill, this will

- disincentivise energy efficiency, once the embedded generator is operational (because energy efficiency would reduce the electricity bill and thus the maximum achievable revenues from the embedded generator) and
- inevitably exclude all low-income households from participation in the scheme (because they do not have enough demand / sufficient electricity bill to justify a PV installation.

4 Proposed regulatory approach: Net Feed-in Tariff (NETFIT)

The CSIR has developed the concept for a regulatory framework that would promote embedded PV generators in South Africa, a Net Feed-in Tariff (NETFIT) concept. It builds on and takes the net metering concept further in several dimensions. The NETFIT concept makes the electricity distributors (municipalities and Eskom Distribution) financially indifferent to embedded PV, while establishing a business case for the PV owner that has the right risk/return profile to enable large-scale uptake of embedded PV at very low effective costs to the power system.

The details of the concept are as follows. It is proposed to create a "Central Power Purchasing Agency (CPPA)", a legal entity that is either state-owned or fully regulated, that is the nation-wide sole off-taker of all energy fed back into the grid from embedded PV generators.

The CPPA has two roles:

1) **Feed-in Tariff for <u>not</u> self-consumed energy (energy A):** CPPA buys the energy from embedded PV generators that is <u>not</u> self-consumed and thus fed back into the grid from the PV owner at a guaranteed tariff
2) **Financial compensation for self-consumed energy (energy B)**: CPPA compensates the electricity distributor (municipality or Eskom Distribution) financially for lost gross margins due to energy from embedded PV generators that is self-consumed on site and therefore reduces the sales of the distributor

The CPPA makes two standard offers: One to the electricity distributor, and once the distributor has subscribed to the standard offer by CPPA, then to PV owners in the distributor's supply area. It is within the electricity distributor's discretion whether or not to accept CPPA's standard offer. If a distributor does not subscribe to the CPPA offer, then CPPA will consequently not make any offer to PV owners in the respective distributor's supply area.

4.1 Funding requirements for CPPA

The CPPA will have a total funding requirement of approx. R 530 million per year for every 500 MWp of embedded PV that are built under the scheme. This is shown in the Figure 13 below, assuming preliminary assumptions on tariff levels and costs for illustration purposes. CPPA will have two sources of funding: 1) Onward sales of the PV energy that CPPA buys from the PV owners to the Eskom Wholesaler. 2) Residual funding to come from either tax money or from a mark-up on all kWh's sold in the electricity system (similar to the funding of large-scale Independent Power Producers).

The net funding requirements are estimated to be R 290 million per year for every 500 MWp of PV capacity installed under the scheme, which translates into an increase of the average tariff of approx. 0.15 R-ct/kWh (for every 500 MWp of PV under this regime). This value will very likely go down over time with reduced PV system costs and increasing fuel costs on the conventional fleet (and therefore increasing wholesale value of the PV energy bought by the CPPA from the PV owners). The net funding requirements can potentially even reach zero in the future.

It should be mentioned that any new power generator will inevitably increase the average tariff (because the current average tariff is below the cost of any new power generator). The question is therefore not whether the average tariff will increase with new generators, the question is by how much and how to keep the increase as low as possible. Embedded PV will have one of the smallest effects on the average tariff, being cost neutral to any alternative new-build option.

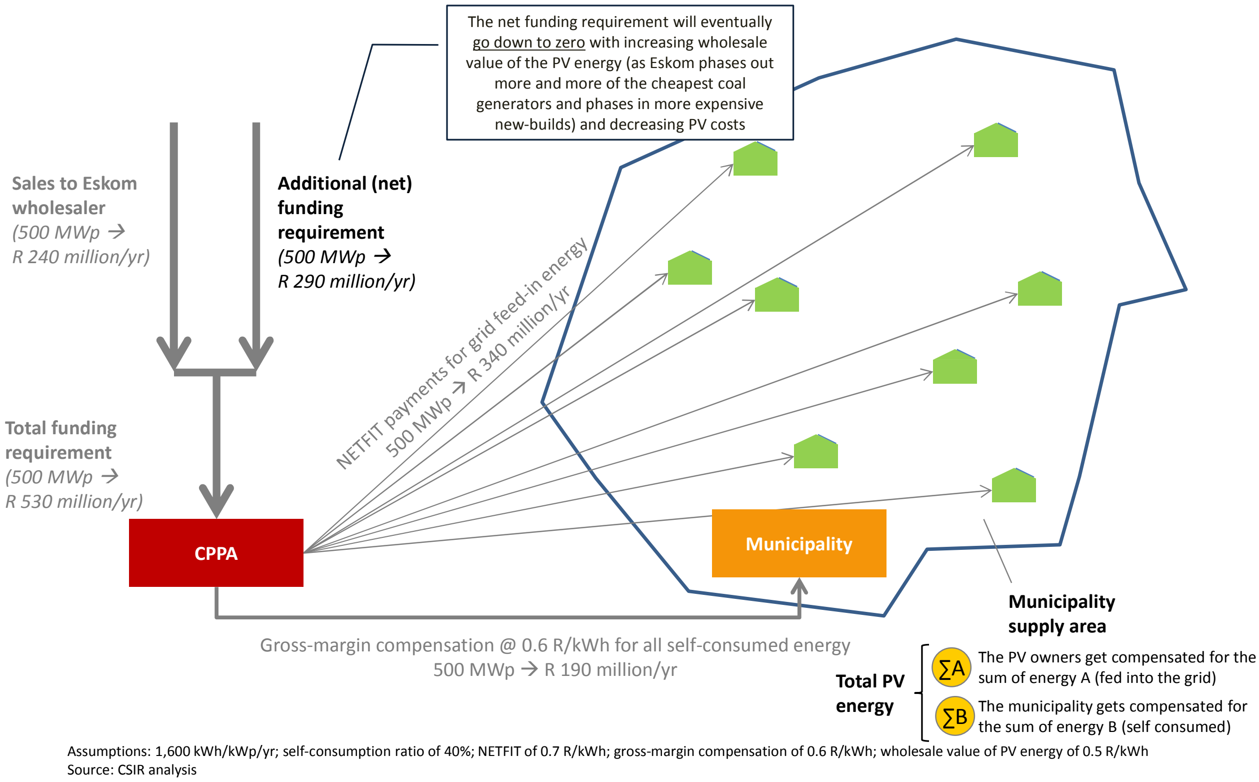


Figure 13: Monetary streams under the proposed NETFIT concept

4.2 Standard offer from CPPA to the electricity distributor

The CPPA makes a standard offer to all holders of an electricity distribution license (municipalities and Eskom) that will make the electricity distributor indifferent to embedded PV generators from a pure financial perspective.

Offer

- CPPA guarantees the distributor financial compensation for lost gross-margins due to energy from embedded PV generators that is self-consumed on the customer's site (behind the distributor's meter). The level of financial compensation in R/kWh will be determined in a transparent manner and will be the same for all distributors

- Meter reading
    - CPPA reads the feed-in meter and in addition reads the consumption meter on behalf of the electricity distributor OR
    - The electricity distributor reads the consumption meter and in addition reads the feed-in meter on behalf of CPPA

Terms and conditions

CPPA attaches Terms and Conditions to this offer, which will include:

- Requirement on the distributor to have safe practices in place for embedded generators
- Requirement on the distributor to not impose a different tariff / tariff structure to their customers whether they have a PV system or not
- Requirement on the distributor to ensure that the consumption meter is not counting (neither upwards nor downwards) in case of power flowing in reverse direction through the consumption meter (i.e. from the customer's premise to the grid) in case a second feed-in meter is installed OR
- The distributor has to install a new, bi-directional, two-register meter

4.3 Standard offer from CPPA to the PV owner

The CPPA makes a standard offer to all customers that are in supply areas of distributors that have signed up to the "standard offer from CPPA to the electricity distributor". This standard offer will provide very high investment security to the PV owner. The financial return for the PV owner will be relatively low if <u>all</u> PV energy is sold to CPPA (no self-consumption). The CPPA essentially provides the safety-net for the business case of the PV owner and makes it bankable.

Offer

- CPPA guarantees to off-take any percentage (between 0% to 100%) of the energy from the embedded PV generator that the PV owner decides to feed back into the grid
- CPPA guarantees the PV owner a predefined tariff at a predefined annual escalation rate for the energy that is fed back into the grid for a period of 20 years. This "Net Feed-in Tariff" will be substantially below today's residential end-customer electricity tariffs

Terms and conditions

CPPA attaches Terms and Conditions to this offer, which will include:

- Requirement on the PV owner to only use PV inverters that are compliant to the grid requirements (CPPA could publish a shortlist on its website of allowed PV inverters)

- Requirement on the PV owner to have a Certificate of Compliance by a certified electrician that certifies the correct installation and grid connection of the PV system according to all relevant norms and standards

4.4 Roles and responsibilities

The conceptual set up and the roles of the distributor, CPPA, PV owner and electricity customer with indicative values for energy consumption and production, self-consumption ratio, electricity tariff and NETFIT levels for illustration purposes only is shown in Figure 14 below. Metering would in most cases work through one bi-directional, two register meter.

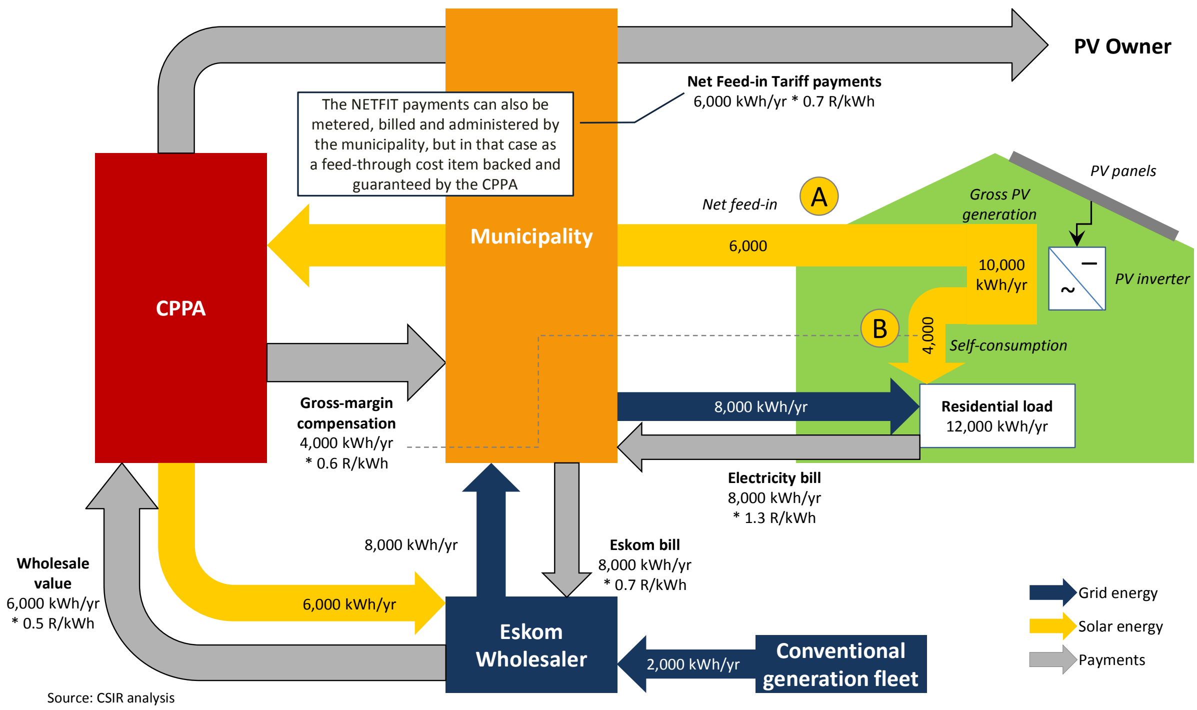


Figure 14: Mechanism of the proposed NETFIT concept

Key logic for the business case of the PV owner is that CPPA de-risks the revenue stream to the PV owner. Hypothetically the PV owner could build the PV system purely based on self-consumption or even direct sales to the Eskom Wholesaler. Both tariff levels however of these off-takers are uncertain over the lifetime of the PV system. The NETFIT is the stable, guaranteed tariff that it requires to bring cost of financing down for PV. CPPA essentially takes the risk and volatility of the wholesale tariff away from the PV owner and replaces it with a stable tariff, the NETFIT.

The roles and responsibilities of the different actors are described in the table below.

Actor	Role	Responsibility
Municipality or Eskom Distribution	Distribution grid operator & electricity distributor	• Physical delivery of electricity to match the residential load at all times • Billing & revenue collection from the electricity customer • Timely approval of grid connection of PV generators • Physical off-take of energy leaving customer's premise
Central Power Purchasing Agency (CPPA)	Buyer	• Buys all energy that flows through the NETFIT meter at a predefined tariff (the NETFIT) • Billing and payment to the PV owner (potentially administered as a feed-through cost item by the municipality) • Gross-margin compensation to the electricity distributor (municipality or Eskom Distribution) • Consolidate all registration data for embedded PV generators and give status reports to NERSA, Department of Energy, System Operator
Electricity customer	Consumer	• Pay the electricity distributor for electricity metered on the consumption meter • Pay the PV owner for "self-consumption" electricity flowing directly from the PV installations to the residential load (not applicable in case electricity customer and PV owner are the same entity)
PV owner	Generator	• Install the PV installation according to all relevant norms and regulations after formal approval by distributor • Pay for both PV installation, NETFIT meter (or bi-directional meter and/or replacement of consumption meter) and electrical reticulation up to the grid connection point • Register the PV installation with the CPPA • Supply the residential load with electricity from the PV installation and feed the residual into the distribution grid • Get compensated by the CPPA for energy fed into the grid via the NETFIT • Get compensated by the electricity customer for energy directly supplied to the residential load (not applicable in case electricity customer and PV owner are the same entity) – this might require another meter between PV installation and residential load, but is governed by a bi-lateral arrangement between two private parties (PV owner and electricity customer)

It is anticipated that the NETFIT will be substantially below the consumption tariff, therefore incentivising the electricity customer to maximise the self-consumption of the PV energy. In the shortr term, this will lead to shifting of non-essential loads (like pool pumps, geysers, etc.) away from traditional peak hours into daytime hours, when the PV system produces. In the medium term, investments into different load structures might be triggered through this differential in import and export tariff. For example, customers might consider investing into electrical space heating including thermal storage. They would charge the thermal storage during daytime, when the PV system produces, and discharge the thermal storage during evening and night hours. In the long term, electricity customers will likely consider electrical storage in form of batteries in order to maximise self-consumption of the PV energy.

All these anticipated effects of the price differential between import tariff (consumption – high) and export tariff (feed-in – lower) have immense benefits for the broader electricity system, as they help to “flatten” the residual load from electricity customers that have deployed PV systems.

4.5 Assumed effect on the average tariff

Assumptions (simplified, “worst case”)

- 230 TWh/yr total electricity sales in RSA
- 10 TWh/yr from embedded PV (approx. 6 GWp capacity), of which
- 40% (4 TWh/yr) supply self-consumption
- 60% (6 TWh/yr) are compensated via the NETFIT
- NETFIT @ 0.7 R/kWh
- Electricity tariff @ 1.3 R/kWh
- Marginal variable costs of the power system @ 0.3 R/kWh
  (i.e., how much money is saved from not burning conventional fuels thanks to one kWh from PV?)

Results: 6 GWp embedded PV less than 3 R-cents/kWh tariff increase

- The power system as a whole looses 40% * 10 TWh/yr * 1.3 R/kWh = R 5.2 billion in revenues per year due to self-consumed PV energy
- The power system compensates all PV owners with 60% * 10 TWh/yr * 0.7 R/kWh = R 4.2 billion per year for PV energy fed back into grid
- The power system saves 10 TWh/yr * 0.3 R/kWh = R 3 billion from not burning conventional fuel
- The total costs to the power system to have 6 GWp of embedded PV installed and compensated via the NETFIT scheme are therefore
  R 5.2 billion + R 4.2 billion – R 3 billion = R 6.4 billion
- Distributing these R 6.4 billion across all remaining kWh sales (230 TWh/yr – 40% * 10 TWh/yr = 226 TWh/yr) results in an increase of the average tariff of 2.8 R-cents/kWh

- Hence, installing 6 GWp of embedded PV increases the average tariff by less than 3 R-cents/kWh (or < 5% of today's average tariff), assuming a) no further cost reductions on the PV side, b) no increase in conventional fuel costs, c) no increase in electricity demand

This result is very conservative based on worst-case assumptions. With a gas fleet existing in the future, for which the fuel costs are significantly higher than for coal (R0.7-0.8 as compared to R0.3 per kWh), the tariff effect could even be negative, meaning that installing PV would save the power system money.

It should also be mentioned that PV is one of the cheapest options to add new energy to the power system. Any other new-build power generator would have at least the same effect on the average tariff, potentially higher. To supply the 10 TWh p.a. from alternative sources (gas, new coal) would cost at least the same amount of money and therefore would increase the average tariff at least by the amount as the embedded PV would. The tariff increase is therefore a logical mathematical consequence of adding new energy to an existing system based on largely written-off coal-fired power generators with access to very cheap coal field, and it is by no means an expression of a "subsidy" of any form. PV does not require a subsidy anymore, because it does not increase the average cost more than any other alternative new-build option.

4.6 Difference between net metering and proposed NETFIT

The differences between a net metering scheme and the proposed "NETFIT" are highlighted in Figure 15 below.

	Approach 1: Net Metering (potential "first step")	Approach 2: Net Feed-in Tariff with central off-taker (end state?)
Power Flows	Bi-directional: importing and exporting of energy allowed	Bi-directional: importing and exporting of energy allowed
Tariff Structure	Tariff for import and export can be different (e.g., export tariff lower than import tariff)	Tariff for import and export can be different (e.g., export tariff lower than import tariff)
PV Investment Security	Both import and export tariff uncertain over lifetime of the PV asset; fixed charge add. risk	Export tariff is **guaranteed** over the lifetime of the PV asset; no fixed charge introduced
Energy Balance	Must be a net energy consumer over an energy-balancing cycle (typically one year)	Net energy consumer or **producer** over an energy-balancing cycle (typically one year)
Financial Balance	Must be a net payer over a billing cycle (i.e. no cash payments back to the customer)	Can be **net receiver** of payments over a billing cycle (→ **PV as a micro-utility business**)
Off-taker	Local authority (i.e. municipality or Eskom Distribution)	**Nationwide central off-taker**
Funding	From municipalities' bottom line	Nationwide funding scheme **outside** of the municipalities' financial system

Proposal in this document

Source: M.P.E. GmbH proposal on net metering; Eskom Pricing proposal on net metering; NETFIT proposal by CSIR analysis

Figure 15: Difference between net metering and the proposed NETFIT concept

Both net metering and NETFIT attach a certain value to the excess PV energy (part "A" of the total PV energy production) and both allow self-consumption (part "B" of the total PV energy production). The fundamental differences between net metering and net feed-in tariff however are:

- In net metering, the level of the tariff for the excess energy fed back into the grid is not guaranteed over the lifetime of the PV asset (20-25 years). In the NETFIT concept it is
- Net metering limits the amount of excess energy fed back into the grid to the energy consumption on site (not instantaneously, but over an annual balancing cycle). NETFIT doesn't do that. No limits on the energy fed back into the grid
- Net metering limits the amount of money that can be accrued on the "excess/fed-in energy" account in a year to the value of the customer's annual electricity bill, because the financial compensation of excess energy works through a reduction/rebate of/on the electricity bill. NETFIT doesn't do that. The compensation of excess energy is completely separate from the electricity bill (real cash payments into the bank account of the PV Owner that are not related with the electricity bill). NETFIT in that sense separates generation from consumption

These three aspects might sound small, but they make all the difference for the PV investor. They will push the required effective tariff compensation for the PV investment up (in the net metering case), and therefore increase the total system cost of PV.

Limiting the maximum revenues of the PV business case to the electricity bill, one disincentivises energy efficiency. Any energy efficiency measure introduced after the installation of the PV system would reduce the revenues achievable by that PV system and therefore cannibalise the PV business case.

Limiting the amount of energy produced by the PV system to the amount of energy consumed on site has the following negative effects:

- The PV system size is determined by the load and not by the roof size and the grid-connection capacity. That artificially limits the PV system size without technical justification and therefore increases the specific system cost in R/kWp and therefore the LCOE in R/kWh
- Low-income households with low electricity consumption are per design excluded from participation in the scheme

The NETFIT concept enables the creation of "micro utility" businesses, because it allows selling all of the produced PV energy into the grid, if the PV owner decides to do so, and it allows producing more PV energy than actual energy consumption on site – i.e. the customer can become a net energy producer. This gives a business opportunity to everybody wherever there is an electricity grid.

From a municipality/Eskom perspective, the NETFIT scheme makes them profit-neutral and therefore financially indifferent to embedded PV generators, because the funding of the NETFIT concept does not come from their bottom-line. That is different in net metering.

4.7 Transition phase and immediate implementation

Net metering (which some municipalities have already introduced) should work as the immediate solution, relatively easy to implement, while in parallel the NETFIT concept should be prepared for implementation. Once NETFIT is available, all then existing net metering-based PV installations should then be migrated under the NETFIT concept.

4.8 Additional aspects of the NETFIT concept

As part of this concept, the level of the NETFIT can be adjusted periodically for new PV installations under the scheme to steer the size of the embedded PV market towards a set government target of new PV installations per year (i.e. adjust the NETFIT downwards for new installations if the embedded PV market is higher than the government target, or upwards if it is below).

The NETFIT concept can also be utilised to stimulate local manufacturing, by giving a NETFIT premium for PV installations that use locally assembled/manufactured modules and/or inverters.

4.9 Benefits of pro-actively stimulating the embedded PV market

There are a number of advantages of incentivising embedded PV in several dimensions. The list below highlights the most important ones and is not comprehensive.

1. Job creation and local content
    a. Tens of thousands of small PV installations per year will be supplied through wholesaler/installer channels, which is an ideal steady market for local manufacturers to supply and to give them security about their investment into manufacturing capacities
    b. Potential for rural enterprises to run a "micro-utility business" with small PV generators
    → wherever there is a grid, there is a PV business opportunity
    c. Huge potential for SMMEs in PV design, installation and verification for residential and commercial customers

2. Reduced grid losses and system costs
    a. Embedded PV is close to the load, i.e. grid losses are low (saves add. up to 5% of costs)
    b. Only little grid strengthening and no grid extension required (PV follows the grid)
    c. Aggregated supply profile of spatially distributed embedded PV generators is very smooth and highly predictable, which reduces costs on system operator side for balancing power and reserves

3. Funding is easier due to granularity (small project size, starting from R100,000 to a few millions)
    a. With a guaranteed NETFIT, rooftop PV installation would become bankable
    b. Banks could put the asset into the home loan for easy, standardised financing

    c. Installing several GW of capacity through the NETFIT scheme is like crowd-funding of power-generation assets
    d. That reduces the costs to the power system. Partially because of low financing costs, residential PV systems can be installed for R 0.8-0.9 per kWh lifetime costs today

4. Eskom's and municipalities' financial stability that is at risk due to "under the radar" embedded PV will remain unchanged under the NETFIT concept

5. A consolidated, nationwide approach to stimulate embedded PV will lead to an up-to-date nationwide registry of all embedded PV generators, which is essential for safe system and grid operations

5 Next steps

As next steps, the following sequencing is proposed:

1. Connection rules and wiring codes must be put in place as soon as possible
    a. NRS097 suite of documents that governs the relationship between the utility and the embedded generator need to be finalised
    b. The current draft of SANS 10142-3, which is the AC wiring code for embedded generators, needs to be finalised and a wiring code for the DC side of embedded PV generators needs to be drafted
    c. As an interim solution, an Implementation Guide for installers and municipalities needs to be finalised for immediate implementation
2. The proposed NETFIT concept needs to be tested along technical, regulatory, legal and tax implications and an implementation plan (timeline, stakeholder plan, budget requirements, etc.) needs to be developed. That development must start immediately in order to allow for an implementation in 1-1.5 years
3. Municipalities should put net metering in place for immediate implementation in order to avoid a large under-the-radar market. Fixed charges however should not be imposed on the PV owner
4. The Minister of Energy should make a determination which exempts all PV generators up to a certain size from the requirement to apply for a power generation license. Only a registration requirement should be imposed