Small scale on-grid PV embedded generation methodologies in South Africa

by Paul Tuson, Mott MacDonald

The IRP 2010-30 update [2] states that 9770 MW of solar photovoltaic (PV) capacity is planned to be installed in South Africa by 2030.

The update also estimates that embedded generation (EG) residential and commercial PV could reach 22,5 GW by 2030 based on living standards measure 7 (LSM 7) households and 5 kW PV household installations [2]. Even if this estimate is partially correct, this points to a significant level of installed small-scale solar PV embedded generation (SSPVEG) capacity in South Africa by 2030.

The AMEU guideline on embedded generation [3] states that the following PV market uptake is projected for Johannesburg over the next ten years:

- Approximately 45 000 PV systems in the residential market
- Approximately 4000 PV systems in the commercial market
- Approximately 670 PV systems in the industrial market

The AMEU guideline on EG [3] reports that Municipalities and Eskom are being inundated with applications from customers to allow them to install some kind of grid connected embedded generation [3].

This shows that interest in small scale solar PV EG (SSPVEG) is growing and that SSPVEG installations are currently occurring in South Africa, with or without a national SSPVEG framework.

There is an obvious attraction to on-grid residential solar PV installations as the cost of solar PV systems decrease [1, 2, 3, 7], the cost of utility electricity increases [2, 3], Eskom's reserve margin reduces [2], and environmental and sustainability awareness among electricity users increases [3]. EGs in the form of residential or commercial solar PV can also derive income when their generated electricity exceeds their load and they export their surplus electricity to the grid.

Besides the high SSPVEG projections and growing installations, there is a level of frustration in the renewable energy (RE) industry [3, 8] that not enough is being done to encourage SSPVEG in South Africa and that in fact there are real obstacles to the growth of the solar PV EG industry in South Africa. Some of these obstacles are perceived to be as follows:

- Decrease in municipality revenue base. Up to 70% of municipal income is derived from electricity sales in some cases [3, 7, 8].
- Reduced ability for municipalities to cross-subsidise other municipal services using electricity revenue [3].
- Risk of LV and MV system overloading from high simultaneous solar PV EG generation into the local grid at for example midday [3, 5].
- Safety of utility personnel [3, 5, 9].
- Lack of pre-approved, generic standards for the solar PV EG/utility interface [3, 5].
- Regulatory and legal obstacles [3].
- Quality of supply (QOS) impact of PV equipment [3].

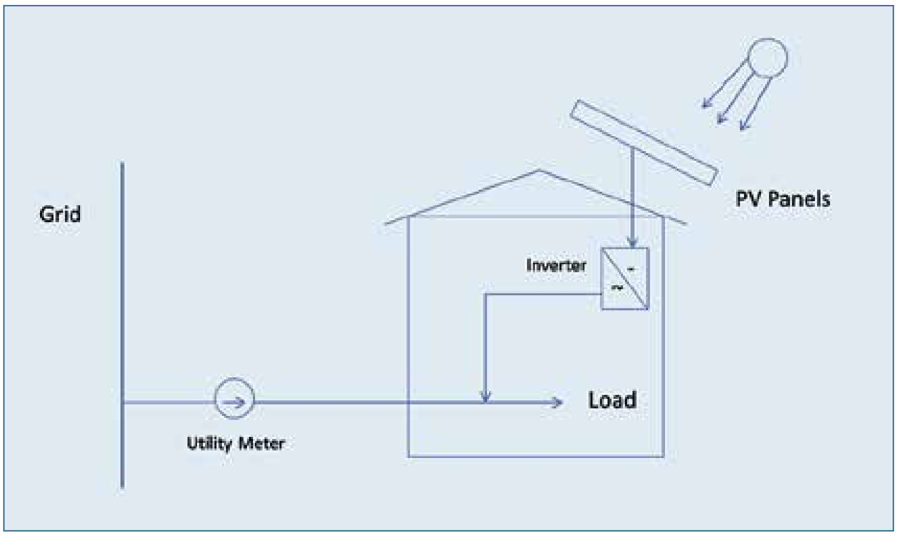

Fig. 1: Self-consumption solar PV EG.

This paper attempts to address decreased municipal revenues. It focuses predominantly on on-grid or parallel-connected SSPVEG (as opposed to off-grid and other RE technologies) at a residential and small commercial level and attempts to find pragmatic and sustainable solutions to SSPVEG roll-out in South Africa. SSPVEG with battery or other storage is not addressed in this paper.

The current situation

Several standards, grid codes, guidelines and acts are being developed or exist in South Africa, intended to regulate the planning and implementation of RE generation and SSPVEG in South Africa.

There is not enough space in this paper to discuss the main technical, legal and regulatory elements in all these documents, but certainly they have a major impact on the SSPVEG landscape in South Africa which will be referred to in the document.

The draft NRS097-2-1 standard proposes the following small-scale EG categories (in line with the renewable power plant grid code [13]:

Category A1: 0 to 13,8 kVA

Category A2: 13,8 to 100 kVA

Category A3: 100 kVA to 1 MVA

Most residential consumers are currently installing small-scale solar PV EG systems [4, 5, 9] in the A1 category and most commercial consumers are currently installing SSPVEG systems in the A2 and A3 categories even in the absence of finalised SSPVEG regulations and legislation being in place.

From a legal/regulatory perspective, any entity wanting to "sell" electricity to another entity requires a generation license from NERSA [22]. While generating licenses are not difficult to obtain if the explicit allocation for that energy is not detailed in the NIRP [1, 2], it is possible that NERSA may not identify a specific allocation to rooftop PV installations. This could be a potential blockage for approval of such a license for EGs. However, the Municipal Structures Act 1998, Section 84 (1) page 32 [23] states that "A district municipality has the following powers: Bulk supply of electricity which includes for the purposes of such supply, the transmission, distribution and, where applicable, the generation of electricity" [2, 3]. It could be argued that there are already precedents to municipal generation e.g. the purchase of Kelvin Power Station power by City Power in Johannesburg and the Renewable Energy Independent Power Producer (REIPP) programme [1] where electricity is purchased from IPPs and sold on to municipal customers.

From a technical point of view, prevailing residential and commercial meter technologies comprise the older electromechanical technology (rotating disc), newer digital meters and pre-paid meters. Bi-directional metering systems are not currently installed in normal residential and commercial points of supply (PoS) but are being investigated in the draft NRS097-2-1 standard [5].

Currently, most SSPVEGs or prosumers [7, 12] especially in the A1 and A2 categories are not compensated for surplus or export power to their connected utility [3, 8]. In addition, existing SSPVEG installations are taking place in the absence of a coherent regulatory and legal environment [3, 4].

In the following sections the author explores a number of SSPVEG methodologies and tariff mechanisms together with their advantages and disadvantages.

SSPVEG mechanisms

Solution 1 – Self-consumption

In the self-consumption mechanism, solar PV electricity is self-consumed during the day by the residential or commercial consumer as shown in Fig. 1.

The SSPVEG installation is conservatively sized to supply a portion of the prosumer load only and not with the intention to export electricity to the grid. Where SSPVEG generation does exceed prosumer load, the prosumer is not reimbursed and is content to supply the grid with electricity without being financially compensated.

NRS097-2-3 [6] recommends simplified connection rules as follows: "an individual [EG connection] limit of 25% of NMD will typically support a penetration level (percentage of customers that install a generator) of 30% to 50%, which is considered a reasonable and acceptable compromise between restricting individual generator sizes versus restricting penetration levels" [6]. "The NMD in many cases is determined by the LV service connection circuit-breaker rating" [6]. This approach simplifies the after diversity maximum demand (ADMD) system overloading risks mentioned in the introduction above, and allows more freedom for SSPVEGs to connect to the grid without lengthy system analysis and approval processes.

In the above arrangement, the prosumer notifies the municipality or connected utility that he has installed solar PV for self-consumption purposes. Notification procedures could align with certificate of compliance and application for inspection authority forms as included in SABS 0142 [18].

Solution 2 – Net metering

In the net metering arrangement, the prosumer both imports and exports electricity from and to the utility grid and expects to be compensated for net export electricity sold to the grid as shown in Fig. 2.

The municipal meter is upgraded to a bi-directional meter, and the net result of the monthly or other periodic electricity import or export usage is charged or compensated to the prosumer.

As in the self-consumption mechanism above, the kW size of the SSPVEG installation can be limited to 25% of the prosumer NMD or incoming circuit breaker rating [6].

In this arrangement, the prosumer applies to its connected utility for a bi-directional meter via the necessary application forms [18].

Solution 3 – Feed-in tariffs (FITs)

The FIT mechanism attempts to promote and incentivise the deployment of RE and places an obligation on specific entities e.g. municipalities or utilities to purchase the electricity output from qualifying RE generators at pre-determined premium prices [5]. In many countries, RE energy has to be dispatched first if it is available [12].

The consumption and generation of electricity by the prosumer is recorded in full and billed and compensated. The prosumer therefore requires two meters as shown in one possible meter arrangement in Fig. 3.

As in the self-consumption and net-metering mechanisms described above, the kW size of the SSPVEG installation can be limited to 25% of the prosumer NMD or incoming circuit breaker rating [6].

Similarly to the net-metering mechanism, the prosumer applies to its connected utility for bi-directional meters via the necessary application forms [18].

Financial considerations

As mentioned in the introduction to this paper, this paper attempts to address the perceived or real risk to municipal revenues from the implementation of SSPVEG [3]. It should be noted that for the first time in 2013 annual national electricity usage dropped and several metropolitan electricity departments reported drops in their electricity sales in the last four years as a result of reduced usage of electricity due to higher electricity costs and energy efficiency (EE) measures undertaken by consumers e.g. light emitting diode (LED) and compact fluorescent light (CFL) lighting, solar water heating (SWH) and heatpumps [3].

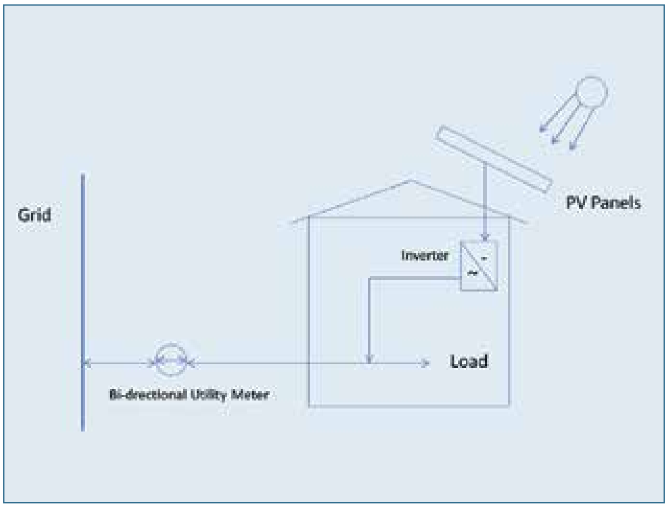

Fig. 2: Net metering with bi-directional meter.

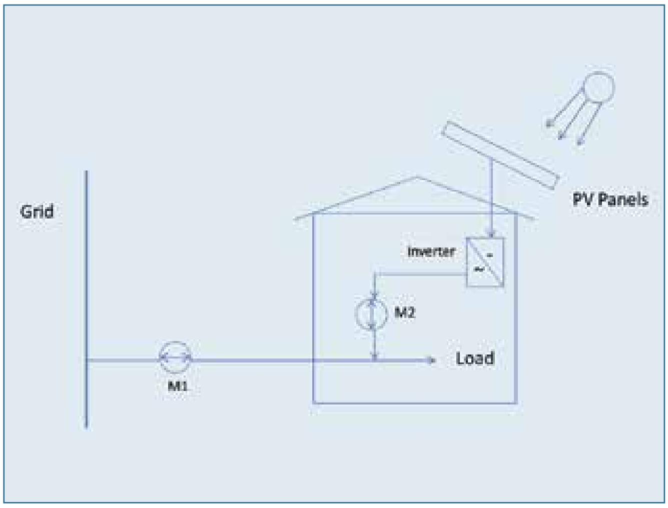

Fig. 3: Possible FIT metering with bi-directional meters.

Therefore, a reduction in municipal revenue is a reality that is occurring and needs to be accommodated and confronted with or without the introduction of SSPVEG.

In all three of the SSPVEG mechanisms described above, the question of loss of revenue exists. For every kWh not purchased from the municipality, the municipality revenue base is reduced.

Two-part tariff

One solution to this could be to introduce two-part municipal tariffs for SSPVEGs or prosumers i.e. a fixed network/service charge component and a variable kWh energy usage component. Where municipal or utility tariffs already include a service/network charge e.g. City Power's tariffs [10], this fixed service/network charge can be modified (where appropriate) when or if the prosumer:

- Notifies the utility of his intention to self-consume.
- Requests a bi-directional meter (net-metering mechanism).
- Requests two bi-directional meters (FIT mechanism).

The fixed service/network component of the two-part municipal tariff is not dependent on the level of kWh import or export and can be calculated based on a number of factors including:

- Estimated pro rata return on utility assets based on the prosumer NMD or circuit breaker size (or customer category).
- Estimated pro rata cost of utility network losses based on the prosumer NMD or circuit breaker size.
- Estimated pro rata operation and maintenance costs based on the prosumer NMD or circuit breaker size.
- Capital charge on new bi-directional meter/s.
- Connection charges.
- Sales and customer services (SACS) charges and administration charges.
- Subsidies for life-line or low income electricity consumers.

The above fixed service/network charge could also be viewed as a use of system (UoS) charge, i.e. a fixed charge to the prosumer for the privilege of being connected to the grid (as opposed to being an off-grid consumer) especially for the occasions when the sun does not shine and the prosumer requires to purchase power from the utility and for the occasions when the prosumer wants to utilise the grid to export and sell his surplus generated electricity.

The energy or kWh component of the two-part municipal tariff can be calculated as follows:

- To recover electricity energy purchases costs from Eskom (e.g. at the Megaflex tariff [21]) to supply electricity to the prosumer.
- To compensate the prosumer for energy purchases from the prosumer to sell onto or wheel [3] onto other grid connected consumers.

Therefore, even if the prosumer does not import any electricity from the municipality/utility in a month or a designated period, the municipality/utility still receives revenue to cover its fixed service/network charges as described above.

Advantages of the two-part tariff structure are as follows:

- The municipality is compensated for its fixed costs or UoS costs even if no electrical energy is imported from the municipality by the prosumer.
- The municipality is compensated for its fixed/UoS costs when the prosumer uses the municipal network to export electrical power to other users on the utility grid.
- The energy kWh usage is recovered as it is incurred. (The prosumer export kWh tariff can match the blended Megaflex tariff [21]. The prosumer import kWh tariff can possibly be reduced over time in a phased approach to match the blended Megaflex tariff).
- Non-prosumer consumers (consumers without SSPVEG) will not be affected and their billing mechanism can remain unchanged.
- The municipality is aware of the SSPVEG installation as the prosumer has to apply for a bi-directional meter system and a two part tariff or an updated two-part tariff.

Disadvantages of the two-part part tariff:

- The lower import or purchase kWh electricity charge (over time) may encourage inefficiency. However, it could be argued that LSM7 or higher level customers who have gone to the effort of being energy responsible by installing energy saving schemes are unlikely to be markedly less efficient as a result of lower kWh energy tariffs.
- Revenue shortfalls to the municipality remain in place.

Net feed in tariff (NFIT)

The "Net Feed-in Tariff" (NFIT) proposed by Dr. Tobias Bischof-Niemz [4], proposes a central power purchasing agency (CPPA) which would be the nation-wide sole off-taker for all surplus energy into the grid from EGs. The NFIT is proposed to function as follows:

- The EG or prosumer needs to install two bi-directional meters, similar to the FIT mechanism described above.
- When self-consuming electricity, the prosumer benefits by reducing his energy costs of approximately R1,2/kWh [4].
- The CPPA compensates the prosumer with a FIT on the net energy spilled into the grid (self-generation minus self-consumption) for twenty years at a predefined tariff path. A NFIT of R0,70/kWh paid to the embedded solar PV generator (calculated by Dr. Bischoff-Niemz but unverified by the author of this paper) was found to be sufficient to stimulate the embedded solar PV market. (Normal utility power purchase price is R1,2/kWh) [4].
- The CPPA compensates the municipality for lost revenues due to self-consumed solar PV energy and therefore makes the municipality profit-neutral to the embedded solar PV generator. This would also cover the municipal fixed costs. Revenue compensation from the CPPA to municipalities is calculated to be R0,6/kWh [4].
- The funding for the NFIT and revenue compensation to municipalities is proposed to come from a mark-up or premium charge of R0,002c/kWh on all nationwide energy (kWh) sales for customers larger than 200 kWh/month for the first 500 MW of PV [4]. For 6 GW of PV installation over a period of e.g. twelve years, the nationwide energy mark-up approaches R0,03c/kWh [4].
- Only registered NFIT Prosumers will be compensated for surplus energy to the utility involved [4].

The advantages from the NFIT approach could be as follows:

- Municipalities are compensated for fixed costs and their revenue surpluses due to the R0,60/kWh revenue compensation from the CPPA [4].
- SSPVEG generation close to the loads will reduce distribution and overall system losses in most cases especially with the 25% NMD SSPVEG limit as proposed in the NRS097-2-1 document [4, 6].
- SSPVEG generation close to the loads may reduce upstream transmission and distribution of non-evening congestion.
- The R1,20/kWh versus the R0,70/kWh import/export tariff differential will incentivise load-shifting and consumer efficiency behaviour [4].
- A centrally and municipally registered NFIT system will highlight distribution congestion issues in time and assist system planning and system reinforcement [4].
- Municipal and distribution grid operators will be fully aware of all embedded solar SSEGPV generators which increases maintenance safety [4].
- Certainty about market size (e.g. 500 MW/year) will give confidence to solar PV module/inverter and balance of plant market participants to set up manufacturing facilities in South Africa [4].
- The socialised "tax" on electrical energy users for solar PV generation, R0,002/kWh, is spread among the electricity users only, so the "user-pays" principle is upheld although non-prosumers or conventional consumers need to contribute [4].

- Better control over the speed and magnitude of SSPVEG development by adjusting the NFIT according to actual market development compared to government targets [4].
- Subsidies to life-line or low income electricity users are maintained.

Disadvantages of the NFIT approach could be as follows:

- An increased tariff for all customers of R0,002/kWh so non-SSPVEG prosumers or normal consumers need to contribute to the socialised "tax".
- Setting up of another government run structure or organisation i.e. the CPPA.
- Municipalities are subsidised by society for lost revenues or to maintain a revenue surplus.

Revenue shortfalls to municipalities from the two-part tariff

The NFIT [4] approach discussed above, attempts to address the threat of revenue losses to municipalities by introducing a CPPA which compensates municipalities when prosumers self-consume their own generated electricity.

This approach poses some questions as follows:

- Should municipal electricity revenue recover municipal UoS costs as well as subsidise other municipal service costs (e.g. roads and libraries)?
- How should the fixed network/service charge component of the two-part tariff be calculated to recover UoS costs and subsidies?

The AMEU embedded generation guideline report [3] shows a calculated 1,5 to 3,6% reduction in municipal revenues for customers over 600 kWh/month depending on a range of SSPVEG uptake periods and a range of assumptions e.g. assumed sales growth, no assumed sales growth, SSPVEG uptake, etc. [3].

If fixed charges are increased to the point of cancelling out the municipal revenue shortfalls, little or no incentive remains for prosumers to install SSPVEG other than for environmental or altruistic reasons?

The AMEU EG guideline [3] further mentions an estimated R5/kW/day/installed PV service charge for SSPVEG for the municipality to recover lost revenues. This equates to a SSPVEG service charge of R300/month for a 1 kW SSPVEG installation and R1500/month for a 5 kW installation.

If an example is taken of an 80 A City Power single phase "Three part flat tariff" customer who uses 1500 kWh/month, the following situation could arise:

- Service fee: R260,52/month
- Network charge: R109,43/month
- Cumulated energy charge (for the different thresholds): R1453,60/month
- Total electricity bill for the month: R1823,55

If the customer installs a 1 kW SSPVEG system, he would have to pay an additional SSPVEG service charge of R300/month, as mentioned above.

If for the particular month being analysed, the prosumer achieves 6 kWh/day (sun is not bright for eight hours), he would make a saving on his bill of R143/month. This is less than the R300/kWh service charge described above and would be even less if the municipal energy kWh energy tariff were to reduce as a result of increasing fixed network/service charges.

This simple example shows that the calculation of fixed service/network charges would need to be studied carefully in order to both protect municipal revenues and to provide incentives for SSPVEGs.

Alternatively, UoS costs only could be recovered from a reduced fixed network/service charge and other municipal services costs could be recovered via increasing the rates and taxes components of the prosumer's electricity, water and rates bill. There is a risk that low-income consumers will be negatively affected by increased rates and taxes, however this could possibly be resolved by differentiating rates and taxes tariffs based on various factors e.g. property size, NMD, geographical area, etc.

The advantages to the increased rates and taxes approach are as follows:

- Using electricity revenue to cross-subsidise other services is reduced.
- SSPVEGs financial benefits are not eroded by other-services subsidies.

The disadvantages of the increased rates and taxes approach are as follows:

- Rates and taxes tariffs for lower income citizens may increase unless differentiated rates and taxes tariffs are utilised.

Net-metering versus FIT

The net-metering mechanism may be simpler to implement as the installation of only one bi-directional meter is required, as opposed to two bi-directional meters in the FIT mechanism, however some prosumers may prefer to know in more detail exactly what magnitude of power was exported and imported and at what times. These factors will become more important as tariffs migrate to time of use (ToU) methodologies.

Due to negative experiences in countries where aggressive SSPVEG incentives or FITs are provided [12], this paper proposes that the energy kWh tariff rate compensation to prosumers when exporting power to the grid in either the net-metering or FIT mechanism is the same or similar to the blended Megaflex tariff that the municipality purchases electricity from Eskom.

Conclusions

In this paper, the observation is made that SSPVEG installations are being carried out in the absence of a finalised regulatory and legal framework, although standards are being finalised e.g. the small-scale EG NRS097-2 standards [5, 6].

It was also noted that besides the high level of existing and projected solar PV EG implementation, there is a degree of frustration in the RE industry that not enough is being done to encourage solar PV EG in South Africa and in fact that there are real obstacles to the growth of the SSPVEG industry in South Africa [3, 8]. One of the main obstacles is the revenue risk to municipalities resulting from reduced kWh sales as existing municipal tariffs are predominantly kWh based with relatively small fixed network/service charges [1, 3, 8].

The paper overviews the technical aspects of three on-grid SSPVEG interconnection mechanisms as follows:

- Self-consumption (no change in existing meter required)
- Net-metering (single bi-directional meter required)
- Feed-in tariffs (FITs) (two bi-directional meters required)

The net-metering mechanism may be simpler to implement as the installation of only one bi-directional meter is required, as opposed to two bi-directional meters in the FIT mechanism, however some prosumers may prefer to know in more detail exactly what magnitude of power is exported and imported and at what times. These factors may become more important as tariffs migrate to time of use (ToU) methodologies.

Two financial approaches to compensating both the prosumer and the municipality resulting from the installation of SSPVEG are discussed as follows:

- Two-part tariff
- Net feed-in tariff (NFIT) [4]

The two-part tariff comprises a fixed service/network (or UoS) charge component and a variable kWh energy usage component. The fixed or UoS component of the two-part municipal tariff is not dependent on the level of kWh import or export and can be calculated to cover fixed costs based on pro rata assets associated with the NMD of the particular prosumer or prosumer category. The energy or kWh component of the two-part municipal tariff can be calculated using a blended Megaflex energy tariff for surplus electricity sold to the municipality by the prosumer and in time (e.g. a five year window) the municipality purchase tariff can be reduced to match the blended Megaflex tariff.

The net feed-in tariff (NFIT) [4], proposes a central power purchasing agency (CPPA) which would be the nation-wide sole off-taker for all surplus energy into the grid from EGs [4]. In the NFIT approach, the CPPA compensates the prosumer at a NFIT of R0,70/kWh for surplus or export net electricity and compensates the municipality for lost revenues at a tariff of R0,6/kWh [4]. The funding for the NFIT and revenue compensation to municipalities is proposed to come from a mark-up or premium charge of R0,002c/kWh on all nationwide energy (kWh) sales for customers larger than 200 kWh/month for the first 500 MW of PV [4]. The NFIT does perpetuate the concept that municipalities should be allowed to derive revenues from electricity sales in excess of their energy purchase costs and UoS costs.

The paper explores whether municipal electricity tariffs should be maintained which recover both UoS costs and energy kWh costs and cross-subsidies to other services. It also discusses how the two-part tariff can be implemented to assist municipalities to recover at least their UoS costs. However, if fixed service/network charges are increased to the point of cancelling out the municipal revenue shortfalls, little or no incentive may remain for prosumers to install SSPVEG, other than for environmental, self-sufficiency or altruistic reasons [3]. Adjustment of fixed service/network charges would need to be studied carefully in order to both cover municipal UoS costs and life-line customer subsidies and to provide financial incentives to SSPVEGs.

Foregone municipal cross-subsidy services contributions from electricity revenues could be partly or wholly recovered via increasing the “rates and taxes” components of residential and commercial bills, however there is the social risk that low-income consumers would then be penalised with higher rates and taxes tariffs as a result. This risk could possibly be mitigated by differentiating rates and taxes tariffs based on a range of criteria including size of property, customer electrical NMD, residential area, etc.

The reality is that electricity revenues are dropping for municipalities due to EE interventions, increased electricity prices and other drivers [3]. In addition, EG fundamentally changes the traditional Eskom-to-municipality-to-customer electrical supply industry (ESI) model which has been in place for decades and new ideas and new creative solutions regarding municipal revenue recovery are required.

Recommendations

The author of this paper proposes that all three SSPVEG mechanisms (self-consumption, net-metering and FIT) are adopted in South Africa and that a phased approach may be less threatening to all stakeholders involved.

Self-consumption should be allowed to proceed immediately but prosumers should be notified that existing installations should comply with NRS097 standards and that applications and approvals to generate in parallel with the grid need to be made to the municipality or the utility. Approved self-consumption prosumers will need to migrate to an upgraded two-part tariff.

Net-metering should be allowed to proceed following the promulgation of the NRS097-2 standards and other relevant standards. Prosumers applying for net-metering will transfer to a two-part tariff and will apply for the installation of a bi-directional meter at the same time.

The FIT mechanism can follow the other two mechanisms after industry experience is gained in the SSPVEG market and when metering and billing systems are sophisticated enough to take into consideration ToU and other tariff complexities.

Municipalities should possibly explore other mechanisms of funding non-electricity services rather than using electricity revenues. One suggestion is to increase residential and commercial rates and taxes. The risk to low-income consumers can be mitigated by introducing differentiated tariffs based on various factors e.g. size of property, customer electrical NMD, residential area, etc.

The NFIT approach [4] attempts to find an equitable approach to compensating SSPVREs for electricity sold and municipalities for lost revenues. If the two-part tariff approach is found to have other challenges not identified in this paper, the NFIT approach as presented, or an NFIT approach that phases out municipal cross-subsidies should possibly be investigated further.

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