A mini-integrated resource plan for a commercial entity in Gauteng Province: planning for energy autonomous businesses

Mamahloko Senatla, Crescent Mushwana

Abstract— Distributed renewable energy competitiveness is becoming a reality in most countries resulting in an increase of installed capacity in both developed and developing countries. Mexico, India, Germany, Zambia and South Africa have experienced the lowest average tariffs for solar photovoltaic (PV) through their competitive bidding processes between 2015 and 2017. In South Africa, the latest competitive bid resulted in PV costing an average of R0.62/kWh, while the average grid electricity tariff is R0.83/kWh. It is anticipated that the cost of PV will continue to decline while grid connected electricity tariffs will continue to increase. The continued increase of electricity tariffs combined with declining cost of solar PV, means that PV will become even more competitive for commercial entities whose periods of maximum power demand coincides with periods of abundant solar resource in most regions.
This means that campuses or buildings of most entities can be energy autonomous and can supply their electricity demand using PV at least cost. This paper conducts a mini-integrated resource plan using PLEXOS modelling tool for a commercial entity located in Gauteng with a peak capacity of 6MW. The results show that investing in optimal PV capacity by 2030 reduces the network costs by 11%. The entity can also meet 44% of its energy demand with PV which reduces the energy bill by 14% in 2030.

***Index Terms*—commercial sector, PV, cost, embedded PV, integrated resource plan, energy autonomous, distributed renewable energy.**

1 INTRODUCTION

Utilities all over the world are pressurised to reduce carbon emissions and recent increases in new installed capacity of renewable energy resources show that some countries are indeed committed to the transition. In 2016, Figure 1 shows that China, USA and Germany were the three leading countries in terms of size of installed capacity of wind and PV globally [1], [2],[3],[4]. Recently the price of PV has been decreasing at a high rate resulting in countries such as Mexico, India, Germany, Zambia and South Africa experiencing the lowest average tariffs for PV through their competitive bidding processes between 2015 and 2017 [3], [4], [5],[6].

Given the intermittency and variability of wind and PV and the high costs of electricity storage (i.e. batteries), it is logical to assume that the value of electricity produced from wind and PV is highly dependent on it being used as it is produced [5].

PV produces electricity during the day which coincides with period of maximum demand for most commercial demand profiles. This coincidence means that there is more value for PV in the commercial sector as PV generation can reduce peak demand for customers while also reducing the electricity bill. Given the fact that South Africa is endowed with massive solar potential as has been shown in [6], [7] and [8], the commercial sector can benefit from solar electricity more than any other sector because their business is mainly running between 6 a.m. and 6 p.m.

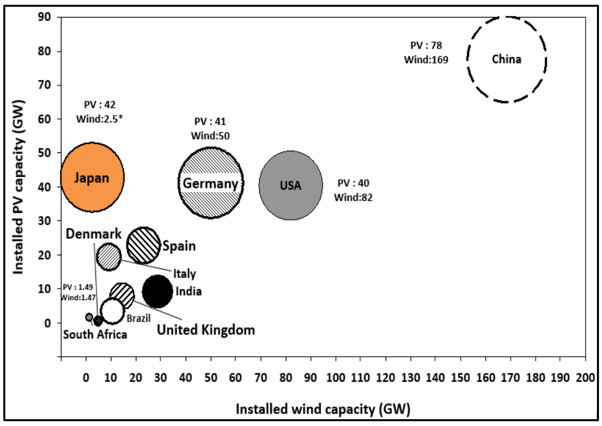

Figure 1: Installed PV and wind in some countries
Based on data from[1],[2], [7], [8], [9]

Given the recent evidence of reduction in PV cost and the high rate of tariff increases demonstrated in Fig. 3 of Section 2, the payback period on PV investments will be very short. This payback period is shortened even more for a commercial entity because investing in solar means reducing the peak demand, reducing the bill from the municipality and being environmentally friendly. The latest Renewable Energy Independent Power Producers Procurement Programme (REIPPPP), called Bid Window 4 expedited, the average cost of PV was R0.62/kWh (in 2016 Rand value) while the average tariff for a typical commercial entity was R0.98/kWh. The average cost of utility scale PV became low because most of the investments are in regions with highest solar resources such as the Upington in Northern Cape.

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In regions with low solar resource, the cost of electricity produced from PV will be higher than for high resource regions. Thus far as a relatively low resource region, Gauteng has no REIPPP PV plant commissioned but there has been significant investment in Embedded PV generation [9]. 38% of all installed embedded PV generation in the country is in Gauteng [9]. The Council for Scientific and Industrial Research (CSIR) installed the latest PV with the levelised cost of generating the electricity at R0.82/kWh which is already lower than the average standard tariff (day tariff when solar is producing electricity) of R0.84/kWh from the municipality [10]. This demonstrates that PV is economic in most regions in South Africa.

Given the increasing installations of PV systems around the country, it is clear that some commercial businesses are seeking to be energy autonomous. This proves the assertions made by Massachusetts Institute of Technology (MIT) in 2011 [11] that the trend of distributed renewable energy resources is unavoidable. As can be seen in Section 2, the increase is bottom-up as generation assets are now bought by consumers. The National Energy Regulator of South Africa is developing standards and policies that will guide these installations working together with municipalities and South African Local Government Association (SALGA). This change, where consumers become producers requires planning for optimal capacity at entity/business level. A consumer that decides to put a solar system in their grid needs to understand the economics of the asset they are investing in. At national or state level, the integrated resource plan (IRP) is usually used to determine optimal capacity of electricity generating assets for the national energy system [12], [13], [14] and it is not common to conduct an IRP for a business/consumer.

This paper conducts an IRP at a small scale for a typical commercial entity with a peak demand of 6 GW which is based in Gauteng and assesses the financial implications of owning generation assets versus buying electricity from the municipality. This mini-integrated resource planning for a commercial entity determines the optimal capacity using resources such as waste and PV which are deemed reasonably cheap to tap into by the entity. The PLEXOS modelling tool is used for the assessment. After the determination of needed capacity, the paper further assesses how the capacity should be economically dispatched using unit commitment modelling functionality of PLEXOS.

Section 2 presents an overview of electricity consumption and generation in South Africa's commercial sector, giving a brief overview of the state of embedded PV. The section also reviews historical the time of use tariff applied to the entity. Section 3 presents the methodology used in the analysis. Section 4 presents results which are further discussed in Section 5 and the concluding remarks are in Section 6.

2. State of electricity usage and generation in the commercial sector of South Africa

The commercial sector consumes 12.6% of electricity in the economy [15]. This means that the commercial sector consumed about 28.5 TWh in 2016. Although there are different types of commercial entities, for most of the commercial entities (offices, retail shops and research institutions), the maximum demand occurs during the day since their operating time is fixed between 6:00 a.m. and 6:00 p.m. [16]. A typical annual profile presented in weekly load profile for a commercial entity is presented in Fig. 2.

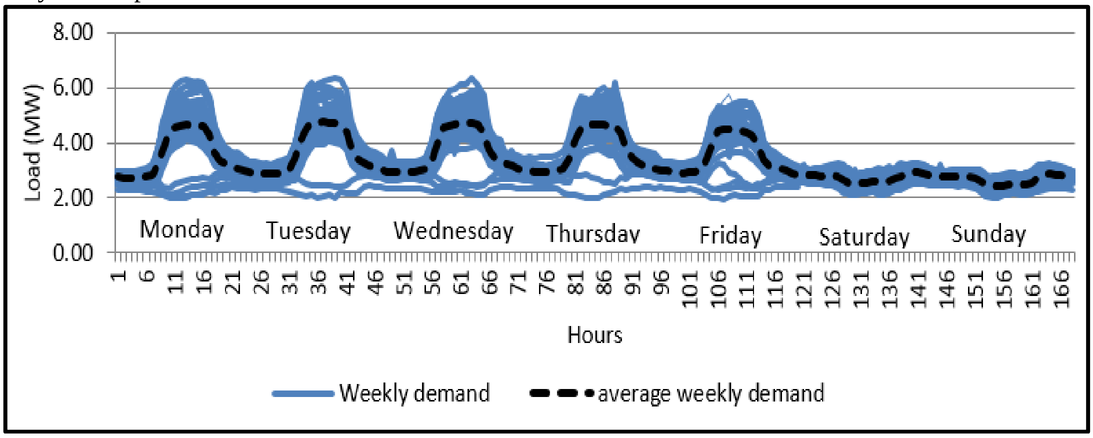

Figure 2: Weekly load profile of the commercial entity under consideration [10]

From the load profile in Fig. 2, it is clear that the peak demand occurs during the day and this coincides with periods of high electricity generation from PV systems as shown in Fig. 3.

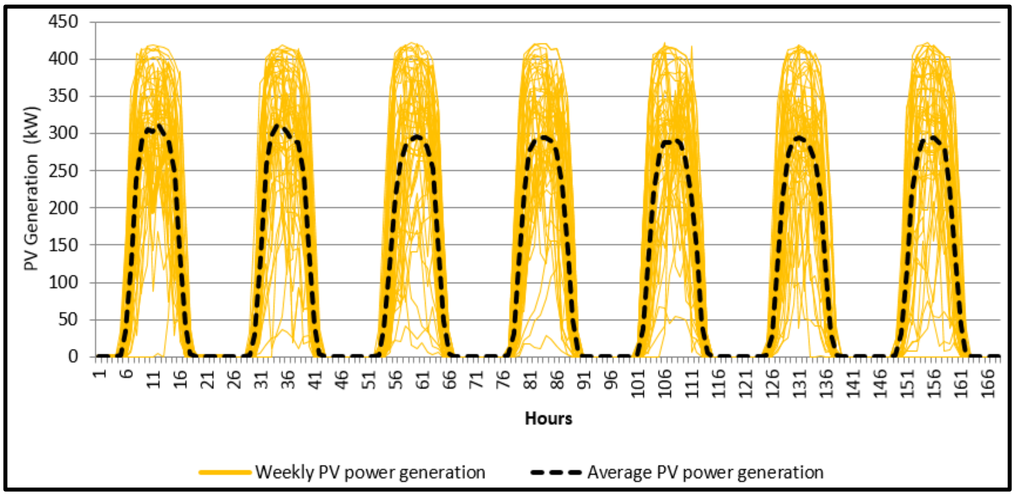

Figure 3: PV generation profile

Most businesses in South Africa are on time of use tariff which comes at different times during the day for low (September – May) and high (June – August) demand seasons. The periods and types of tariffs for low and high demand seasons are shown in Fig. 4. Since 2011, the standard tariff has been increasing faster than the tariff in peak and off-peak periods. Fig 5 shows that the average increase was as high as 34% in winter months while off-peak and peak periods are increasing at lower rates of 15% and 10% respectively during the same period. Given the load profile for commercial entities, this basically means that electricity will be more and more expensive for commercial entities.

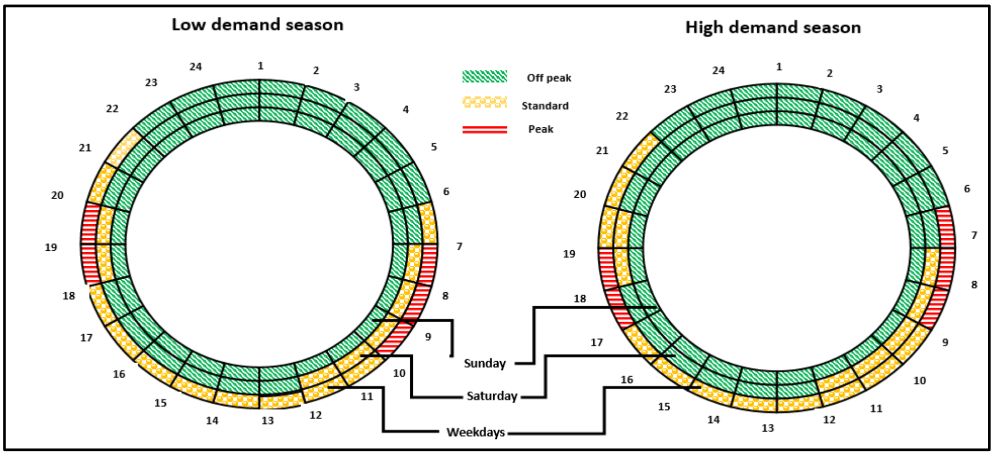

Figure 4: Hours for Megaflex (time of use) tariff for low and high demand seasons [11]

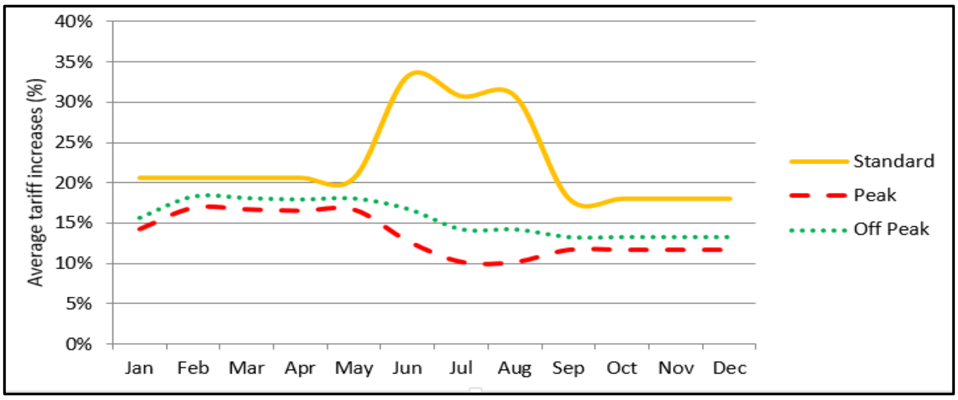

Figure 5: Average tariff increase

Over the period (2011 – 2016), the standard tariff increased by an average of 22% per annum. This increase together with reduction in cost of PV panels has resulted in increased installation of embedded generation. As of December 2016, the database collected by [12] at CSIR's Energy Centre showed that there is an installed embedded

PV capacity of 62.32 MW as shown in Table I. Gauteng and Western Cape are having the highest number of installations resulting in 38% and 28% of installed capacity in South Africa residing in these two provinces respectively. As can be seen in Table I, more than 50% of installed capacity is in the commercial sector with the exception of Limpopo, Mpumalanga and Kwazulu Natal. In Mpumalanga and Kwazulu Natal, most installations are in industrial sector while Limpopo has most installation in industry and in agriculture. The monitoring of these installation is on-going and given the low cost of PV panels, the installation rate might increase in the near future.

Table I: Embedded PV systems in South Africa classified by province and sector

Province	Number of Installations	Installed capacity (kW)	Commercial Capacity (kW)	Share of capacity by Province (%)	Share of capacity installed in commercial sector (%)
Gauteng	358	23840	20002	38%	84%
Western Cape	325	17420	11194	28%	64%
Eastern Cape	58	1320	952	2%	72%
Kwazulu Natal	67	3790	1655	6%	44%
Mpumalanga	20	2230	1037	4%	47%
Free State	15	2170	2103	3%	97%
North West	20	5050	4470	8%	89%
Northern Cape	24	2790	2485	4%	89%
Limpopo	12	3.71	1268	6%	34%
Total	899	62320	45170	100%	72%

The data is taken from [12]

3 METHODOLOGY

The emerging power system is shown in Fig 6 [19] where distributed generation will play a big role in balancing customer demands. This means that consumers are now becoming producers and consumers of electricity, which is termed prosumers [20]. As producers of electricity, there is a need to conduct planning that determines optimal capacity penetration in consumer grids. To conduct the planning, the concept of integrated resouce planning is used in this work.

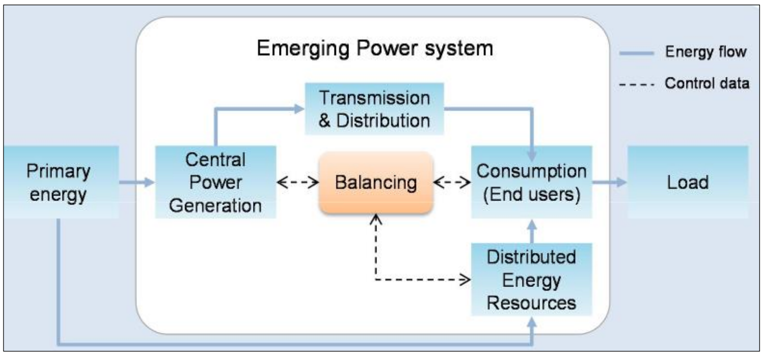

Figure 6: Emerging way of balancing power generation and consumption

Taken from [13]

The mini - IRP modelling is done using PLEXOS software package. PLEXOS is a power systems modelling tool used for electricity market modelling and planning [21]. PLEXOS applies mixed integer linear programming (MILP) to solve the unit commitment and economic dispatch problem (unit commitment and economic dispatch are solved simultaneously) [14]. The schematic diagram that shows inputs and expected outputs of this work are shown in Fig. 7. PLEXOS solved the demand/supply balance using unit commitment modelling.

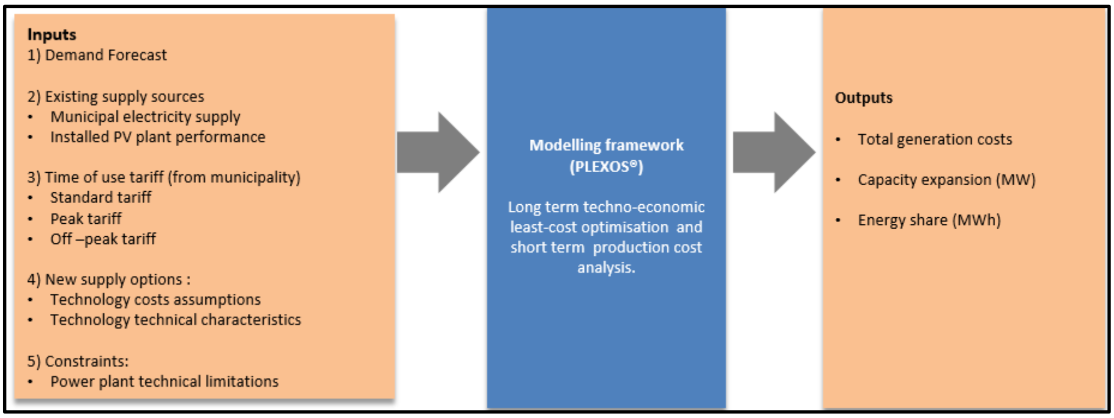

Figure 7: Schematic modelling diagram
Adapted from [14]

To conduct the mini-IRP, inputs used are demand forecast, electricity supply from the municipality and from own generation, the tariff for electricity from the municipality. Demand is assumed to grow at an annual rate of 1.5% such that by 2030, the demand is 37.41 GWh, increasing from 29.10 GWh in 2010. The municipality charges the commercial entity the network charge and energy charges. The peak demand in each month is used to charge for network charges. The energy charge contains the time of tariff structure as shown in Fig. 4 and the typical tariff charges in a week from the municipality are shown in Fig. 8 and Fig. 9 for summer and winter. It is only during weekdays when we have peak tariff. Saturday has both standard and off peak periods while Sunday has off peak tariffs only.

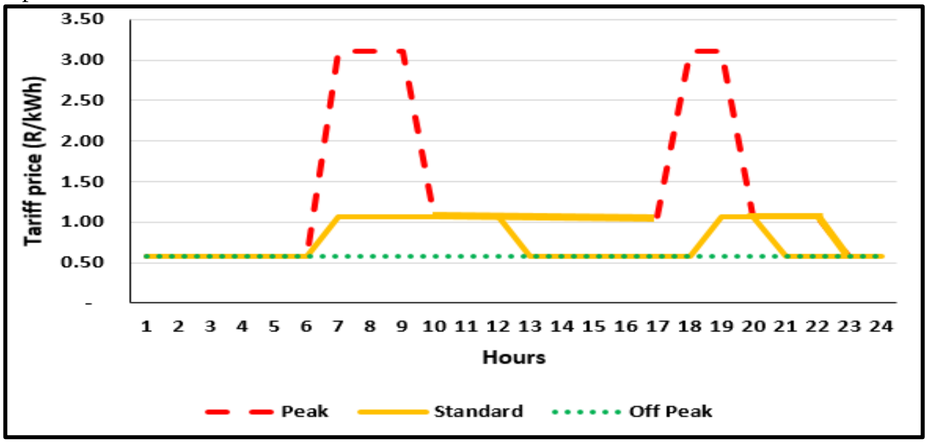

Figure 8: Typical time of use tariff for winter

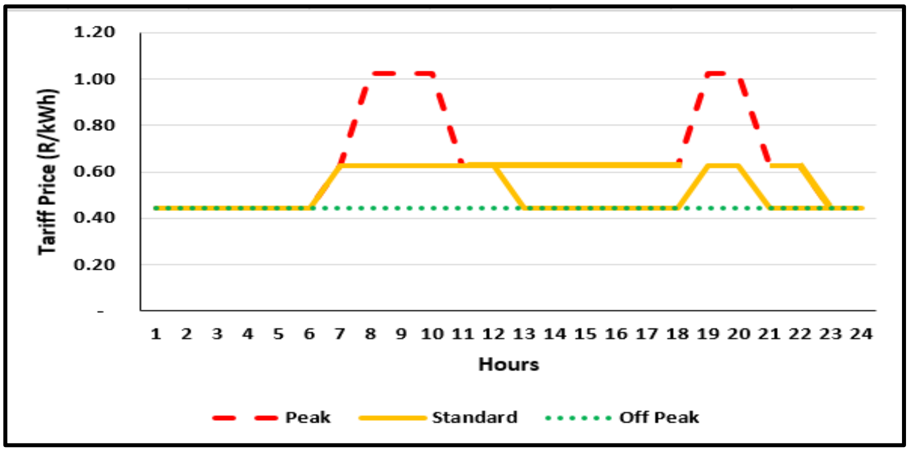

Figure 9: Typical time of use tariff for summer

Total electricity bill for the entity is the sum of consumed electricity and sum of demand charges for the 12 months of the year. The municipality bill is calculated using (1).

$$Munic\_bill = \sum_{t=1}^{8760}(elec_t)(ene\_char) + \sum_{m=1}^{12}(p_m)(dem\_char) \quad (1)$$

where $elec_t$ is the amount of electricity consumed every hour (t) of the year and p_m is the monthly peak demand. Ene_char is the energy charge while dem_char is the demand or network charge. Network charge is the money paid for utilising the network and the unit of measurement is the peak demand (in MW) in a month. If a business operates below its negotiated peak demand, this charge is constant throughout the year. If the negotiated peak demand is exceeded, the business is charged a penalty for exceeding the negotiated maximum demand.

According to the bill data that was analysed, the network charge decreased by 5% in real terms between 2006 and 2016. Although there was a decrease of network charge, therefore this work assumes 10% increase over the entire modelling period. This translates to 0.7% annual increase such that in 2020, the network charge will be R106 and R114 /MW in 2030, increasing from R93 in 2016. The energy charge which is the time of use tariff (TOU) is assumed to grow at the rate of 9.98% annually excluding inflation. Within the modelling framework, the municipality supply is treated as an unlimited power plant. The munic_bill (Rands) is used as a variable operating and maintenance costs for municipal supply.

The new options analysed are presented in Table II. The levelised cost (LCOE) for biogas, PV and battery are R1.50/kWh, R0.87/ kWh and R3.56/kWh respectively. The average tariffs in 2016, 2020 and 2030 are R0.98/kWh, 1.092 and R2.80/kWh respectively.

Table II: New supply options analysed in this work

Plants	Resource	Overnight cost (R/kW)	Fixed operating cost (FO&M) (R/kW)	Variable costs (VO&M) (R/MWh)	Cap on installable capacity (MW)
PV	Solar	20282	0	0	Unlimited
Biogas	Waste	85000	1941[2]	1320[3]	2
Battery	Battery	24301[1]	618	0	Unlimited

4 RESULTS

In 2016, there was an installed PV capacity of 560 kWp for this entity. According to the modelling conducted, an additional PV capacity of 4.5 MW is needed by 2020, making the cumulative installed capacity of 5 MW (see Table III). As the tariff and demand increase, it is optimal to install an additional capacity of 6 MW by 2030, bringing the total cumulative installed capacity to 11 MW. In addition to the PV, by 2030, 2 MW capacity of biogas is installed, which is mainly used during peak tariff periods to reduce demand during that time. The total energy produced by PV increases from 1.04 GWh in 2016 to 16.64 GWh in 2030. By installing 11 MW of PV and 2 MW of biogas, the entity will meet 49% of its demand with their own generation in 2030. The excess energy of 0.37 GWh and 0.94 GWh is produced by PV systems in 2020 and 2030 respectively. By introducing PV, the entity reduces both network demand charges (charged on the peak demand) and energy cost (related to the amount of energy consumed).

Table III: Installed capacity and associated energy produced in 2016, 2020 and 2030.

	Installed capacity (MW)			Energy Produced (GWh)			Energy Share (%)		
Power Plant	2016	2020	2030	2016	2020	2030	2016	2020	2030
Biogas	-	-	2.00	-	-	1.75	0%	0%	5%
PV	0.55	5.00	11.00	1.04	9.42	16.64	4%	40%	44%
Municipality	6.10	4.05	5.40	29.36	21.78	19.01	96%	60%	51%
Total	6.65	8.05	18.40	30.40	31.20	37.40	100%	100%	100%

Table IV shows that the entity's energy bill is reduced by R305 060 in 2016 with just 500 kW and the reduction mainly comes from peak demand charges. The peak demand charge reduced from R6.82 million to R6.41 million.

[2] Cost for Biogas are taken from CSIR Submission to the IRP [6] and the capital is increased by 10% because smaller systems cost higher than the small systems.

[3] Assumed cost to transport cost to the side

Table IV: Total energy cost of the entity in 2016, 2020, and 2030 (R Million)

	Total generation costs			Total Network charges			Total bill to the company			Total bill without embedded generation		
Power Plant	**2016**	**2020**	**2030**	**2016**	**2020**	**2030**	**2016**	**2020**	**2030**	**2016**	**2020**	**2030**
Biogas	-	-	2.63				-	-	2.63			
PV	0.90	7.94	13.87				0.90	7.94	13.87			
Municipality	21.08	38.95	77.15	6.41	3.63	7.76	27.49	42.58	84.91	28.69	56.42	114.82
Total	21.97	46.89	93.65	6.41	3.63	7.76	28.38	50.52	101.41	28.69	56.42	114.82

The energy cost increased slightly by 0.5% because the cost of generating power with PV was R0.87/kWh while the average standard tariff from the municipality was R0.76/kWh. In 2020 and 2030, the energy bill is reduced by 12% and 14% respectively.

5 DISCUSSION

The assumption in this analysis is that, the structure of time of use tariff does not change. This means that the standard peak will be during the day and peak times are in the evening and off-peak periods are at night. The reduction is energy bill is relevant if the structure of the tariff stay the same in 2020 and 2030.

If the bottom-up uptake of PV increases, it is highly likely that the tariff structure will change. Without changing the structure, municipalities will incur massive revenue losses. This work excludes the scenarios of changes in tariff structure. Even without the impact on electricity sales from the municipality, there is a need to refurbish the existing distribution networks so that they can handle the massive installations of embedded generation. This refurbishment will come at a cost which will influence tariffs also.

In 2012, research in [15], highlighted that there was maintenance backlog on the distribution systems in the country. In [16], it was estimated that the maintenance backlog was around R35 billion in 2012. It was assumed this cost might be growing at R2.5 billion per annum and that implies that the backlog might be standing at R48 billion in 2016. Given that in 2014, National Energy Regulator of South Africa (NERSA) found that only 35% of municipal distributors had acceptable network condition [17], the cost of this backlog is still rising.

With introduction of renewables, there is a need to change existing networks to smarter grids with enhance visibility and controllability. It is clear that preparing the existing networks for renewable energy transition, a hefty cost will have to be paid and it can only be paid sustainably through tariffs.

Therefore when looking at decentralized energy generation, it is of paramount importance to consider this impending changes that will occur on the tariff structure. The results in this work assume there are no major changes on tariff structure. Given the above accounts of distribution network maintenance backlog and the need to make distribution networks smarter, the tariff of the future will change significantly and an analysis for optimal system will be required once the changes occurs. As long as the time of use tariff does not change, it is optimal to install PV to reduce demand of companies from municipality and Eskom.

6 CONCLUSION

In the beginning (in the next 2 – 5 years), i.e. 2018 to 2022, the PV systems mainly reduce peak demand charges but as tariff from the municipality keeps increasing, PV starts to reduce the cost of energy consumed as well. If installations of embedded PV systems increase and almost 100% of the commercial sector peak demand met by renewables mainly solar, there will be some implications on the national load. This impact may lead to changes in the tariff structure and on the way the integrated resource plan is done. This will mean that energy resource planning will occur at company or community level, hence introducing a new way of planning for energy in future energy systems. The next step of this research is to assess the impact of increased penetration of PV in commercial sector can have on national load and quantify what it means for the electricity tariff system in the country. For the particular entity under study, it will also be interesting to investigate what optimal placement of distributed energy resources are.

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