Carbon neutral built environment by 2050: what does this mean for municipal electricity distributors?

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Introduction

Around the world, countries are taking bold action to respond to the climate crisis, and South Africa – being the world's 14th largest emitter of greenhouse gases – is following suit. Buildings generate nearly 40% of annual global emissions and are an important site of emissions reduction. Four of our metros have committed to carbon neutral new buildings from 2030, and city-wide carbon neutrality by 2050. Ultra-energy efficiency with residual energy requirements met with renewable energy will become the 'new normal'.

This paper uses the City of Cape Town to investigate what a net zero carbon new buildings policy means for electricity distributors and the existing business models. The reduction in building energy demand from *new* buildings off a Business-as-Usual growth trajectory is quantified by forecasting floor area growth and regulated energy intensities per building type. Renewable energy (SSEG) growth to meet residual demand is forecasted, and the associated reduction in municipal energy demand is quantified. The additional demand for off-site renewable energy is also explored, and mechanisms to offer these services are proposed.

Understanding the implications – challenges and opportunities – of these changes is important for municipal distributors to manage this well and contribute to the energy transition. The paper concludes by suggesting steps to be taken towards managing the carbon neutral ambition, including the necessity of ensuring that City policy remains flexible enough to ensure optimal investments are made and that building related electrical infrastructure can accommodate yet unknown demand changes arising from technology innovation, such as electric vehicle charging.

Role of the built environment in municipal energy consumption and emission reduction policy commitments

The City of Cape Town has a 20-year history of climate change response through strategy, policy and project implementation. In 2017, the City of Cape Town, along with other major South African cities, ramped its ambition to accelerated climate change action by committing to carbon neutrality by 2050[1].

[1] C40 Cities (2021). *Deadline 2020 – How cities will meet the Paris Agreement*. Available at: https://www.c40.org/other/deadline_2020

Compared to other the sectors, buildings have the largest unrealised potential for cost-effective energy and emissions. According to the City of Cape Town Greenhouse Gas Inventory 2018, residential and commercial built environments account for approximately 25% of energy consumption in the city. Due to the high carbon intensity of South African electricity, they are responsible for the largest proportion of carbon emissions (approximately 45%) as shown in Figure 1 and Figure 2 below.

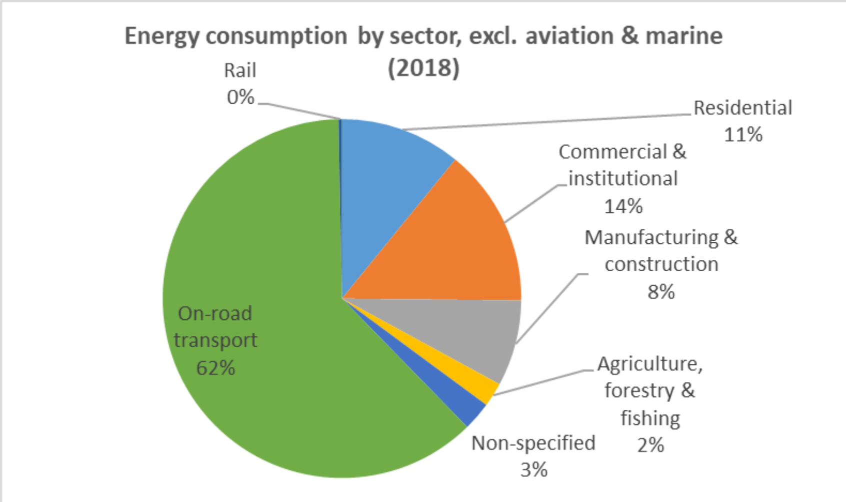


Figure 1: Energy consumption by sector. (Source: City of Cape Town Greenhouse Gas Inventory 2018)

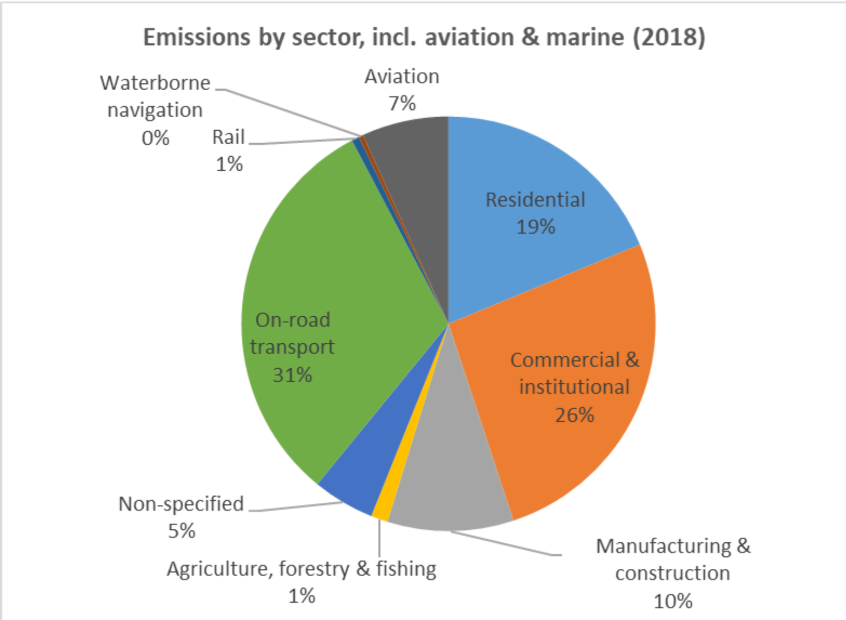


Figure 2: Carbon emissions and by sector. (Source: City of Cape Town Greenhouse Gas Inventory 2018)

Urbanisation is still underway in South Africa and the growth of Cape Town's building stock will significantly increase the city's GHG emissions unless aggressive action is taken to address the efficiency and carbon intensity of buildings. It is therefore important that buildings are designed and constructed to be highly energy-efficient to prevent the lock-in effect of inefficient design and to negate the need for expensive retrofitting in the future.

To avoid the potentially negative economic and social impacts of inefficient, high carbon buildings in the future, the City of Cape Town, along with the eThekwini, Johannesburg, and Tshwane – and recently joined by Ekurhuleni, is a signatory of the C40 Net Zero Carbon Buildings declaration. This commitment requires net zero carbon performance of all *new* buildings on a citywide basis by 2030 and the pursuit of net zero carbon for all existing buildings by 2050. These commitments are in line with national policy directives, particularly those articulated in the draft National Energy Efficiency and Climate Change Strategies and the National Development Plan, which envisages building standards of net zero emissions by 2030.

As part of the suite of measures aimed at achieving net zero carbon buildings, the City is looking to promote the adoption of more stringent energy efficiency targets and renewable energy use in new buildings, possibly through a bylaw. This can be achieved through integrated passive design, higher performance building envelopes, energy-efficient lighting, and HVAC,[2] building management systems and appliance specifications, with the remaining energy demand increasingly being met by on-site embedded generation, City-supplied green energy or alternative procurement of renewable energy.

A financial model undertaken to explore the impact of these requirements on the development sector indicates that for almost all building types, the proposed requirements have a strongly positive financial outcome. The model looked at the cumulative costs (adding costs for each year to each other) of building construction (financed), electricity use & PV costs over time. Figure 3 below, show the breakeven year for each building type, when cumulative costs for EE/NZC comes in at lower than cumulative costs for conventional building. The implication is that even without regulation, the market will move in this direction. Regulation helps to provide certainty to the market which can assist with more rapid and concerted uptake.

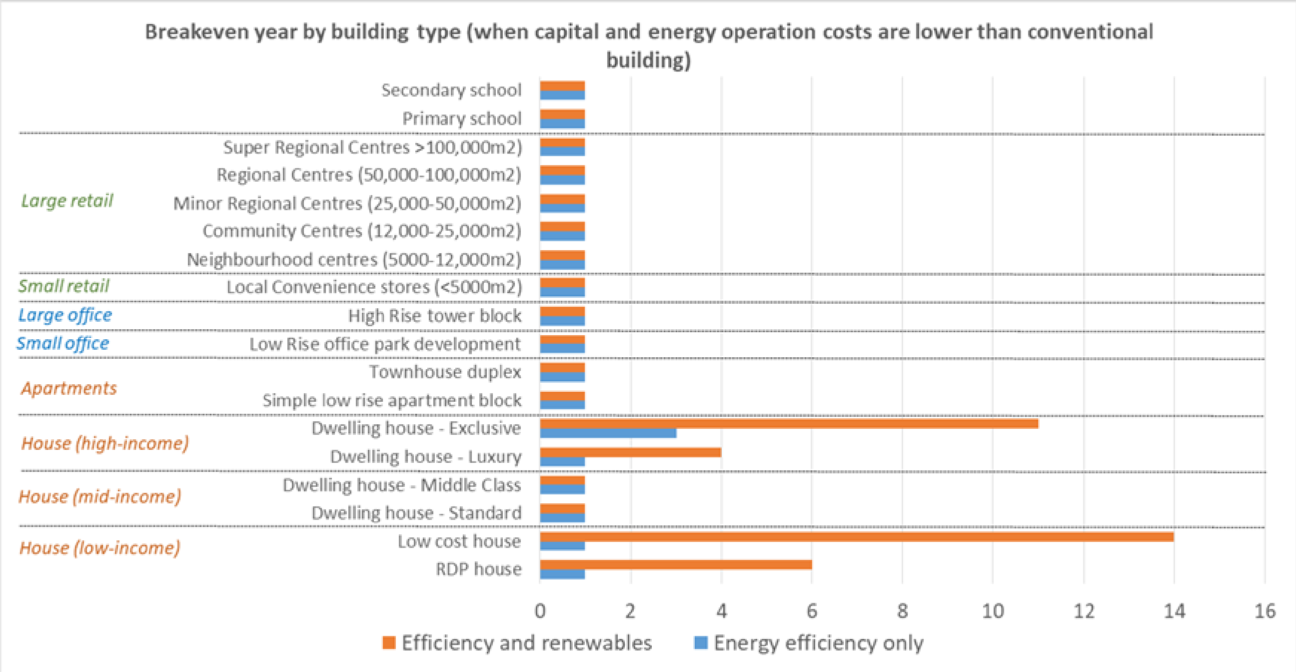


Figure 3: Green Building Cost Model (v2021). (Source: Sustainable Energy Africa, 2021).

Implications of the climate agenda [built environment] for the distribution sector

Decarbonising the built environment relies on energy efficiency and renewable energy. Energy efficiency (EE) reduces overall energy consumption (without impacting building comfort), while renewable energy decarbonises the electricity that is consumed. As the built environment currently accounts for *75% of the City of Cape Town's electricity consumption* (Figure 4 below), changes in consumption patterns from this sector need to be anticipated and well understood.

[2] Heating, ventilation and air-conditioning

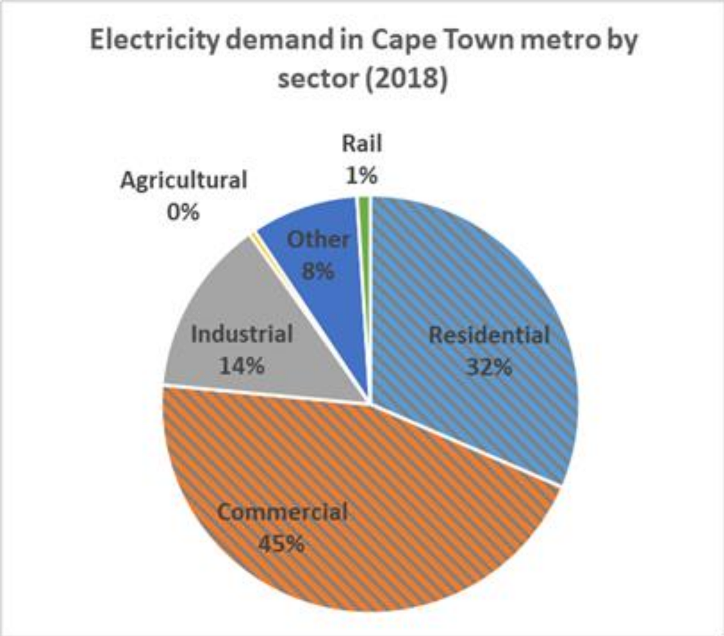
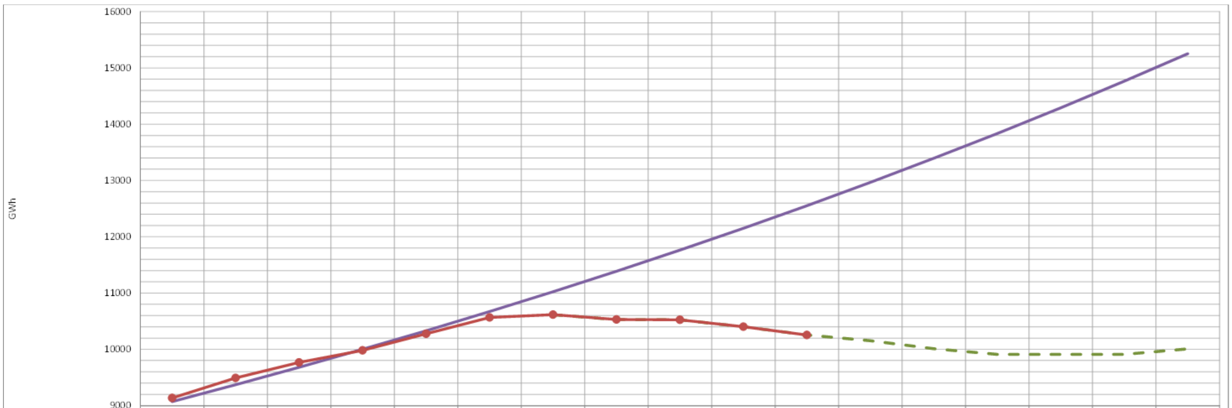


Figure 4: Electricity demand in Cape Town metro by sector (2018). (Source: City of Cape Town State of Energy 2021 (unpublished))

Energy efficiency

While renewable energy tends to grab the headlines, energy efficiency has led a more silent revolution within the electricity distribution business. Driven by technology changes (efficient appliances such as LED lighting) and some degree of fuel switching (gas stoves) in response to loadshedding, South African cities experienced a dramatic 'decoupling' of energy demand from economic and population growth around 2008.

Below, Figure 5 shows how electricity demand (red line) grew in Cape Town between 2003 and 2008 and then plateaued. As practitioners say, "Sales *grew 2% each year and that is what we planned for.*" The expected growth forecast is shown with the blue line. However, in 2009, the actual demand decoupled from the forecast and began to decrease year to year. The decrease in electricity demand was caused by a combination of energy efficiency and behaviour changes. Analysis of City of Cape Town sales data by customer type indicates that this was driven strongly by the residential sector the built environment.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Old Forecast 3.3%	9072	9371	9681	10000	10330	10671	11023	11387	11763	12151	12552	12966	13394	13836	14292	14764	15251
New Forecast							10615	10529	10523	10401	10255	10152	10010	9910	9910	9910	10009
Actual	9134	9491	9768	9982	10278	10565	10616	10530	10523	10402	10255						
Growth		3.9%	2.9%	2.2%	3.0%	2.8%	0.5%	-0.8%	-0.1%	-1.2%	-1.4%	-1.0%	-1.4%	-1.0%	0.0%	0.0%	1.0%

Figure 5: City of Cape Town Electricity Demand and Demand forecast 2003 – 2019. (Source: Electricity Distribution and Generation 2013)

In 2011, the first efforts of enforcing building energy efficiency to reduce carbon emissions were introduced with the National Building Regulations (NBR) SANS 10400-XA. The requirements for new buildings have since been revised, improved on, and provided in a drafted second version of the SANS 10400-XA. The main feature of this draft is the reduced maximum energy use intensity (EUI) values allowed by buildings, requiring improved EE.

With their ambitious climate commitments, the four South African major metropolitans (Joburg, Cape Town, Tshwane, and eThekwini) are introducing bylaws that go beyond SANS 10400-XA v2, calling for further energy efficiency improvements. They start by adding a 30% energy efficiency improvement required by 2025, followed by 55%, 65% and 75% energy efficency improvements for 2030, 2040, and 2050 respectively.

The City bylaws and national regulations can be combined with a simple floor area growth forecast to illustrate their impact on electricity consumption. This was done to produce Figure 6. Floor area growth data from Stats SA was utilized for the years 2011 to 2017. Data for 2018 onwards is projected at a rate of 0.5 to 1.5%. This simple assumption was required, as the amount of data acquired is insufficient and inconsistent, creating unrealistic floor area growth rates. The data did however indicate that non-residential buildings typically have a higher floor area growth rate than residential buildings.

Figure 6, below illustrates the impact of the bylaw and updated national regulation (SANS 10400-XA v2) on the electricity consumption of new buildings in Cape Town. It includes a business as usual (BAU) scenario based on current regulation for building energy use intensity (SANS 10400-XA v1) to provide a baseline for comparison.

A standard compliance rate and a high compliance rate are both illustrated. The standard rate represents national regulations and city bylaws implemented and followed 70% of the time. A high compliance rate assumes full adherence from 2030 onwards. In both adherence scenarios, SANS 10400-XA v2 is shown to result in large consumption reductions in new buildings compared to the BAU. City bylaws improve on this further with additional energy savings. Despite the continually increasing floor area, the electricity consumption slows rapidly as buildings increasingly are designed more efficiently.

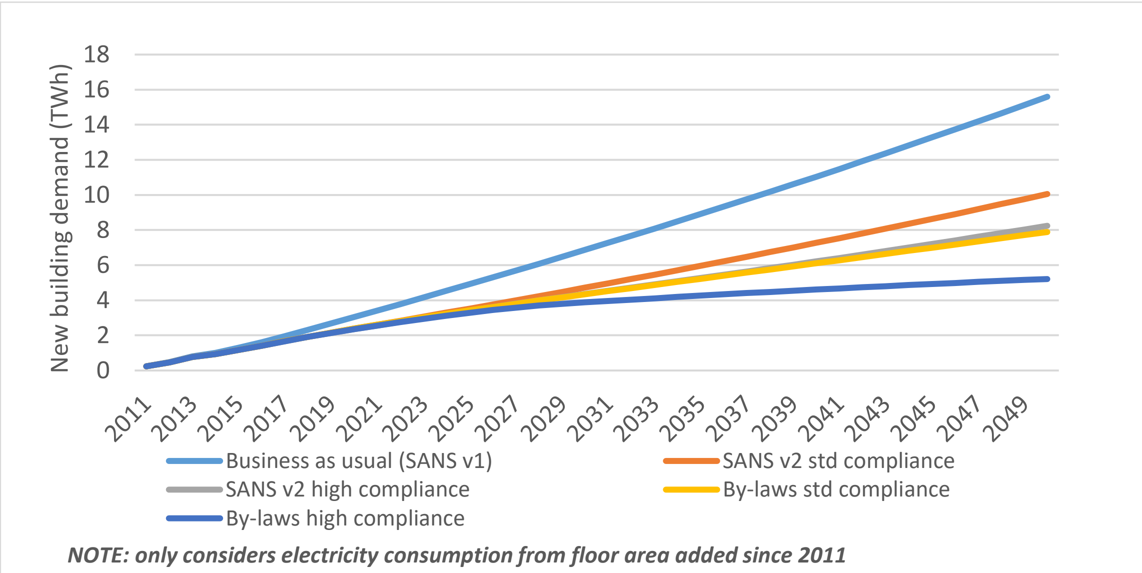


Figure 6: Policy implications on new building energy demand in Cape Town

Municipal electricity distributors will likely see an energy demand decrease within the Built Environment sector (Residential and Commercial customer base) considering the decelerating energy consumption of new buildings coupled with energy efficiency practices applied to existing buildings. Utilizing forecasts from Cape

Town's land use management (LUM) electricity demand model, Figure 7 was generated. It presents how the policy commitments and national regulations would impact the overall city-wide electricity consumption[3].

The national regulations as updated in 2021 (SANS 10400-XA v2) is highlighted in Figure 7[4] as the main contributor to EE, decreasing the rapid speed of electricity growth to almost a flat projection. It entails a reduction of almost 5 TWh of annual consumption for 2040 compared to the previous SANS v1. This in fact lines up with current demand trajectories, indicating that growth in the built environment (the new development market) may already be far more efficient than what is required under current regulation. Cape Town's city bylaw adds a further reduction of some 2 TWh of demand to the point that energy consumption is expected to begin decreasing in absolute terms.

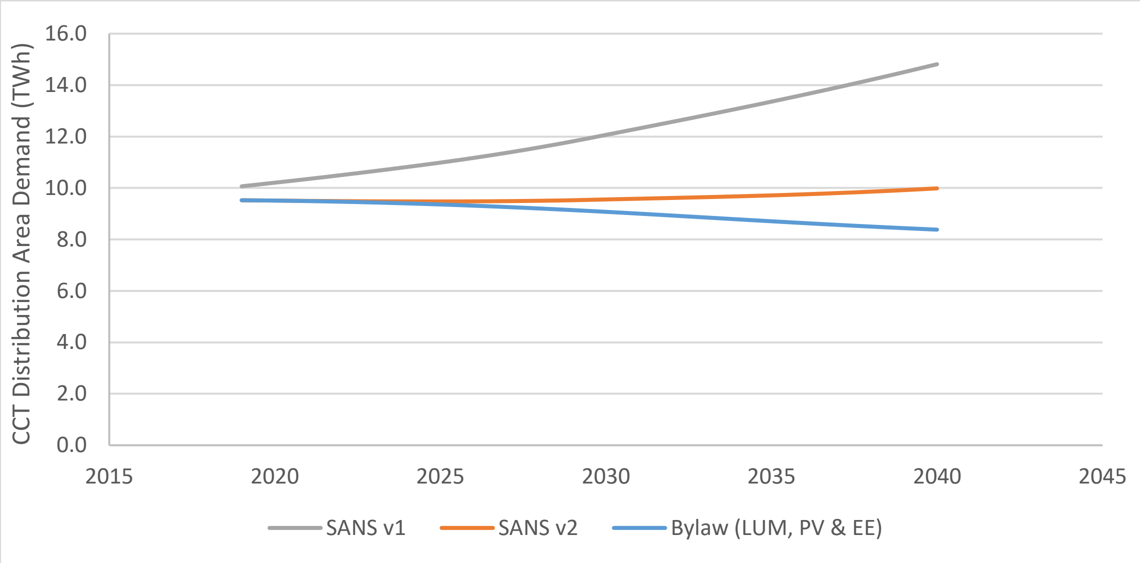


Figure 7: City-wide electricity demand forecasts for Cape Town (SEA, 2021)

It is anticipated that the energy efficiency requirements will not only change total demand, but also the patterns of demand. City load profiles are likely to change and see reductions from customers changing their consumption habits. Smart devices available today, such as new thermostats, geysers, or electric vehicles, can serve as flexible loads. Flexible loads refer to loads that can shift their energy consumption to another time. This may be to align with renewable energy generation or to avoid peak time of use (TOU) tariff periods. Flexible loads offer the potential to delay or prevent the need for new costly infrastructure upgrades. Battery storage also begins to play a role in these scenarios, offering additional flexibility to previously non-flexible devices along with allowing renewable energy to be stored and used outside typical generation windows.

Renewable energy

The 'net zero' approach to new buildings requires that residual energy demand is met by renewable energy. For the City of Cape Town this translates into approximately 1GW of energy demand, as illustrated in Table 1 below.

3 The Cape Town LUM model provided data for 2019 to 2040, limiting the projection to these years.

4 Due to a lack of data for previous years, the SANS v1 scenario suddenly jumps from v2 in 2019. If one were to include data from 2011, this would not be a sudden jump but rather a gradual increase from then.

Table 1: Renewable energy required to meet 100% residual energy demand for new buildings for City 2025 - 2050 (MW)

Cape Town	**2025**	**2030**	**2040**	**2050**
Residential	77	200	452	651*
Commercial / institutional	63	140	305	447
Total	**140**	**340**	**757**	**1 097**

(Source: Sustainable Energy Africa PV Required by Building Type, 2019).

** If residential free-standing dwellings <80m2 are excluded (it is difficult to make a financial case for this type of building), this would reduce the total MW added by 2050 by some 116 MW*

Renewable energy (RE) generation is typically divided into two separate groups: utility-scale generators and small-scale embedded generation (SSEG). Utility-scale renewable energy are large systems that are connected to the high-voltage transmission system while SSEG is typically connected to the distribution network "behind-the-meter". SSEG is usually 'onsite' meaning that it is on the same premises at the building consuming the energy, while utility-scale renewable energy is termed 'offsite' meaning that it is on a separate location to the building(s) and requires use of the grid to transport the energy to the building. Globally the green building movement prioritises on-site renewable energy before off-site.

Onsite Renewable Energy

The total installed capacity of SSEG – predominantly solar PV – has grown exponentially over the last 3 years. The financial business case for customers installing SSEG to reduce their consumption of grid electricity has continued to improve due to increasing electricity prices and the reducing cost of solar PV installations. Recent estimates are that the total installed SSEG capacity in South Africa exceeds 1GW [5]. All forecasts point towards the continued growth of the SSEG sector.

This growth will be compounded by the metro net-zero carbon bylaw requirements that will require all new buildings to consume renewable energy from 2025, as illustrated in Table 1 for the City of Cape Town. In 2020 Cape Town had 46 MW of officially registered SSEG installed. If the 'net zero carbon' requirement to meet all residual energy use from new buildings with renewable energy was met through SSEG alone, this would add around 1 GW of installed capacity to the distribution grid by 2050.

Not all buildings will be able to meet all their energy requirements with on-site renewable energy. A model has been developed to get an *indicative* sense of the scale of potential on-site SSEG solar versus what would need to be met via off-site sources. The model calculates the area of rooftop PV required per building type, based on the average floor area and energy intensity by building type, and whether this area of PV can realistically be accommodated by the building's estimated roof space[6].

Figure 8 below provides an interesting reflection, indicating that a high proportion of energy consumption could be met through on-site SSEG, although many office blocks and larger shopping centres could not meet their annual consumption through on-site production. The figure also indicates a high potential for wheeling of embedded power within the distribution grid.

[5] GreenCape, 2021, Industry Brief: SSEG Licensing and Registration

[6] It is extremely difficult to model likely available roof space given that building floor area data often doesn't specify building footprint, so the model is purely indicative. Details of how the model was developed can be obtained from Sustainable Energy Africa.

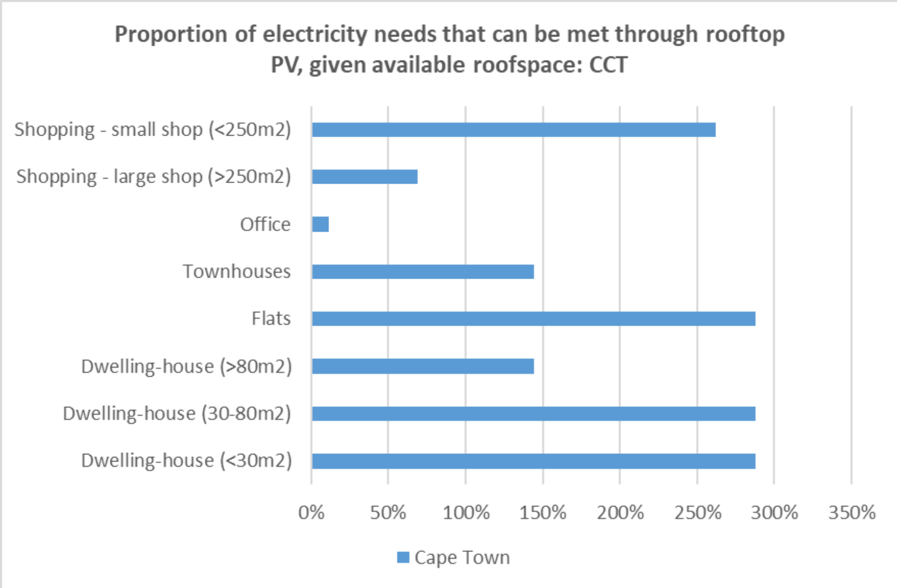


Figure 8: Proportion of electricity needs that can be met through rooftop PV, by building type, given available roof space for Cape Town. (Source: Sustainable Energy Africa PV Required by Building Type, 2019).

The growth of SSEG is not without its challenges; municipalities need to develop a range of new skills and processes to safely connect these generators to the distribution grid. Municipal uptake of these processes has grown steadily since 2017 with roughly 70 municipalities now having application processes in place to connect SSEG to the grid[7]. Key challenges that remain a barrier to SSEG uptake are the slow approval of grid connection applications and the high cost of bi-directional meter installations. Grid impact studies would also be required to establish the feasibility of these growing quantities of SSEG within the network.

Offsite Renewable Energy

Offsite renewable energy will be required by buildings that are not able to generate sufficient renewable energy onsite; this can be due to a range of factors including insufficient roof space, poor solar resource, or insufficient grid connection capacity. As such, it is important that municipalities facilitate offsite renewable energy either through the contracting of power between willing buyers and willing sellers, or through providing carbon-free electricity in the form of a dedicated Green Tariff. South Africa's regulatory framework (Schedule 2 of the Electricity Regulation Act) has recently been amended to explicitly allow both arrangements:

1. Private wheeling of power between generators and customers through Eskom and municipal networks is explicitly allowed.
2. Municipalities are explicitly allowed to enter into power purchase agreements with independent power producers (IPPs).

Enabling offsite renewable energy purchases will require improved metering and billing capabilities to track the consumption and generation on a more granular (half-hourly) basis. In addition, offsite renewable energy requires municipalities to unbundle their electricity tariffs into a fixed network component and a variable energy component. This is a precursor to the separation of the "wires business" from the "energy business". When customers wheel electricity they are still required to pay for the fixed network tariff component (wires) but determine their energy purchase price independent from the municipality.

Onsite vs offsite debate: what is optimal for the system?

Green building practice prefers on-site approaches to renewable energy, whereas electricity industry stakeholders query whether onsite renewable energy is the most optimal investment for the system. The

[7] SALGA, Status of SSEG 2020 and www.SSEG.org.za

argument stems from the fact that large utility-scale renewable energy systems are cheaper on a per kW basis due to economies of scale. To unpack this question, a full-system model was built to quantify the trade-off between onsite, embedded rooftop PV versus utility-scale solar PV[8].

Interestingly, the model found that onsite solar PV does not significantly increase the cost of the power system when compared to an equivalent amount of utility-scale PV. This is due to the significant savings onsite renewable energy provides in terms of reducing electricity losses (due to onsite consumption) and resulting fuel expenditure, and, in instances where peak demand is reduced, by reducing capital expenditure on network upgrades and peaking power plants. In addition, onsite renewable energy offers significant value to the local economy by creating local jobs. However, with rapid and unanticipated technology changes, it is critical that policy does not lock in a certain energy supply. Policy must remain flexible to allow consumers to decarbonise their buildings in the most suitable manner.

Conclusion: managing a net-zero built environment future

The latest science from the Intergovernmental Panel on Climate Change indicates that more needs to be done faster to avoid dangerous climate change. The carbon intensity of South Africa's built environment threatens our global economic competitiveness. It also offers the least cost mitigation – the lowest hanging fruit – and national and city government are directing their mitigation ambitions here. The transition to a carbon-free future will have wide-ranging impacts on distribution utilities, and distributors need to be prepared for disruptions within the energy sector as the conventional electricity supply shifts to decentralised, renewable energy systems.

The indication from the analysis is that this is a movement that is already underway with electricity demand long since decoupled from economic growth and SSEG is growing exponentially. The new policy directions and regulations will deepen this. In Cape Town the indications are that urban growth and new buildings will not drive electricity growth, will increasingly offer more flexible loads, and will increasingly generate their own energy with SSEG/off-site renewable energy. All of this will have impacts on the municipal grid that must be managed.

Municipalities can and must take advantage of declining renewable energy costs, improved availability of renewables, and the uptake of energy efficient technologies. Further to this, it is imperative that municipalities consider the implications of improved energy efficiency within the built sector on municipal revenue and explore more client-centred and service-oriented utility business models and the unbundling of electricity retail from generation and distribution to ensure optimal cost recovery.

Municipal utilities can no longer base their business plans on a growth model. Important distribution utility business opportunities exist within the new policy direction: flexible load, grid services for wheeling of renewable power, sale of storage facilities. Practically, distributors must have metering systems able to manage new approaches, tariffs that charge appropriately for the grid business and the ability to evaluate grid impact of new installations. Given the enormous technology and market reform disruptions underway in the electricity sector it is also important that policy is developed to be flexible rather than prescriptive, emphasising required outcomes and leaving the means of getting there to the innovations of the market, thus ensuring optimal investments.

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8 Sustainable Energy Africa, 2021, "A system cost analysis of embedded generation vs utility-scale solar PV", South African Sustainable Energy Conference 2021