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RENEWABLE ENERGY FOR INDUSTRIAL DEVELOPMENT: PATHWAYS AND IMPLICATIONS

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CONTENTS

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ABBREVIATIONS

BAU	Business as usual
B-BBEE	Broad-Based Black Economic Empowerment
BESS	Battery Energy Storage System(s)
BTM	Behind-the-Meter
C&I	Commercial and Industrial
CapEx	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CPI	Consumer price index
dtic (the)	Department of Trade, Industry and Competition
DevEx	Development expenditure
Dx	Distribution
EU	European Union
GHG	Greenhouse Gas
GW	Giggawatt
Gx	Generation
IEA	International Energy Agency
IPP	Independent Power Producer
kVA	Kilovolt-amps
kVArh	1000 reactive volt-amps per hour
kWh	Kilowatt-hour
kWp	Kilowatt-peak
LCOE	Levelised cost of electricity
MFMA	Municipal Finance Management Act
MWp	Megawatt peak
NERSA	National Energy Regulator of South Africa
NMD	Notified Maximum Demand
NPV	Net Present Value
O&M	Operation and maintenance
OEM	Original equipment manufacturers
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
REI4P	Renewable Energy Independent Power Producer Procurement Programme
SARB	South African Reserve Bank
SAREM	South African Renewable Energy Masterplan
SIC	Standard Industrial Classification
SMME	Small, Medium and Micro Enterprises
SSEG	Small-Scale Embedded Generation

EXECUTIVE SUMMARY

In the face of rising electricity costs, persistent power outages (loadshedding), and the emergence of domestic and international carbon taxes, there has never been a better time for businesses in South Africa to adopt renewable energy (RE) to realise significant savings on their electricity bills, lower their tax liability, secure a reliable supply of electricity, and reduce their carbon footprint.

However, there are different ways businesses can adopt or procure RE. Different "adoption pathways" are more suitable depending on the objective as well as the specific circumstances. The simplest way for all businesses to decarbonise is to wait for the grid itself to decarbonise as more sources of RE are connected to it. This pathway, referred to in the study as "pathway #1", is risky as substantial decarbonisation of the grid may take too long for businesses to derive the above-mentioned benefits. It also does not shield the business from loadshedding.

Other pathways involve actively procuring RE either from a source that is some distance away from the business (off-site: "pathway #2") or directly on the premises of the business (on-site: "pathway #3"). Pathway #2 involves transmitting the electricity across the grid (a process known as wheeling) while pathway #3, which is often referred to as an "embedded" or "behind-the-meter" system, would be able to provide RE without going through an electric meter and having to be transmitted through the electricity grid. In both cases, businesses could decide to invest in the system themselves or to purchase the electricity generated via a Power Purchase Agreement (PPA) with an Independent Power Producer (IPP)/generator or an energy trader.

By looking at a range of indicators, the study finds that, in the case of these two active approaches to the procurement of RE, a lot can be done with on-site solar photovoltaic (PV).[1] However, it is also clear that space constraints for businesses in an urban setting makes it virtually impossible to decarbonise completely unless the adoption of off-site sources of renewable energy are also explored. In the context of the current electricity crisis, which led to a steep increase in on-site PV plus battery installations, it is important that businesses begin to look beyond the short term need to "keep the lights on" to a state of affairs when the demand for energy is determined primarily by the need to decarbonise. Ignoring this new reality will not only negatively impact on firm-level profitability in a high-cost environment but has serious implications for the long-term manufacturing and industrial capabilities of the economy as a whole.

The key findings of the study are summarised below:

- The net present value (NPV) is uniformly negative for pathway #1 (i.e., doing nothing is not a commercially viable strategy). In most cases, NPV is positive for pathway #2 and in all cases NPV is positive for pathway #3. This implies that, given current tariff structures, the procurement of renewable energy almost always makes commercial sense.
- The carbon tax liability for electricity consumption falls to zero for pathway #2 for an installation size equivalent to 100% of annual electricity consumption. For smaller installation sizes, carbon tax is reduced but not eliminated.
- PV can only be exported at a maximum of 75% of Notified Maximum Demand (NMD). So, if more than 75% of NMD is installed and electricity is generated but not used (or stored), then this surplus will need to be curtailed (reduced) to avoid congestion in the local electricity system. For larger PV systems, e.g., systems sized at 100% of annual electricity consumption, the curtailment of electricity

[1] The study focuses on solar PV generation as it is unlikely that wind can be deployed on-site by most businesses in an urban setting.

becomes an issue for on-site installations. While installing a battery energy storage system (BESS) can significantly reduce the amount of electricity curtailed, the PV system will require an area more than two-thirds of the size of a rugby field to install and would neither eliminate curtailment altogether nor eliminate the need to procure electricity from a utility. A sufficiently large BESS capable of shifting load and minimising curtailment is unlikely to be a viable option for the majority of small manufacturing firms on top of the cost of installing PV alone.

These findings reinforce the argument for an integrated policy framework that supports a mixed approach to RE adoption. A coordinated policy response is required from different ministries, including the Department of Trade, Industry and Competition (the dtic), to:

- Expand and strengthen energy trading in the South African energy sector.
- Accelerate the establishment of a national wheeling framework, and harmonised municipal wheeling mechanisms and regulations to facilitate wheeling across municipal boundaries, including establishing integrated billing systems capable of handling wheeling via both Eskom-to-municipality and municipality-to-municipality wheeling.
- Encourage municipalities with significant concentrations of industrial activity to think about how they can attract investment in RE into their areas, increase their portfolio of RE assets, and dependably provide RE to their industrial customers from off-site sources.
- Support the roll-out of RE in South Africa by supporting local manufacturers to improve their capabilities and competitiveness and secure local supply.
- Drive collaboration between public and private stakeholders – Eskom, municipalities, property managers, owners, body corporates, financial institutions – to accelerate the roll-out of PV systems and BESS in industrial areas (dedicated industrial zones as well as areas of concentrated industrial activity) and thus provide low-carbon, energy security for industrial activities.
- Reinvigorate the Renewable Energy Independent Power Producer Procurement Programme (REI4P) and provide returns to developers that are at least as attractive to the returns they can achieve elsewhere.

In conclusion, mitigating the effect of power outages (loadshedding) is important but adopting RE to decarbonise and realise significant savings that could be invested in strengthening firm-level capabilities should be regarded as longer-term objectives by small and large businesses alike. As such, space constraints for businesses in an urban location make it virtually impossible to decarbonise completely and realise significant savings on their electricity bill unless the adoption of off-site sources of renewable energy in addition to on-site solutions are explored.

It is therefore imperative that an appropriate policy framework that supports a mixed approach to RE adoption – i.e., that supports both on-site and off-site PV adoption – is developed. Moreover, a co-ordinated and collaborative approach is required from all stakeholders, public and private, to achieve this successfully. National government departments such as the dtic need to work with all stakeholders to ensure that PV and BESS are widely adopted as a basis for preserving long-term manufacturing capabilities within the country.

1. INTRODUCTION

There are several compelling reasons for businesses to transition to renewable energy. RE contributes to increased environmental sustainability by reducing greenhouse gas (GHG) emissions and decreasing reliance on fossil fuels. RE is also relatively cheap. As the cost of RE continues to decline, households and businesses that adopt RE stand to make substantial long-term savings on their electricity bills.

RE capacity addition is dominated by solar PV, which is now considered a mature technology that is widely available, simple to integrate, and scalable. Worldwide PV electricity generation from PV increased by 26% in 2022 (IEA, 2023a). Solar PV is also the fastest growing RE technology in South Africa, with a total installed capacity of 5.6GW in quarter one of 2023, up from 4.5GW in quarter four of 2022 (25% growth in three months) (SAPVIA, n.d.). For a breakdown of the type of installations, see Table 1.

Table 1: Installed solar PV capacity in South Africa, 2023

	MARKET SEGMENT	SYSTEM SIZE	TOTAL CAPACITY
	Residential	0 – 30kWp	621MWp
	Commercial and Industrial (C&I) – Small-Scale Embedded Generation (SSEG)	30kWp – 1MWp	1 248MWp
	C&I Large Scale and utility scale	1MWp – 50MWp	1 925MWp
	Utility Scale	> 50MWp	1 865MWp
		TOTAL	**5 659MWp**

Source: SAPVIA, n.d.
Note: Total installed capacity of systems identified grouped by market segment. Listed values across market segments include both public and private generation capacity procurement.

The rapidly falling cost has played a key role in the significant expansion of PV adoption. Between 2010 and 2021, the global weighted average levelised cost of electricity (LCOE) of utility-scale solar PV plants declined by over 80%, from US$0.417/kilowatt hour (kWh) to US$0.048/kWh (IRENA, 2022). Despite some short-term volatility in the cost of modules in 2021 due to higher freight and commodity prices, the downward price trajectory is clear.

There are other commercial and economic benefits to RE. Adopting RE helps businesses build a positive brand image and strengthen stakeholder relations while capitalising on available incentives. Beyond individual businesses, shifting to RE also allows for a more distributed electricity generation system, reducing energy losses and enhancing resilience. Finally, RE adoption promotes technological innovation, job creation, and economic development in the clean energy sector and has the potential to build a more inclusive and diverse economy.

The case for RE adoption by energy-intensive businesses is strengthened considerably in the South African context. First, according to research conducted by the South African Reserve Bank (SARB), the average Eskom tariff increased by 333% between 2007 and 2017. By 2022, it had increased by 450% since 2007 (Ismail and Wood, 2023). The high price of electricity relative to intermediate inputs and to gross value added across the economy continues to erode the competitiveness of South African businesses while driving up the overall price level and impacting South Africa's price stability (Ismail and Wood, 2023).

Second, the country's electricity supply has become increasingly unreliable, and South Africans are subject to frequent and numerous electricity supply interruptions and constraints. Load curtailment for heavy users and loadshedding – a method of reducing demand on the energy generation system by temporarily switching off the distribution of electricity to certain geographical areas – both have a direct impact on firm-level competitiveness through lost production time, higher energy costs and lower revenues. Loadshedding has been imposed in nine of the 13 financial years (ending in March) from 2008 to 2023, including every year from 2019 to 2023. For less energy-intensive businesses, loadshedding and municipal grid breakdowns have often proved more burdensome than rising prices.

Some of the costs of loadshedding are difficult to quantify but ultimately manifest in the form of investments not being made and jobs not being created as well as direct employment losses due to businesses closing or scaling down. The investment cost of an alternative electricity supply, such as a diesel generator or a BESS, with or without PV panels to charge the batteries, is easier to quantify. When the electricity grid is operating normally, a PV system will use the electricity it generates for self-consumption, to charge the BESS, or export the surplus to the grid. In the case of loadshedding, a BESS or a generator can supply the electricity. Moreover, a PV system will require a BESS or a generator during loadshedding to regulate the electricity supply. At this time, the electricity generated by the PV system can be self-consumed, used to charge the BESS, or curtailed. If the PV system is not equipped with a BESS or generator, it will be deactivated during loadshedding.

Nevertheless, the collective power produced by several PV systems integrated into the grid will help alleviate loadshedding across the entire system by contributing to electricity generation during supply shortages. However, the combined power required to charge batteries integrated into the grid aggravates loadshedding throughout the system by contributing to a higher load at times when the demand for electricity already exceeds supply. While BESS can minimise the impact of loadshedding on individual businesses, it is important to recognise that the operation of BESS for loadshedding is different to the operation of BESS for maximising RE usage and reducing carbon emissions.[2]

Third, and perhaps most importantly, several major economies and economic blocs in the Global North, including the European Union (EU) (European Commission, 2023), the United States (EPA, 2023), Canada (Government of Canada, 2023) and Japan (Obayashi and Golubkov, 2023), have developed, or are in the process of developing, instruments designed to put a price on GHG emissions from goods entering their markets and thus prevent "carbon leakage".[3] The EU's Carbon Border Adjustment Mechanism (CBAM) is an example of such an instrument that has already come into force, albeit in a transitional phase, and will have significant implications for energy-intensive exporters which rely on carbon-intensive electricity generation for their energy needs.

Since coal-fired power generation contributes 82% (Eskom, 2023:85) of total system demand in South Africa, the introduction of domestic and international carbon taxes in key export markets represents a significant challenge to South African producers of energy-intensive products. Simply put, the higher the carbon-intensity of the manufactured product, the higher the tax and the greater the need for

[2] When batteries are used to safeguard against power outages, they are typically charged from the grid when the grid is available rather than relying on excess power generated from PV systems when the sun is shining.

[3] Carbon leakage refers to a situation when a company decides to move its production from a country with stringent GHG emission policies, to a country that is more lenient, leading to an overall increase in greenhouse gas emissions (Clear Center, 2020).

businesses to reduce their carbon emissions through investing in RE and improving the energy efficiency of existing production technologies and/or switching to low-carbon technologies.

In short, there has never been a better time for businesses to switch to RE. However, there are different ways to procure RE with different costs and benefits. Against the backdrop of both domestic and global pressure to adopt low-carbon production pathways and South Africa's own energy crisis, the options available to businesses merit further consideration. Businesses can benefit greatly from switching to RE but there are limits to what can be done under certain adoption pathways, and different adoption pathways are more appropriate than others depending on the primary reason for wanting to decarbonise in the first place.

As loadshedding should be regarded as a temporary phenomenon[4] – in other words, not a normal state of affairs but one that should come to an end at some point in the near future – the need to transition to a low-carbon pathway, as opposed to the need to seek alternative sources of off-grid electricity generation, represents a "new normal" with significant implications for domestic and export-oriented producers alike.

This study therefore focuses on an assessment of RE adoption pathways without a "loadshedding lens". In particular, the study focuses on the commercial viability (NPV) of different RE adoption pathways and mechanisms (off-site versus on-site, PPA versus self-owned) by quantifying the savings businesses can achieve on their utility bills and their carbon tax liability by decarbonising their energy source. Furthermore, the study focuses on medium-sized manufacturing firms with a moderate energy profile, and on solar PV generation as it is unlikely that wind can be deployed on-site by most businesses in an urban setting.

The rest of this document is set out as follows. Section 2 explores the key pathways available to businesses for adopting PV. Section 3 describes the core assumptions used in the model to generate the results for each adoption pathway. Section 4 presents results and observations for three different sizes of installed RE capacity, with and without BESS, for a representative firm in Cape Town and Ekurhuleni. Section 5 summarises key findings and draws policy conclusions.

2. RENEWABLE ENERGY ADOPTION PATHWAYS

Businesses can transition to RE in three main ways:

1. The easiest option for businesses to reduce their carbon emissions is to wait for the grid to gradually transition to green energy. This is referred to as Pathway #1 in this report.
2. Businesses also have the option to procure RE from off-site sources, referred to in this report as Pathway #2, which could be self-owned, directly procured from a generator or purchased from an electricity trader.
3. Finally, businesses have the option of installing RE solutions directly on their premises (on-site), referred to as Pathway #3. Whereas these on-site installations are traditionally owned by the businesses themselves, it is becoming increasingly popular for specialised RE companies to own the installation and sell the generated electricity to the business (Energy Partners, 2023).

Table 2 presents a comparison of the three pathways for integrating renewable energy into a business operation. Each option offers both advantages and disadvantages that are considered when making decisions about RE adoption. These options are described in further detail in the rest of this section.

[4] "Loadshedding will be used under emergency conditions for limited periods" (Eskom, n.d.).

Table 2: Summary of pathways to renewable energy

	PATHWAY #1: BUSINESS AS USUAL	PATHWAY #2: OFF-SITE GENERATION	PATHWAY #3: ON-SITE GENERATION
CAPITAL OUTLAY	No capital outlay required	Usually no capital outlay required, however, it is possible to own an off-site generator	Capital outlay often required, however, PPA with an on-site generator increasingly popular
TAX BENEFIT	No direct tax benefit	Can directly benefit from accelerated depreciation incentive if self-owned (and can indirectly benefit from same if purchased with PPA)	Can directly benefit from accelerated depreciation tax incentive if self-owned (and can indirectly benefit from same if purchased with PPA)
SPEED AND EXTENT OF TRANSITION	Slow transition to RE; limited to decisions outside of business	Fast and full transition possible	Fast transition possible; limited by available space at premises
ELECTRICITY LOSSES	Higher electricity losses as not used on-site	Higher electricity losses as not used on-site	Lower distribution and transmission losses for self-consumed electricity
DISTRIBUTION AND TRANSMISSION SYSTEM COSTS	Use of distribution and transmission system costs	Use of distribution and transmission system costs	Electricity used on-site so no or low distribution or transmission system costs
WHEELING	Electricity wheeled so higher possibility of all electricity generated utilised	Electricity wheeled so higher possibility of all electricity generated utilised	Limited by existing load patterns – electricity might be curtailed
ECONOMIES OF SCALE	Can benefit from economies of scale	Can benefit from economies of scale	Could have a higher price due to specifics of the installation
INSTALLATION TYPE	Possibility of ground-mounted optimally inclined installation with higher yield	Possibility of ground-mounted optimally inclined installation with higher yield	Installation limited by roof structure, shading, etc.
YIELD	Systems can be installed in high resource areas subject to grid availability	Systems can be installed in high resource areas subject to grid availability	Yield limited by solar resource on-site
USE OF SYSTEM	No possibility of also utilising system during power cuts	No possibility of also utilising system during power cuts	Battery energy system could be utilised during power cuts (although will lower carbon reduction potential)

CARBON NEUTRALITY	Possibility of carbon neutrality only in the very distant future	High technical possibility of carbon neutrality	Typically, very difficult to become carbon-neutral due to size restrictions and solar generation not coinciding with load
CONTROL	Businesses have no control of installations and transition plans	Businesses usually not directly responsible for installation and operation	Businesses tend to have greater control of installation and operation as on-site
FEEDBACK	n/a	Feedback to grid limited at generator site	Feedback to grid limited by NMD on-site
BESS	n/a	Batteries not generally needed as unlimited capacity assumed	Batteries needed to make optimal use of PV generation for large installations to avoid curtailment (add costs to the system)

2.1 Pathway #1 – Procurement of RE as existing Eskom/municipal customer

The first pathway reflects RE that is procured from grid-connected sources of RE as an existing Eskom or municipal customer. In other words, this pathway reflects the "business-as-usual" scenario (BAU) – businesses would transition to a lower-carbon energy path as Eskom and municipalities increase their share of RE in generation via, for example, the REI4P or directly procured sources of RE by municipalities within their own jurisdictions. Consequently, the proportion of RE used by a business would increase as the share of RE available to the grid increases (i.e., as electricity generated from renewable sources of energy displaces electricity generated from fossil fuels in the respective grid's total energy mix).

Under pathway #1 businesses are not exposed to investment risk but they remain fully exposed to increases in the Eskom tariff (and therefore increases in the municipal tariff where applicable). Carbon taxes that apply to both Scope 1 and Scope 2 emissions will be reduced in proportion to the greenness of the grid and the extent to which businesses reduce their Scope 1 GHG emissions by adopting low-carbon production technologies.[5] Setting aside the direct and indirect costs of loadshedding, the key financial costs a business would incur under pathway #1 would be the utility bill (and the various constituent charges – see Box 1) and the carbon tax (domestic and/or international).

[5] In the case of CBAM, indirect emissions (i.e., Scope 2 and Scope 3 emissions), such as the emissions generated from electricity used for manufacturing, heating or cooling during the production process, will not be used as a basis for the CBAM charge during the transitional phase of the mechanism (currently 1 October 2023 to 31 December 2025). However, indirect emissions will be covered by CBAM once the permanent system enters into force on 1 January 2026 on the basis of a methodology to be defined during the transitional phase.

Box 1: Components of Eskom's Industrial Electricity Bill[6]

The cost of electricity varies depending on several factors, such as the amount of electricity used, the time or season of usage, the supply capacity required, the location of the customer, and the voltage at which supply is provided.

To determine tariffs (the price customers pay for electricity), the overall costs are broken down into specific cost categories using different cost drivers. These cost drivers help ensure that costs are allocated appropriately and not pooled incorrectly.

Common cost drivers include:

- R/customer/month or R/customer/day: These are customer service and administration costs.
- R/kVA or R/kW: These are network costs.
- c/kWh: This is the cost for the energy used.
- c/kVArh: This refers to reactive energy costs.
- Energy loss factors: These account for energy loss costs.

The complexity of the tariff structure depends on factors such as the customer's electricity usage and whether they are more energy-intensive or not. Tariffs for larger customers tend to be more complex, while tariffs for domestic customers are simpler.

Smaller customers often have higher supply costs compared to larger customers. This is because they tend to use more electricity during expensive peak periods and have a lower load factor. In addition, supplying smaller customers requires more electrical networks and incurs more losses, which contributes to the higher cost.

Eskom's overall electricity price is regulated and based on approved costs plus a return on investment determined by the National Energy Regulator of South Africa (NERSA). However, individual price levels for different customers might not fully represent their actual costs due to cost averaging, historical cross-subsidies, and social factors like the customer's ability to pay.

There are two major risks to adopting pathway #1 as a business. First, waiting for the share of RE in the overall energy mix to increase will take time. The pace of transformation is slow compared to direct procurement and the increase in the share of RE on the grid may not be enough to offset the deterioration in competitiveness as a result of the combination of a carbon tax and above-inflation increases in the cost of electricity.

Second, there is a real risk that all renewable energy available to the grid could be allocated as green certificates or sold directly to other customers/businesses, leaving the rest of the grid completely based on non-renewable energy sources. This situation would leave businesses worse off than is currently the case with at least a small (and rising) proportion of the electricity on the grid coming from renewable energy sources.

Eskom's Renewable Energy Tariff pilot programme is an example of the second risk. The pilot programme allows Eskom customers to procure renewable energy from Eskom's own accredited RE plants, including Sere Wind Farm and the Run-of-River hydro facility, without the initial capital investment in an owned generator. The pilot is only available to Eskom customers but if the Renewable

[6] This subsection is drawn from Eskom's Electricity Pricing Definitions (Eskom, n.d.) and the National Cleaner Production Centre's *A Guide to Understanding Your Industrial Electricity Bill* document (NCPC, 2020).

Energy Tariff Programme were to be adopted by Eskom as a permanent scheme and extended to municipal customers, this would almost certainly result in "de-greening" the grid and making pathway #1 virtually unviable for business owners that either do not participate in the programme or miss out on the RE allocation.

2.2 Pathway #2 – Procurement of off-site, grid-connected sources of RE

The second pathway reflects the procurement of green electricity from off-site sources of RE. Under pathway #2, businesses can invest directly in the source of RE generation or purchase the electricity by way of a PPA with the IPP/generator or trader (see Box 2 for more information on PPAs).

Off-site, grid-connected RE essentially involves wheeling – the delivery of electricity from a generator to an end-user located in another area through the use of existing distribution or transmission networks – and requires amended electricity supply and connection agreements and use of system agreements where applicable. (In the case of an off-site, directly connected system, a dedicated line would need to be built to transport the electricity from the site of RE generation to the business although this type of arrangement is probably closer in essence to an on-site solution.)

Box 2: Power Purchase Agreements

PPAs are contracts when a company, not a utility like Eskom, buys electricity for its own operations. These companies need their own sources of electricity due to a generation capacity shortfall and rising electricity tariffs from Eskom and municipalities.

To fund their renewable energy projects, companies often require significant initial capital, so they seek third-party funding, like loans from banks. However, third parties may be hesitant to lend without security. PPAs provide that assurance by committing to pay a fixed price for the electricity generated by the renewable energy asset over a long-term period (usually 10-20 years).

PPA projects can either be located on-site – located on a company's rooftop or adjacent land – or off-site, where the energy produced by the project is said to be "wheeled" over the Eskom or municipal grid to the buyer.

For companies, the benefits of PPAs include fixed long-term costs and the ability to indirectly fund a renewable energy project while receiving "green attributes". For lenders, benefits include revenue certainty as a specific amount of energy has been pre-sold at a set price, and they can claim their contribution to the renewable energy industry. (Pexapark, n.d.)

Most corporate PPAs in South Africa are fixed-price agreements, meaning the price is agreed on upfront and remains constant throughout the contract's duration. PPAs typically require a long term (15-20 years) to ensure the project is fully paid off and returns are met, while keeping the price per kWh attractive to buyers. However, this also comes with risks related to long-term market stability, developer viability, and compliance with regulatory changes.

For some companies with shorter business strategies, a long-term PPA may not be suitable. Large buyers and their financiers must carefully consider factors like business stability, potential bankruptcy, or technological changes.

Key considerations for funding/bankability in PPAs include:

1. No sovereign guarantee for private projects.
2. The form of take or pay obligations.
3. Heavy reliance on the financial strength of the electricity buyers (off-takers).
4. Uncertainty over how excess energy will be managed if the generator produces more electricity than the off-taker requires due to Eskom constraints.

Under pathway #2 (and pathway #3), businesses are not dependent on the "greenness" of the grid to decarbonise and have significantly more control over their transition to greener sources of energy. In the case of an off-site, grid-connected RE source, businesses do not have the possibility of also using the system to alleviate loadshedding when needed although they are less exposed to increases in the Eskom/municipal tariff.[7] Assuming the business makes no investment in low-carbon production technologies then the carbon tax is inversely proportional to the amount of renewable energy procured.

Table 3: Key costs associated with pathway #2

COSTS: OFF-SITE GRID CONNECTED RE SYSTEM	
PPA	**Capital investment (own system)**
PPA tariff (RE)	DevEx and CapEx (plant)
Capacity charges	Operation and maintenance (O&M)
Energy charges (Generation – Gx)	Capacity charges
Energy charges (Distribution – Dx)	Energy charges (Gx)
Carbon tax	Energy charges (Dx)
	Wheeling charges
	Carbon tax

If a business decides to invest directly in its own solar PV plant, it will then need to finance the investment through debt and/or equity to cover the development and capital expenditures associated with building the plant and fund the ongoing O&M costs associated with running the plant. These expenditures also include the cost of building a direct line in the case of investing in an off-site, directly connected RE system. The overall cost of a dedicated line depends primarily on the length of the line as well as pole spacing, pole heights, line ratings, river crossings and other topographical obstacles (Miranda et at., 2017). Underground lines are considerably more expensive than overhead lines.

Pathway #2 offers businesses the potential to transform their energy mix and decarbonise much faster than pathway #1. Energy savings are higher and carbon taxes are currently almost always less than what businesses would pay under pathway #1 if, as is the case in South Africa, a substantial portion of the national energy mix is generated by fossil fuels and transition to renewable sources of energy is slow. Ultimately, however, off-site, grid-connected systems rely on existing grid infrastructure and the ability of particular grid networks to absorb additional capacity – while billing and other complications may arise if the electricity is wheeled via both Eskom-owned and municipal networks. Businesses are also exposed to investment risk and longer time horizons if they decide to invest directly in the RE system. This risk increases in the case of off-site, directly connected systems requiring a dedicated line.

2.3 Pathway #3 – Procurement of on-site sources of RE generation

The final adoption pathway reflects the procurement of RE via an on-site or "behind-the-meter" (BTM) source of generation. As with pathway #2, businesses could decide to invest in the system themselves or to purchase the electricity generated via a PPA with the IPP/generator. Unlike "front-of-meter" systems, BTM systems are able to provide RE directly to businesses without going through an electric meter and interacting with the electric grid. (Marsh, 2023).

Under pathway #3, businesses are less exposed to increases in the Eskom/municipal tariff and, unlike off-site grid connected RE systems, no wheeling charges would apply. As with pathway #2, the carbon tax is inversely proportional to the amount of RE installed, assuming no new investments are made in

[7] Since electricity is generated from a grid-connected system and therefore transported along the transmission/ distribution networks, the system cannot be used to provide electricity during loadshedding.

green production technologies. Because the RE generated electricity is used where it is generated, the losses are much lower than under pathway #1 and pathway #2. Businesses are also able to exert more control over the installation of on-site RE systems with shorter decision-making times. (Businesses that install BTM systems are also less reliant on the existing grid infrastructure and could therefore use the system to protect their business from loadshedding and its associated costs.)

While pathway #3 potentially offers businesses the fastest route to transform their energy mix, energy bill savings, the carbon tax payable, and loadshedding costs all depend on the capacity of the installed system, which in turn depends on the space available on-site on which to install the PV panels. Unlike mining houses, for example, that typically have the space to install ground-mounted RE systems on-site, this is not an option for many small or medium-sized companies located in an urban industrial area. Consequently, PV systems are often installed on the roofs of factories or as solar carports to maximise the space available for RE generation. Given the limited space available, the installation of an on-site/ BTM RE system is also likely to include a BESS so that energy generated by the system during periods of low demand can be stored for use during periods of high demand, resulting in an increase in the consumption of RE beyond the installed capacity of the system. In most cases, however, typical battery solutions for businesses can only absorb the extra midday sun and use it earlier and later as opposed to storing surplus solar energy generated on the weekend (assuming no weekend production runs) for use during the week.

Table 4: Key costs associated with pathway #3

COSTS: ON-SITE / BTS RE SYSTEM	
PPA	**Capital investment (self-owned system)**
PPA tariff (RE)	DEVEX and CapEx (plant)
Capacity charges	CapEx (BESS)
Energy charges (Gx)	O&M (plant and BESS)
Energy charges (Dx)	Capacity charges
Carbon tax	Energy charges (Gx)
	Energy charges (Dx)

Like pathway #2, pathway #3 offers businesses the potential to transform their energy mix and decarbonise much faster than pathway #1. Depending on the size of the system, energy bills and carbon tax savings can be significant and businesses that procure RE via this pathway are not reliant on the grid for their RE. Complications arising from wheeling energy via different networks is not an issue as electricity is not wheeled and the costs associated with loadshedding can be avoided entirely if the business invests in an integrated solar PV-BESS that can meet total demand by load shifting. However, space remains the major constraint to scaling up and, over the short term at least, the total cost of an integrated system that can take a business entirely off-grid may be out of the reach of many small and medium-sized companies.

3. CORE ASSUMPTIONS

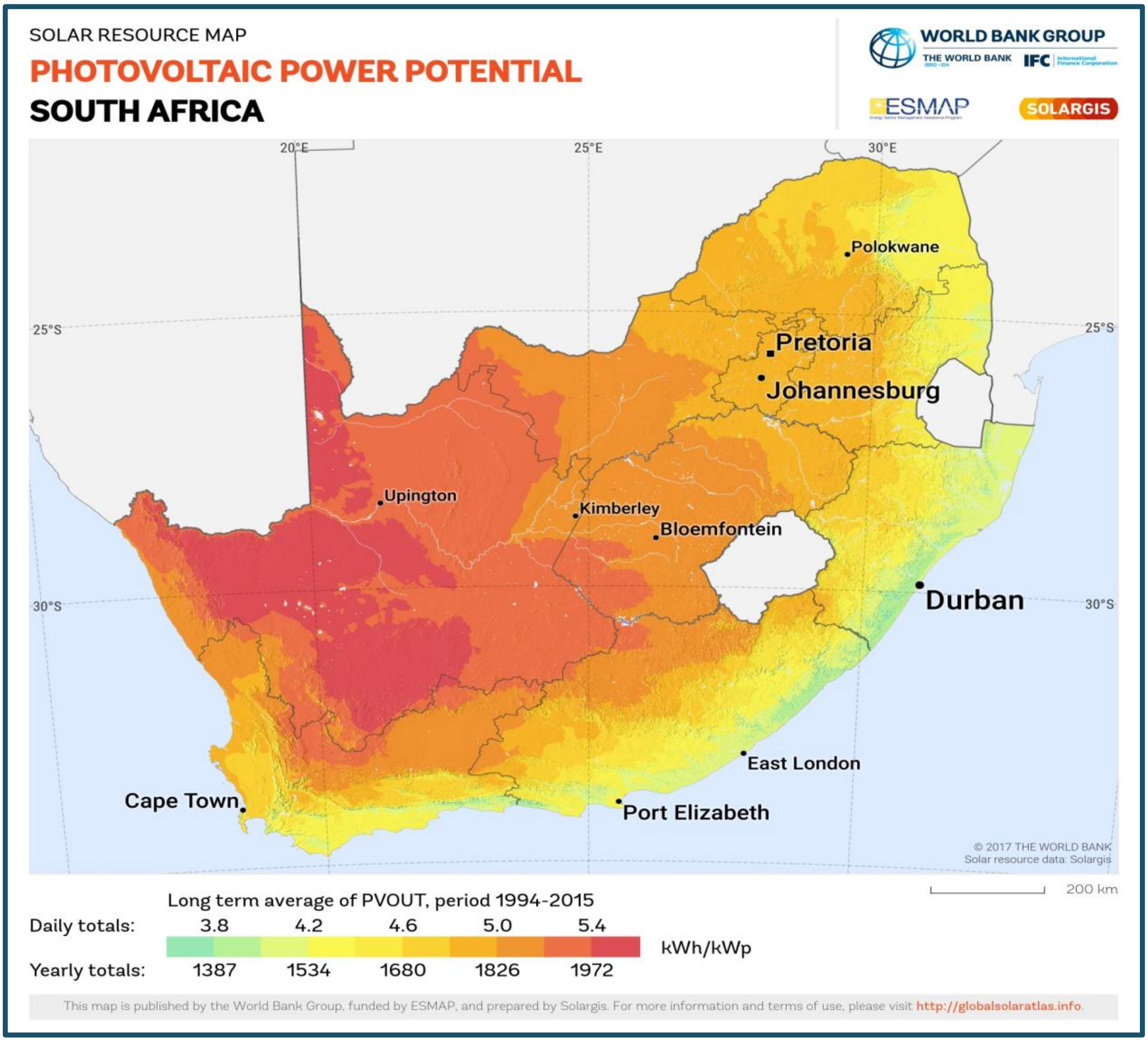
In addition to the input values (see Annex 1), the model relies on a number of core assumptions to quantify each adoption pathway in terms of, inter alia, system cost, commercial viability (NPV), and savings on the utility bill and carbon tax. These core assumptions are made with respect to PV generation, the representative firm (consumer of electricity), underlying tariff structures for Eskom and municipal customers, carbon tax, capacity and battery sizing, capital cost of PV and batteries, and generation location, voltage connection, and feedback. The remainder of Section 3 describes each of these core assumptions in more detail.

3.1 PV Generation

The amount of electricity produced by a PV installation relies on various factors, including the geographical location, the orientation and inclination (tilt) of the panels, the mounting method (rooftop or free-standing), and the presence of shading caused by nearby structures or mountains. In general, South Africa offers good solar potential for PV electricity generation.

When a ground-mounted PV system is optimally inclined in Gauteng, it can generate an average of 1 700kWh per year per kWp installed. Similarly, an optimally inclined system in Cape Town will produce around 1 550 kWh per year per kWp, and in Durban it will generate approximately 1 400 kWh per year per kWp. (See Figure 1).

Figure 1: Solar PV Electricity generation potential for South Africa



© 2020 The World Bank. *Source*: Global Solar Atlas 2.0, Solar resource data: Solargis. https://solargis.com/maps-and-gis-data/download/south-africa

The inclination at which the PV panels are installed plays a crucial role in electricity generated. The optimal tilt angle is based on the location relative to the equator. Closer to the equator, the most electricity is generated if the PV is installed at tilt angles closer to the horizontal, while the further away the installation is from the equator, the tilt angle will have to be increased to generate more electricity.[8]

For the sake of simplicity, the PV generation figures used in this report are derived from hourly solar production figures for optimally inclined north-facing rooftop and ground-mounted orientations only. In other words, for rooftop PV, it is assumed that the representative firm (see below) is optimally positioned to maximise the amount of solar PV that is able to be generated given its location.

Consequently, for businesses that are either unable to install ground-mounted solar or have non-optimal roof orientations and/or rooftop tilt, the model would overstate the amount of kWh generated by the PV and the percentage of green electricity generated by self-owned PV systems. Therefore, it is important to consider the relative values when comparing the different pathways and avoid focusing too much on absolute values since the significance of the results lies in the narrative conveyed rather than the exactness of the data.

3.2 Representative firm

Because annual hourly solar data is used, annual hourly load data for a representative firm was simulated by taking the average of the electrical machinery and apparatus, transport equipment, and furniture sectors (respectively SIC 36, 38, and 39) normalised for a peak demand of 250kVA. While industry accounts for roughly half of total energy demand in South Africa (DMRE, 2022), firms in these sectors, on the whole, are neither energy-intensive nor particularly low-energy users.

Figure 2: Annual load curve for electrical machinery and apparatus (SIC 36)

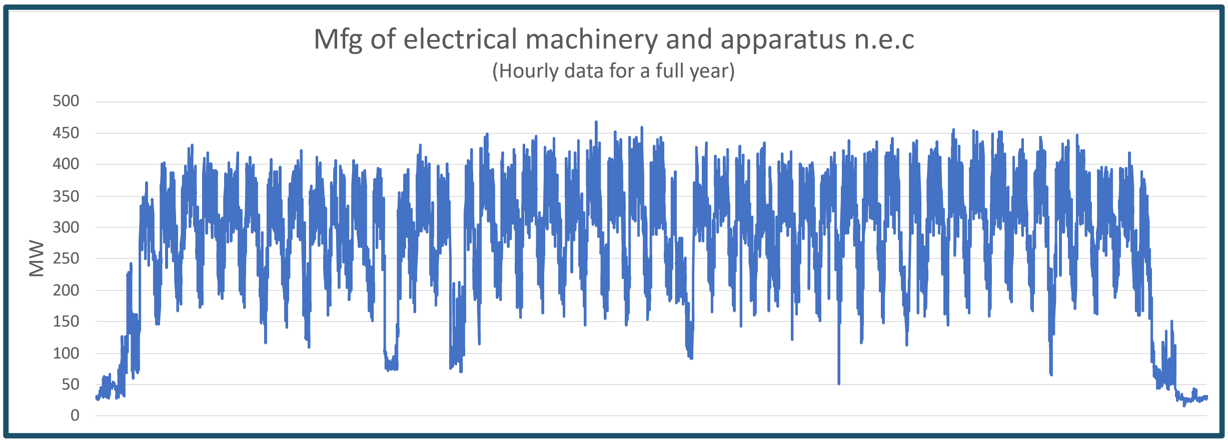
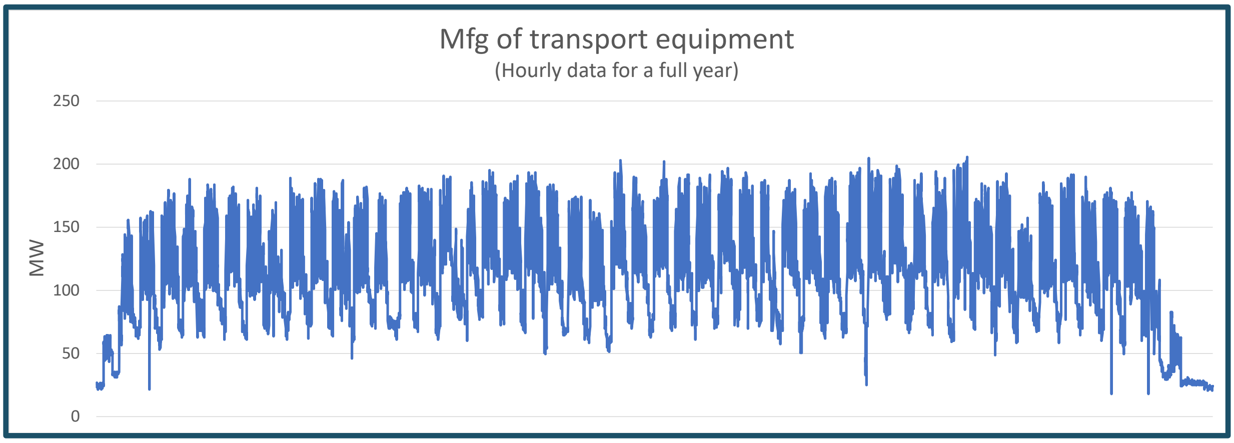
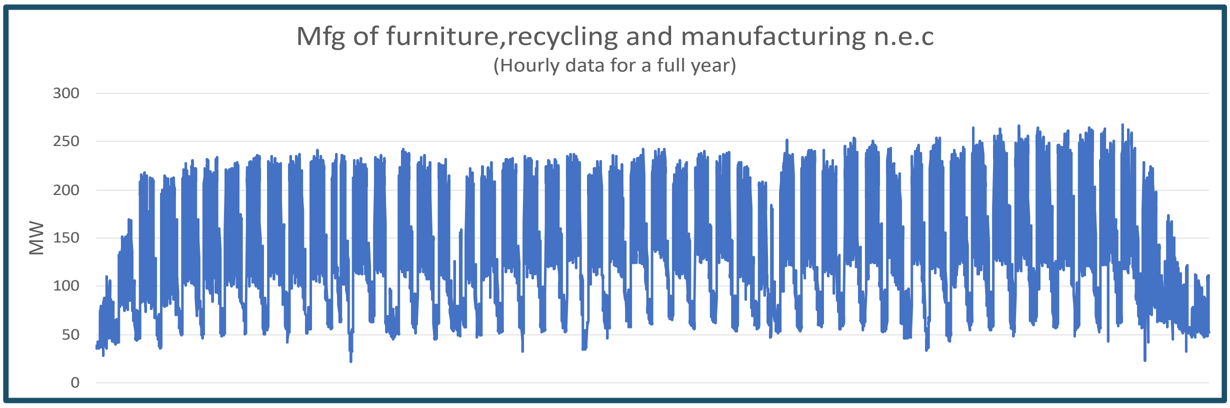


Figure 3: Annual load curve for transport equipment (SIC 38)



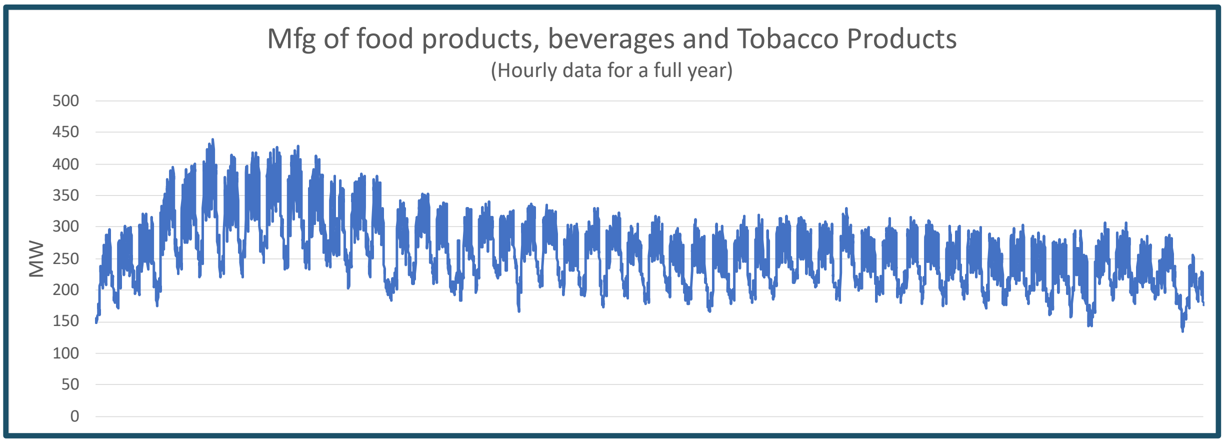
[8] The optimal generation potential from PV systems is achieved with solar tracking, which allows panels to follow the sun's path throughout the day. However, in the current context, this is not considered – this report only focuses on fixed-mount PV installations. While tracking systems can significantly increase energy output, fixed-mount PV setups are more commonly used due to their simplicity and lower costs.

Figure 4: Annual load curve for furniture, recycling and manufacturing (SIC 39)



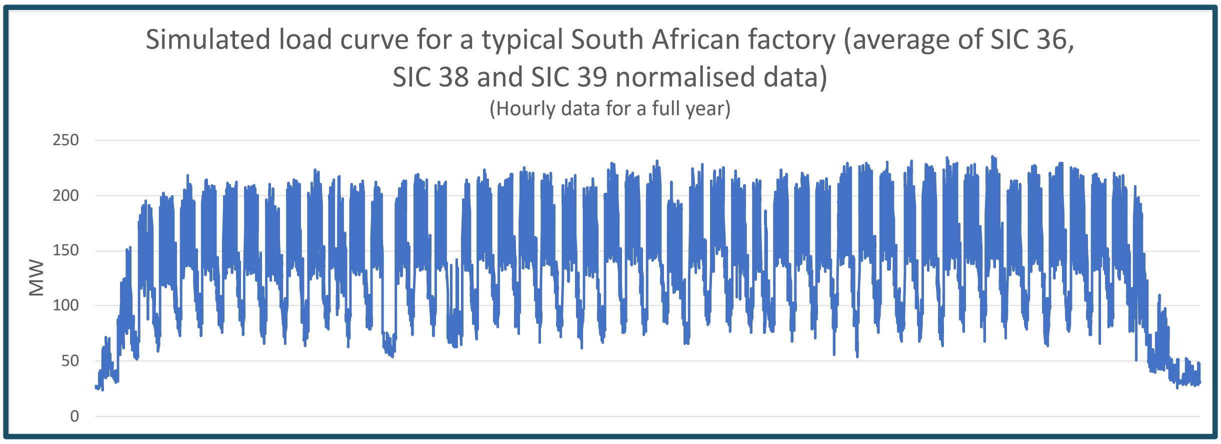
Energy-intensive industries such as petroleum and chemicals were excluded in favour of industries with more moderate load profiles. The load profile of the food and beverage industry (see Figure 5) was also excluded because this industry tends to operate over weekends and public holidays, and hence would skew the calculated average load profile.

Figure 5: Annual load curve for food products, beverages and tobacco products (SIC 30)



Load data per SIC was obtained from Eskom energy forecasters and normalised by dividing the hourly load by the maximum demand for each industry for every hour. The average of this multiplied by 250 is then taken as the load curve for a "typical" factory. This provides with an average, normalised load curve that has a maximum demand of 235kW. The NMD is taken as the maximum demand plus 10%. See Figure 6.

Figure 6: Simulated annual load curve based on normalised data of SIC 36, SIC 38 and SIC 39



3.3 Tariff

The consumption of solar PV-generated electricity leads to significant savings on the electricity bill. This is a well-established fact, confirmed by numerous studies that have highlighted the cost-effectiveness of solar PV systems, especially in the context of substantial nominal increases in the average electricity tariff charges by the state-owned utility, Eskom, since 2007. (Walsh, 2023). In many cases, the payback period for solar PV installations is less than five years, further bolstered by an accelerated depreciation allowance under Section 12B of the Income Tax Act No. 58 of 1962 of 125% in the first year for all renewable energy investments brought into use for the first time between 1 March 2023 and 28 February 2025. The combination of the low cost of solar PV and favourable financial incentives contributes to an attractive return on investment for businesses.

A summary of the main tariff structures applicable to Eskom and municipal industrial customers in Ekurhuleni and Cape Town is provided below (see Table 5 and Table 6).[9] The daily charges range from just over R90 a day for Ekurhuleni municipal customers[10] to just under R150 a day for Eskom customers. The demand charges range from just under R50 per kVA per month for Eskom customers to almost R270 per kVA per month for Ekurhuleni municipal customers in the high demand season. The active energy charge ranges from just under R1 per kWh for Eskom customers in the low demand season to over R6 per kWh for Eskom customers in the high demand season.

Similarly, there is also a wide range in tariffs for the electricity that is fed back to the grid, ranging from 65c per kWh for Eskom customers in Cape Town in the low demand season to R4.43 per kWh for Eskom customers in Ekurhuleni in the high demand season at peak times (note that the sun is unlikely to shine at these times). See Table 5 for a summary of the applicable electricity tariffs for loads and Table 6 for the relevant tariffs for generated electricity that is exported to the grid.

Table 5: Electricity tariffs for loads

CHARGE	CAPE TOWN		EKURHULENI	
	ESKOM	METRO	ESKOM	METRO
Per day	R148.46	R133.69	R148.46	
Per month				R2 800.21
Per kVA NMD per month – low season	R47.26	R219.93	R47.26	R233.06
Per kVA NMD per month – high season	R47.26	R219.93	R47.26	R267.64
kWh Peak high season	R6.22	R5.15	R6.06	R2.77
kWh Standard high season	R2.19	R1.82	R2.15	R2.77
kWh Off-Peak high season	R1.10	R1.16	R1.08	R2.77
kWh Peak low season	R2.32	R1.93	R2.28	R1.66
kWh Standard low season	R1.74	R1.45	R1.71	R1.66
kWh Off-Peak low season	R0.97	R1.05	R0.96	R1.66

[9] To calculate the utility bill for a representative factory in Gauteng and the Western Cape, Ekurhuleni's Tariff C and the City of Cape Town's Large User Low Voltage Time of Use tariff is used in the case of municipal customers, and Eskom's Miniflex tariff for non-local authority Eskom customers. All three tariffs are NERSA-approved for 2022/23, available for industrial customers, and involve Time-of-Use pricing that is higher in peak periods and lower in off-peak periods to incentivise customers to lower peak loads. All tariffs are excluding VAT.
[10] Ekurhuleni has a monthly charge that has been converted to a daily amount for this report.

Table 6: Electricity tariffs for generators

CHARGE	CAPE TOWN		EKURHULENI	
	ESKOM	METRO*	ESKOM	METRO
kWh Peak high season	R4.26	R0.86	R4.43	R1.19
kWh Standard high season	R1.32	R0.86	R1.37	R1.19
kWh Off-Peak high season	R0.74	R0.86	R0.77	R1.19
kWh Peak low season	R1.42	R0.86	R1.48	R0.82
kWh Standard low season	R0.99	R0.86	R1.03	R0.82
kWh Off-Peak low season	R0.65	R0.86	R0.67	R0.82

Note: *To be paid to customers who wish to retain/claim the green attributes of the energy exported and sold to the City of Cape town plus the SSEG Feed-in Incentive of 25c per kWh applicable until 30 June 2025.

Note that the analysis does not assume any fundamental changes to the structure of any of the tariffs, such as a revised structure that would significantly increase the fixed charges *vis-à-vis* the (variable) energy charges. Such a rebalancing will have different implications for the relative costs and savings of each adoption pathway to the implications that are made based on current tariff structures. Meridian Economics delved into the issue in some detail in a 2022 briefing note and concludes the following:

> *"... under the current tariff structure... there is sufficient margin above the market range to state with confidence that a customer could achieve a meaningful saving on their electricity bill for both PV and wind wheeling projects. In other words, it is very likely that a customer will be able to secure a PPA price required that will realise at least a 10% discount on their electricity bill. However, for the overnight change in tariff structure... there is a ~25% decrease in the value of PV energy that is wheeled, and a ~15% decrease in the value of wheeled wind energy. Realising a meaningful saving... would require the customer to source a PPA price which is less likely to be available in the market for a number of years."* – Steyn et al., 2022

If, for example, a rebalancing of the Eskom tariff structure is ultimately approved by NERSA, this would then have implications for both the tariff Eskom charges local authorities as well as the tariffs that municipalities charge to their customers (residential and commercial). For a given PPA price and capital cost of PV and batteries, utility bill savings and thus the commercial viability of PV would change as well as the commercial viability of pathways #2 and #3 relative to pathway #1.

3.4 Carbon tax

Depending on the rate, the carbon tax estimated by the model can be considered a proxy for either a domestic or international tax levied on the carbon dioxide equivalent emissions required to produce a good (or service). For pathway #1 (BAU), the carbon tax is calculated by multiplying the product of the total kWh the representative factory receives from the utility (Eskom/municipality) and the electricity grid emission factor for South Africa (measured in kilograms of CO_2 equivalent per kWh) by the relevant rate.

For pathway #2 and pathway #3, the calculation of the carbon tax is slightly different because the representative firm directly procures RE in some form. Hence, the carbon tax for these pathways is calculated by multiplying the product of the total kWh the representative factory receives from the utility (Eskom/municipality) after PV and the electricity grid emission factor for South Africa by the relevant rate. (It should be noted that the carbon tax calculated for pathway #2 and pathway #3 does not take into account the carbon intensity of solar PV systems since this is negligible compared to the grid emission factor.)

For the purposes of this study, it is assumed that production technology is constant; in other words, the representative firm does not make any improvements in lower carbon production technologies. If this were the case, the carbon tax for all three pathways would be lower than that estimated by the calculator, although the relative costs would remain the same unless the adoption of RE under pathway #2 and pathway #3 was made in conjunction with an investment in green production technology.

3.5 Capacity and battery sizing

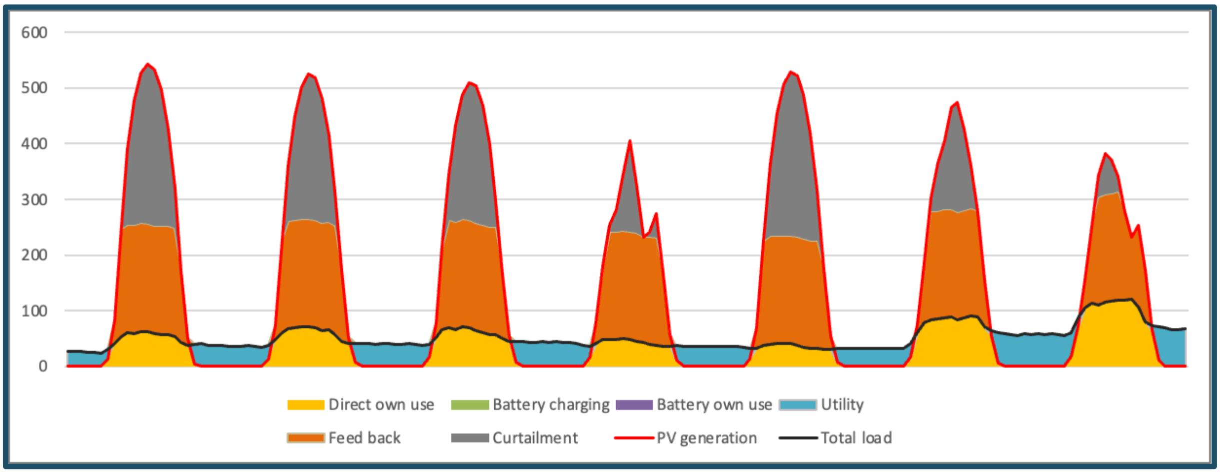
As per 097-2-3:2023 Edition 2 (NRS Association, 2023), the installation size of solar PV is no longer limited; however, the electricity that can be exported to the grid is limited to a maximum of 75% of the Notified Maximum Demand.[11] The study therefore considers three solar PV installation sizes: 75% of the NMD, 100% of the NMD, and 100% of the annual electricity consumption of the business in kWh.

The representative firm has a NMD of 259 kW and uses 1 181 947 kWh per year. This means that a solar PV installation of 75% of NMD will have a maximum output of 194kWp. Similarly, a PV installation of 100% of NMD will have a maximum output of 259kWp while a system sized to generate 100% of the annual electricity consumption of the business will need to equate to a maximum output of 663kWp in Cape Town and 585kWp in Ekurhuleni (i.e., the installation must be larger in Cape Town than in Ekurhuleni to generate the same amount of kWh used by the business in a year).

The alignment of PV generation with the electricity load presents both a conundrum and an opportunity for energy storage and grid feedback. Solar PV generation primarily occurs during daylight hours when the sun is shining, which may not perfectly match the timing of electricity demand. This creates a challenge as surplus PV-generated electricity may need to be curtailed or wasted when it exceeds immediate consumption. To address this issue, a BESS can be employed to store excess energy for later use, thereby maximising self-consumption and reducing reliance on the grid.

Furthermore, a BESS allows for feedback to the grid during periods of high demand, contributing to grid stability and potentially earning revenue through feed-in tariffs or other incentive programmes. As illustrated in the figures below, balancing the coincidence of PV generation and load through efficient energy storage solutions enables better utilisation of renewable energy and enhances the overall effectiveness and sustainability of the electricity system. By better utilising renewable energy procured/ generated, a BESS also lower the carbon tax for a given production technology.

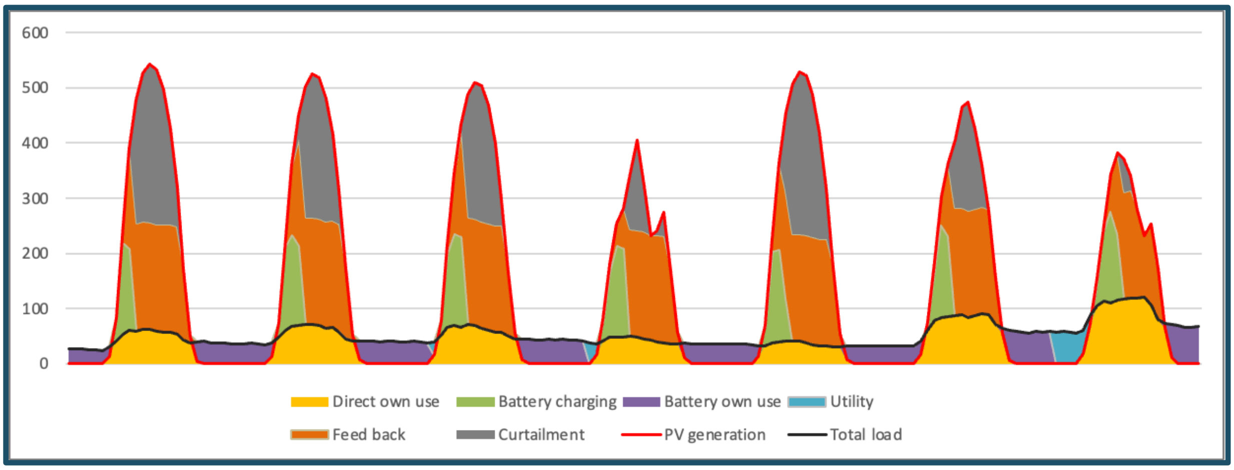
Figure 7: Electricity generation from a 663kWp PV installation without batteries in Cape Town (annual electricity generated from the PV = annual electricity use) in a low demand week



Source: Own analysis.

[11] NMD is based on the requirements of the customer and the capacity of the network reserved for that customer's use under normal system conditions in all time periods. Consumers of electricity (loads) apply for NMD while generators apply for maximum export capacity, or MEC. (NERSA, n.d.)

Figure 8: Electricity generation from a 663kWp PV installation with a 166kVA/498kWh battery in Cape Town (annual electricity generated from the PV = annual electricity use) in a low demand week



Source: Own analysis.

For each installation size, the size of the battery in kVA is assumed to be 25% of the installation size measured in kWp. It is important to note that a BESS is only considered for pathway #3. Pathway #2 does not consider battery energy storage since it assumes no constraints on the feedback of generated electricity.

3.6 Capital cost of PV and batteries

When a business invests in its own (off-site or on-site) solar PV system, all the capital expenses incurred in installing the system are borne by the business. This includes the cost of equipment (such as solar panels, inverter, cables, brackets, switches) as well as design and construction costs such as labour, permits and licences, logistics and insurance, and development fees. By owning the system, businesses have greater control over the build/installation as well as the type of technology used and the quality of the components. They can also take advantage of any accelerated depreciation benefits that may be offered by the relevant tax authority. While it does not usually take very long for owners to recover their investment, they are exposed to all the risks involved in operating and maintaining the PV system.

The capital costs of installing a PV system depend on whether it is off-site or on-site, and the type of system being installed (i.e., ground-mounted or rooftop). Economies of scale that can typically be achieved by large off-site systems, combined with space limitations and other complexities of on-site PV installation, generally make the per kWp cost of installing an on-site system more expensive than a system installed off-site – although this is not always necessarily the case. To keep things simple, the same installation cost per kWp for an on-site PV system versus an off-site PV system is assumed. In addition, it is assumed that the maintenance cost of a self-owned system is 1% of the capital expense incurred to install the system (CapEx) and that self-owned systems are entirely debt funded and repaid over a period of 10 years in equal annual instalments.

While the cost of batteries differs widely according to size and manufacturer (and length of guarantee) wider deployment and the increased commercialisation of of new battery storage technologies has led to rapid cost reductions in the price of lithium-ion batteries since 2014 (IRENA, n.d.), increasing the commercial viability of integrated PV-BESS systems that are able to significantly increase RE consumption relative to installed PV capacity. For the purposes of this study, a battery cost of R7 000 per kWh is assumed.

3.7 Generation location, voltage connection, and feedback

Three further assumptions are made with respect to the location of RE generation vis-à-vis the offtaker (firm), voltage connection, and feedback. In the case of off-site RE generation, it is assumed that the offtaker is located within 300km of the generator (PV plant). In addition, it is assumed that the voltage connection is less than 500 volts and that feedback is allowed (i.e., any excess electricity produced can be fed back into the grid). All these factors will influence the cost of supplying electricity, and therefore the tariff charges, but they do not fundamentally alter the carbon tax. In the absence of a carbon tax (and in a world without loadshedding), changing these assumptions will either increase or decrease the viability of pathway #1 relative to pathway #2 and pathway #3. However, regardless of what assumptions are made with respect to location, connection and feedback, the introduction of a carbon tax will significantly reduce the viability of pathway #1.

3.8 Summary

The following table summarises the core assumptions used in this study.

Table 7: Core assumptions

ISSUE / ITEM	ASSUMPTION
PV GENERATION	• The representative firm is optimally positioned to maximise the amount of solar PV that is able to be generated given its location.
LOAD DATA FOR A REPRESENTATIVE FIRM	• Annual hourly load data for a representative firm is simulated by taking the average annual hourly load data for the electrical machinery and apparatus, transport equipment, and furniture sectors (respectively SIC 36, 38, and 39) normalised for a peak demand of 250kVA.
TARIFF	• For a representative factory in Gauteng and the Western Cape respectively, the following NERSA-approved industrial tariffs for 2022/23 are assumed for municipal customers: Ekurhuleni “Tariff C” and City of Cape Town “Large User Low Voltage Time of Use” tariff. For non-municipal customers, the Eskom Miniflex tariff is assumed.
CARBON TAX	• For pathway #1 (Business as Usual), the carbon tax is calculated by multiplying the product of the total kWh the representative factory receives from the utility (Eskom/municipality) and the electricity grid emission factor for South Africa (measured in kilograms of CO2 equivalent per kWh) by the relevant rate. • For pathway #2 and pathway #3, the carbon tax for these pathways is calculated by multiplying the product of the total kWh the representative factory receives from the utility (Eskom/municipality) after PV and the electricity grid emission factor for South Africa by the relevant rate. • The carbon tax calculated for pathway #2 and pathway #3 does not take into account the carbon intensity of solar PV systems as this is negligible compared to the grid emission factor.
CAPACITY AND BATTERY SIZING	• Three solar PV installation sizes are assumed: 75% of the NMD; 100% of the NMD; and 100% of the annual electricity consumption of the business in kWh. • For each installation size, the size of the battery in kVA is assumed to be 25% of the installation size measured in kWp. • BESS is only considered for pathway #3. Pathway #2 does not consider battery energy storage since it assumes no constraints on the feedback of generated electricity.

CAPITAL COST OF PV AND BATTERIES	• It is assumed there is no difference in the installation cost per kWp for an on-site PV system versus an off-site PV system. • The maintenance cost of a self-owned system is assumed to be 1% of the capital expense incurred to install the system and that self-owned systems are entirely debt funded and repaid over a period of 10 years in equal annual instalments.
GENERATION LOCATION, VOLTAGE CONNECTION, AND FEEDBACK	• In the case of off-site RE generation, it is assumed that the offtaker is located within 300 kilometres of the generator (PV plant). In addition, it is assumed that the voltage connection is less than 500 volts, and that feedback is allowed (i.e., any excess electricity produced can be fed back into the grid).

4. RESULTS AND OBSERVATIONS

This section provides an estimated quantification of each pathway (pathway #1 – procurement of RE as an existing Eskom/municipal customer; pathway #2 – procurement of off-site, grid-connected sources of RE; pathway #3 – procurement of on-site sources of RE generation) for three different sized PV systems (75% of the NMD, 100% of the NMD, and 100% of the annual electricity consumption of the business in kWh) across a range of indicators, including electricity generation, total system cost, commercial viability (NPV), area needed for PV installation, utility bill, and carbon tax. For each pathway, commercial viability is depicted as positive or negative NPV according to the following scale:

<0	-
0 - 5 million NPV	+
5 - 20 million NPV	++
> 20 million NPV	+++

Since NPV is not differentiated by the electricity distributer or supplier (Eskom Distribution or the metro), NPV is depicted as a combination of different ranges (e.g., + / ++). In some cases, NPV is depicted as both negative and positive. So, for example, - / +++ means that the NPV for a particular system (self-owned or PPA) ranges from a (small) negative value to a value greater than R20 million, depending on the location of the business. This, often significant, variability in the commercial viability is mostly due to the differences in the applicable electricity tariff structures.[12]

The carbon tax payable in the first year under each pathway is shown for three different rates:

- R190 per ton – the rate of domestic carbon tax for 2024, as per the Taxation Laws Amendment Act, 2022 (Act No. 20 of 2022). (Republic of South Africa, 2023).
- R462 per ton – the rate of domestic carbon tax for 2030 as per the Taxation Laws Amendment Act, 2022 (Act No. 20 of 2022). (Republic of South Africa, 2023).
- 90 Euros per ton – the carbon price suggested by the International Energy Agency (IEA) for developing countries for 2030. (IEA, 2023b).

The remainder of the section is set out as follows: Section 4.1 presents the observations and tables of results for each pathway for a 194kWp PV installation (75% of NMD). Section 4.2 presents the observations and tables of results for each pathway for a 259kWp installation (100% of NMD). Section

[12] An electricity tariff with comparatively higher active energy charges, and/or comparatively higher rates paid for electricity exported to the grid, will result in a higher comparative NPV.

4.3 presents the observations and tables of results for a 585kWp installation (100% annual electricity consumption).

4.1 Size 1: 194kWp installation (75% of NMD)

Observations are presented first under four headings: (1) the area required for the PV system; (2) financial/commercial viability; (3) carbon tax; (4) and curtailment. Four tables of results on which the observations are based follow: two for a representative firm in Ekurhuleni (with and without a BESS) and two for a representative firm in Cape Town (with and without a BESS).

Observations

Area required for PV system

- The total estimated area to install a PV system with an installed capacity of 75% of NMD is 1 454m^2. (Approximately a fifth of a rugby field.)

Financial / commercial viability

- The total cost of a self-owned, 194kWp PV system (75% of NMD) is approximately R2.9 million. When a BESS of 48kVA145kWh is added to this, the cost rises to R3.9 million. (In other words, adding a BESS of this size constitutes roughly one quarter of the total cost of an integrated PV system sized at 75% of NMD)
- The NPV for pathway #1 is uniformly negative relative to pathway #2 and pathway #3. While there is no capital outlay under pathway #1, businesses are fully exposed to increases in the electricity tariff, receive no direct tax benefits for self-owned PV systems, and ceteris paribus, will also pay more in carbon taxes than they would if they adopted PV under either pathway #2 or pathway #3 (see below).
- For pathway #2, NPVs are uniformly positive and range between R800 000 and R33.5 million. Total NPV variability is high in both locations (> R30 million) but lowest for a firm in Gauteng (Ekurhuleni) investing in its own system (approximately R3.9 million) followed by a firm in Cape Town procuring RE via a PPA (approximately R5.7 million).
- For pathway #3, NPVs are uniformly positive and range between R7.4 million and R35.3 million. Total NPV variability is much higher in Gauteng (Ekurhuleni) than in Cape Town (R25.4 million without BESS and R26.9 million with BESS in Gauteng versus R900 000 without BESS and R4.4 million with BESS in Cape Town). NPV variability is lowest for a firm in Cape Town procuring RE via a PPA with or without a BESS (approximately R200 000). This implies that the underlying tariff structure for a representative firm in Cape Town is structured similarly to the applicable Eskom tariff.

Carbon tax

- The domestic carbon tax payable by a representative firm in the first year is highest under pathway #1 (approximately R230 000 @ R190 per ton) as there are no additional savings from the mitigation of carbon by RE.
- The carbon tax payable in the first year falls under pathway #2 and pathway #3 when compared to pathway #1 (i.e. the procurement of RE, regardless of the adoption pathway, will reduce the amount of carbon tax payable for a given production technology and price of carbon).
- The carbon tax is lower for pathway #2 for a representative firm in Gauteng (approximately R160 000 @ R190 per ton versus approximately R170 000 @ R190 per ton for a representative firm in Cape Town as more RE is generated in Gauteng for the same size of installation due to higher solar irradiance).

- Under pathway #3, the carbon tax is lower with a BESS than without a BESS. However, in both cases the tax is still higher than it is under pathway #2 because more of the RE that is generated is used. (Under pathway #3 the possibility of curtailment is higher due to limitations on immediate own use, limitations on the BESS size, and size of the grid connection.)
- For all three pathways, a rise in the price of carbon leads to an equivalent increase in the carbon tax for a given production technology.

Curtailment

- There is no curtailment under pathway #3 because all of the RE generated electricity can either be self-consumed or exported to the grid without exceeding capacity limitations.

Results tables

Table 8 presents the results generated for each adoption pathway for a representative firm in Ekurhuleni sourcing electricity from a PV system sized at 75% of NMD with a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 8: RE generation and carbon reduction: Ekurhuleni, 194kWp installation (75% of NMD) – with 48kVA/145kWh battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	790	810
Self-consumption + exports (kWh)	MWh		390	390
Self-consumption (kWh)	MWh		390	370
Exported to the grid (kWh)	MWh			20
Curtailed (kWh)	MWh			–
System cost and total area				
Total system cost (including tax benefit)	ZAR '000s		2 900	3 900
Total area needed for installation (m^2)	m^2		1 454	1 454
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	-	+ / ++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	-	+ / ++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	-	++ / +++	++ / +++
NPV (Munic, PPA)	ZAR '000s	-	++ / +++	++ / +++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 000 – 3600	2 500 – 3 000	1 700 – 2 200
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 000 – 3 600	1 700 – 2 600	1 700 – 2 200
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	160	160
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	380	390
Y1 carbon tax (export, 90 Euros per ton)	ZAR '000s	2 210	1 480	1 520

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 (Year 1) utility bill for Eskom vs municipal customers only.

Table 9 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 75% of NMD without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 9: RE generation and carbon reduction: Cape Town, 194kWp installation (75% of NMD) – no battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	840	860
Self-consumption + exports (kWh)	MWh		350	350
Self-consumption (kWh)	MWh		350	320
Exported to the grid (kWh)	MWh			30
Curtailed (kWh)	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		2 900	2 900
Total area needed for installation (m^2)	m^2		1 454	1 454
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	+ / ++	+++
NPV (Munic, self-owned)	ZAR '000s	–	+ / ++	+++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s	–	+++	+++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	2 200 – 3 400	2 000
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	1 800 – 2 100	2 000
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	170	170
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	400	410
Y1 carbon tax (export, 90 Euros per ton)	ZAR '000s	2 210	1 570	1 620

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 10 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 75% of NMD with a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 10: RE generation and carbon reduction: Cape Town, 194kWp installation (75% of NMD) – with 48kVA/145kWh battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	840	850
Self-consumption + exports (kWh)	MWh		350	340
Self-consumption (kWh)	MWh		350	330
Exported to the grid (kWh)	MWh			20
Curtailed (kWh)	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		2 900	3 900
Total area needed for installation (m^2)	m^2		1 454	1 454
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	+ / ++	+++

NPV (Munic, self-owned)	ZAR '000s	–	+ / ++	+++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s	–	+++	+++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	2 200 – 3 400	2 000
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	1 800 – 2 100	2 000
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	170	170
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	400	410
Y1 carbon tax (export, 90 Euros per ton)	ZAR '000s	2 210	1 570	1 600

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

4.2 Size 2: 259kWp installation (100% of NMD)

Observations are presented first under four headings: (1) the area required for the PV system; (2) financial/commercial viability; (3) carbon tax; (4) and curtailment. Four tables of results on which the observations are based follow: two for a representative firm in Ekurhuleni (with and without a BESS) and two for a representative firm in Cape Town (with and without a BESS).

Observations

Area required for PV system

- The total estimated area to deliver renewable energy at 100% of NMD is 1 939 m^2. (Approximately a quarter of a rugby field.)

Financial / commercial viability

- The total cost of a self-owned, 259kWp PV system (100% of NMD) is approximately R2.9 million. When a BESS of 65kVA /195kWh is added to this, the cost rises to R5.2 million. (In other words, adding BESS of this size constitutes roughly one quarter of the total cost of an integrated PV system sized at 100% of NMD.)
- The NPV for pathway #1 is uniformly negative relative to pathway #2 and pathway #3. While there is no capital outlay under pathway #1, businesses are fully exposed to increases in the electricity tariff, receive no direct tax benefits for self-owned PV systems and, ceteris paribus, will also pay more in carbon taxes than they would if they adopted PV under either pathway #2 or pathway #3 (see below).
- For pathway #2, NPVs are uniformly positive and range between R400 000 and R36.1 million. Total NPV variability is high in both locations (> R30 million) but lowest for a firm in Gauteng (Ekurhuleni) investing in its own system (approximately R4.3 million) followed by a firm in Cape Town procuring RE via a PPA (approximately R6.4 million).
- For pathway #3, NPVs are uniformly positive and range between R8.7 million and R38.2 million. Total NPV variability is much higher in Gauteng (Ekurhuleni) than in Cape Town (R26.3 million without BESS and R28.3 million with BESS in Gauteng versus R1.5 million without BESS and R6.1 million with BESS in Cape Town). NPV variability is lowest for a firm in Cape Town investing in PV and batteries (approximately R200 000) followed by a firm investing in just PV (approximately R300 000). This implies that the underlying tariff structure for a representative firm in Cape Town is structured similarly to the applicable Eskom tariff.

Carbon tax

- The domestic carbon tax payable by a representative firm in the first year is highest under pathway #1 (approximately R230 000 @ R190 per ton) as there are no additional savings from the mitigation of carbon by RE.
- The carbon tax payable in the first year falls under pathway #2 and pathway #3 when compared to pathway #1 (i.e., the procurement of RE regardless of the adoption pathway will reduce the amount of carbon tax payable for a given production technology and price of carbon).
- The carbon tax is lower for pathway #2 for a representative firm in Gauteng (approximately R130 000 @ R190 per ton versus approximately R140 000 @ R190 per ton for a representative firm in Cape Town as more RE is generated in Gauteng for the same size of installation due to higher solar irradiance).
- Under pathway #3, the carbon tax is lower with a BESS than without a BESS. However, in both cases the tax is still higher than it is under pathway #2 because more of the RE that is generated is used. (Under pathway #3 there is a higher possibility of curtailment due to limitations on immediate own use and size of the grid connection.)
- For all three pathways, a rise in the price of carbon leads to an equivalent increase in the carbon tax for a given production technology.

Curtailment

- There is no curtailment under pathway #3 because all of the RE generated electricity can either be self-consumed or exported to the grid without exceeding capacity limitations.

Results Tables

Table 11 presents the results generated for each adoption pathway for a representative firm in Ekurhuleni sourcing electricity from a PV system sized at 100% of NMD without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 11: RE generation and carbon reduction: Ekurhuleni, 259kWp installation (100% of NMD) – no battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	660	730
Self-consumption + exports	MWh		520	520
Self-consumption	MWh		520	450
Exported to the grid	MWh			70
Curtailed	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		3 900	3 900
Total area needed for installation (m^2)	m^2		1 939	1 939
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	+ / ++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	–	+ / ++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	–	++ / +++	++ / +++
NPV (Munic, PPA)	ZAR '000s	–	++ / +++	++ / +++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 030 – 3 650	2 390 – 2 820	1 420 – 1 990

Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 030 – 3 650	1 420 – 2 480	1 420 – 1 990
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	130	140
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	320	350
Y1 carbon tax (export, €90 per ton)	ZAR '000s	2 210	1 230	1 370

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 12 presents the results generated for each adoption pathway for a representative firm in Ekurhuleni sourcing electricity from a PV system sized at 100% of NMD without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 12: RE generation and carbon reduction: Ekurhuleni, 259kWp installation (100% of NMD) – with 65 kVA / 194 kWh battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	660	710
Self-consumption + exports	MWh		520	520
Self-consumption	MWh		520	470
Exported to the grid	MWh			50
Curtailed	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		3 900	5 200
Total area needed for installation (m^2)	m^2		1 939	1 939
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	+ / ++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	–	+ / ++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	–	++ / +++	++ / +++
NPV (Munic, PPA)	ZAR '000s	–	++ / +++	++ / +++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 030 – 3 650	2 390 - 2 820	1 420 – 1 970
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 030 – 3 650	1 420 – 2 480	1 420 – 1 970
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	130	140
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	320	340
Y1 carbon tax (export, €90 per ton)	ZAR '000s	2 210	1 230	1 330

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 13 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 100% of NMD without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 13: RE generation and carbon reduction: Cape Town, 259kWp installation (100% of NMD) – no battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	720	780
Self-consumption + exports	MWh		460	460
Self-consumption	MWh		460	400
Exported to the grid	MWh			60
Curtailed	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		3 900	3 900
Total area needed for installation (m²)	m²		1 939	1 939
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	+ / ++	+++
NPV (Munic, self-owned)	ZAR '000s		+ / ++	+++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s		+++	+++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	2 000 – 3 400	1 800
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	1 600 – 1 900	1 800
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	140	160
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	350	380
Y1 carbon tax (export, €90 per ton)	ZAR '000s	2 210	1 350	1 470

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 14 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 100% of NMD with a BESS. Results: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 14: RE generation and carbon reduction: Cape Town, 259kWp installation (100% of NMD) – with 65kVA /194kWh battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	720	770
Self-consumption + exports	MWh		460	460
Self-consumption	MWh		460	420
Exported to the grid	MWh			40
Curtailed	MWh			–
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		3 900	5 200
Total area needed for installation (m²)	m²		1 939	1 939
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	- / ++	+++
NPV (Munic, self-owned)	ZAR '000s	–	- / ++	+++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s	–	+++	+++

Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	2 000 – 3 400	1 800
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	1 600 – 1 900	1 800
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	140	150
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	350	370
Y1 carbon tax (export, 90 Euros per ton)	ZAR '000s	2 210	1 350	1 430

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

4.3 Size 3: 585kWp installation (100% annual electricity consumption)

Observations are presented first under four headings: (1) the area required for the PV system; (2) financial/commercial viability; (3) carbon tax; (4) and curtailment. Four tables of results on which the observations are based follow: two for a representative firm in Ekurhuleni (with and without BESS) and two for a representative firm in Cape Town (with and without a BESS).

Observations

Area required for PV system

- The total estimated area to deliver renewable energy at 75% of NMD is 4,972 m^2. (More than two-thirds of a rugby field.)

Financial / commercial viability

- The total cost of a self-owned, 585kWp PV system (100% annual electricity consumption) for a representative firm in Gauteng is approximately R8.8 million rising to R11.8 million when a BESS of 146kVA /438kWh is added. For a representative firm in Cape Town, the total cost of a self-owned, 663kWp PV system (100% annual electricity consumption) is approximately R9.9 million rising to R13.4 million when a BESS of 166kVA / 498kWh is added. (In both cases, adding a BESS of these sizes constitutes roughly one quarter of the total cost of an integrated PV system sized at 100% annual electricity consumption.)
- The NPV for pathway #1 is uniformly negative relative to pathway #2 and pathway #3. While there is no capital outlay under pathway #1, businesses are fully exposed to increases in the electricity tariff, receive no direct tax benefits for self-owned PV systems and, ceteris paribus, will also pay more in carbon taxes than they would if they adopted PV under either pathway #2 or pathway #3
- For pathway #2, NPV is negative for a representative firm in Cape Town that chooses to invest in its own system and is a municipal customer. In all other cases, NPVs are positive and range from R6.6 million to R41 million. Total NPV variability is high in both locations (> R30 million) but lowest for a firm in Cape Town procuring RE via a PPA (approximately R1.3 million).
- For pathway #3, NPVs are uniformly positive and range between R7 million and R41.1 million. Total NPV variability is higher in Gauteng (Ekurhuleni) than in Cape Town and higher in both locations with a BESS than without. NPV variability is lowest for a municipal customer in Cape Town investing in PV and battery (approximately R5.4 million) followed by a municipal customer in Cape Town investing in PV alone (approx. R6.1 million).

Carbon tax

- The domestic carbon tax payable by a representative firm in the first year is highest under pathway #1 (approximately R230 000 @ R190 per ton) as there are no additional savings from the mitigation of carbon by RE.

- The carbon tax payable in the first year falls to zero under pathway #2.
- Under pathway #3, the carbon tax payable by a firm in Gauteng (Ekurhuleni) falls to approximately R120 000 without a BESS and to just over R95 000 with a BESS. In Cape Town, the carbon tax payable falls to approx. R125,000 and just over R97,000 respectively.

Curtailment

- There is curtailment under pathway #3. Electricity curtailed is lower with a BESS than without, although in each case the amount curtailed is lower in Gauteng than it is in Cape Town.[13]

Results Tables

Table 15 presents the results generated for each adoption pathway for a representative firm in Ekurhuleni sourcing electricity from a PV system sized at 100% of annual electricity consumption without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 15: RE generation and carbon reduction: Ekurhuleni, 585kWp installation (100% annual electricity consumption) – no battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
	MWh	1 180	–	610
Self-consumption + exports	MWh		1 180	1 040
Self-consumption	MWh		1 180	570
Exported to the grid	MWh			470
Curtailed	MWh			140
System cost and total area				Net load from utility (kWh)
Total system cost (incl. tax benefit)	ZAR '000s		8 800	8 800
Total area needed for installation (m^2)	m^2		4 384	4 384
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	–	++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	–	++ / +++	++ / +++
NPV (Munic, PPA)	ZAR '000s	–	++ / +++	++ / +++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 000 – 3 600	1 700 – 1 800	500 – 1 400
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 000 – 3 600	600 - 1 800	500 - 1 400
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	–	120
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	–	290
Y1 carbon tax (export, €90 Euros per ton)	ZAR '000s	2 210	–	1 140

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 16 presents the results generated for each adoption pathway for a representative firm in Ekurhuleni sourcing electricity from a PV system sized at 100% of annual electricity consumption with a

[13] Curtailment of RE electricity adds costs as the benefit of electricity tariff savings and carbon tax savings are lost for the curtailed energy.

BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 16: RE generation and carbon reduction: Ekurhuleni, 585kWp installation (100% annual electricity consumption) – with 146kVA /438kWh battery

RE GENERATION		PATHWAY #1		PATHWAY #3
Net load from utility (kWh)	MWh	1 180	–	480
Self-consumption + exports	MWh		1 180	1 060
Self-consumption	MWh		1 180	700
Exported to the grid	MWh			360
Curtailed	MWh			110
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		8 800	11 800
Total area needed for installation (m^2)	m^2		4 384	4 384
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	–	++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	–	++ / +++	++ / +++
NPV (Munic, PPA)	ZAR '000s	–	++ / +++	++ / +++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 000 – 3 600	1 700 – 1 800	400 – 1 200
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 000 – 3 600	600 – 1 800	400 – 1 200
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	–	100
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	–	230
Y1 carbon tax (export, 90 Euros per ton)	ZAR '000s	2 210	–	900

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of R190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 17 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 100% of annual electricity consumption without a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 17: RE generation and carbon reduction: Cape Town, 663kWp installation (100% annual electricity consumption) – no battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	–	630
Self-consumption + exports	MWh		1 180	1 000
Self-consumption	MWh		1 180	550
Exported to the grid	MWh			460
Curtailed	MWh			180
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		9 900	9 900
Total area needed for installation (m^2)	m^2		4 972	4 972
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	- / +++	+++

NPV (Munic, self-owned)	ZAR '000s	–	- / +++	+++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s	–	+++	+++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	900 – 3 000	900 – 1 200
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	800 – 900	900 – 1 200
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	–	130
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	–	300
Y1 carbon tax (export, €90 per ton)	ZAR '000s	2 210	–	1 190

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of ZAR 190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

Table 18 presents the results generated for each adoption pathway for a representative firm in Cape Town sourcing electricity from a PV system sized at 100% of annual electricity consumption with a BESS. Results are categorised under the following headings: (1) RE generation; (2) system cost and total area; (3) commercial viability; and (4) savings (relative to pathway #1).

Table 18: RE generation and carbon reduction: Cape Town, 663kWp installation (100% annual electricity consumption) – with 166kVA/497kWh battery

RE GENERATION		PATHWAY #1	PATHWAY #2	PATHWAY #3
Net load from utility (kWh)	MWh	1 180	–	490
Self-consumption + exports	MWh		1 180	1 030
Self-consumption	MWh		1 180	690
Exported to the grid	MWh			350
Curtailed	MWh			130
System cost and total area				
Total system cost (incl. tax benefit)	ZAR '000s		9 900	13 400
Total area needed for installation (m^2)	m^2		4 972	4 972
Commercial viability				
NPV (Eskom, self-owned)[a,b]	ZAR '000s	–	- / +++	++ / +++
NPV (Munic, self-owned)	ZAR '000s	–	- / +++	++ / +++
NPV (Eskom, PPA)	ZAR '000s	–	+++	+++
NPV (Munic, PPA)	ZAR '000s	–	+++	+++
Savings (relative to pathway #1)				
Y1 utility bill (Eskom, self-owned)[c]	ZAR '000s	3 700	900 – 3 000	800 – 1 100
Y1 utility bill (Munic, self-owned)	ZAR '000s			
Y1 utility bill (Eskom, PPA)	ZAR '000s	3 700	800 – 900	800 – 1 100
Y1 utility bill (Munic, PPA)	ZAR '000s			
Y1 carbon tax (domestic, R190 per ton)	ZAR '000s	230	–	100
Y1 carbon tax (domestic, R462 per ton)	ZAR '000s	570	–	240
Y1 carbon tax (export, €90 Euros per ton)	ZAR '000s	2 210	–	920

[a] Pathway #1 NPVs are for Eskom versus municipal customers only.
[b] NPV values shown for carbon price of ZAR 190 per ton.
[c] Pathway #1 Y1 utility bill for Eskom vs municipal customers only.

5. KEY TAKEAWAYS AND POLICY IMPLICATIONS

Businesses adopt RE for several reasons. The energy cost saving of adopting RE is hard to ignore in the face of the rapidly falling prices of both PV and BESS, as well as an increase in the average Eskom tariff of 450% between 2007 and 2022, resulting in a real increase in the average Eskom tariff of over 300% (SARB, 2023).

South Africa has also experienced an increase in PV installations due to frequent loadshedding. It is, however, crucial to bear in mind that RE installations located off-site (wheeled electricity) will not shield a business from loadshedding while on-site RE installations need a BESS (charged) or a generator in addition to the PV system to stabilise the electricity supply during outages. The lifting of NERSA licensing restrictions has made it easier for businesses to install larger PV systems on-site which can generate greater amounts of RE and therefore reduce the impact of minor interruptions (lower stage loadshedding) when combined with BESS. It is also worth noting that RE with BESS, which are installed for the primary goal of providing electricity during loadshedding, are operated very differently from those installed for optimising the use of RE-generated electricity.

An increasingly important reason for businesses to procure RE is to lower their exposure to carbon taxes – both domestic and international (e.g., CBAM) – that are levied on the amount of GHGs they emit during production. For energy-intensive firms that emit higher amounts of (Scope 2) GHGs in countries with high grid emission factors, decarbonising by transitioning to sources of RE while also reducing the carbon intensity of their production processes can substantially reduce the amount of carbon tax they will be required to pay.

5.1 Key takeaways

The key takeaways of the results contained in section 4 are as follows:

<u>Area required for PV system</u>

- On-site solar PV installation is impacted by the availability of space. Some businesses are fortunate to have open space on or adjacent to their premises to install ground-mounted solar PV that is optimally positioned. Yet for most small and medium-sized businesses, located in an urban industrial setting, PV systems would need to be installed on factory roofs or on carports. The positioning of the panels may not be optimal, resulting in a reduced solar yield even in high solar resource locations. Importantly, available space and/or structural issues typically limit the amount of rooftop PV that can be installed.

<u>Financial / commercial viability</u>

- NPV is uniformly negative for pathway #1 (i.e., doing nothing is not a commercially viable strategy).
- In the majority of cases, NPV is positive for pathway #2 and in all cases NPV is positive for pathway #3. This implies that, given current tariff structures, the procurement of renewable energy almost always makes commercial sense for the representative firm.
- The variability of NPVs under pathway #2 and pathway #3 is primarily a result of the difference between the underlying municipal and Eskom tariff structures. A closer alignment of Eskom and municipal tariff structures could result in less variability in NPVs while a change in the tariff structure will result in a change in the magnitude of the NPV values (+/-).

Tabe 19 provides a basic summary of what happens to the commercial viability of RE adoption as a result of a change in the variables listed in the first column.

Table 19: Key assumptions and their effect on NPV

VARIABLE	EFFECT ON NPV
CAPITAL COST OF EQUIPMENT	If installation and/or technology costs decrease, NPV will increase.
EQUIPMENT LIFETIME / REPLACEMENT INTERVAL	An increase in equipment lifetime or in equipment replacement intervals will increase NPV.
BESS ROUND TRIP EFFICIENCY	As BESS become more efficient, the NPV will increase provided the cost of the BESS stays the same (pathway #3).
PPA PRICE	A lower PPA price will increase the NPV.
ACTIVE ENERGY CHARGE	An increase in the active energy charge component of the electricity tariff will lead to an increased saving in self-consumed electricity and thus an increased NPV (pathway #3).
FEED IN TARIFF	An increase in the feed-in tariff offered for electricity exported to the grid will lead to an increase in NPV (pathway #3).
ELECTRICITY TARIFF STRUCTURE	A change in the electricity tariff structure has the potential to significantly affect the NPV. This could be a positive or negative effect depending on the change.
CARBON TAX	A higher carbon tax will lead to an increased carbon expense for electricity generated with fossil fuels and an increased saving from electricity generated by PV or other sources of RE.
TAX BENEFITS	A change in the tax benefit derived from the accelerated depreciation offered for RE installations will affect the NPV (an increase in the tax benefit will lead to an increased NPV and vice versa).

Carbon tax

- The carbon tax liability for electricity consumption falls to zero (or near zero if a positive carbon intensity of PV is assumed) for pathway #2, assuming an installation size equivalent to 100% of annual electricity consumption (size 3); in all other cases, carbon tax is reduced but not eliminated.

Curtailment

- While it is always greenest to self-consume solar PV generation (the longer the distance between the point of export and the point of consumption, the more electricity is lost), PV can only be exported at a maximum of 75% of NMD. So, if more than 75% of NMD is installed and electricity is generated but not used (or stored), then this surplus will need to be curtailed to avoid congestion in the local electricity system. For larger PV systems, e.g., systems sized at 100% of annual electricity consumption, curtailment is an issue. Installing a BESS can significantly reduce the amount of electricity curtailed (see, for instance, total kWh curtailed for a representative firm in Ekurhuleni and Cape Town with and without battery in Tables 15-18 above). However, such a system will require an area of 4 972m^2 to install (more than two-thirds of the size of a rugby field) and would neither eliminate curtailment altogether nor eliminate the need to procure electricity from a utility.

- Installing an integrated BESS increases the use of solar PV but batteries are expensive. In the current climate, a sufficiently large BESS capable of shifting load and minimising curtailment is unlikely to be a viable option for most small manufacturing firms on top of the cost of installing PV alone.

5.2 Policy implications

It is clear that taking a business-as-usual approach to decarbonising (pathway #1) is not an option for South African businesses – both in the savings foregone by not adopting RE directly and in terms of a carbon tax to be paid locally or, in the case of exporters, abroad. And if we look to a world beyond the current energy crisis dominated by loadshedding and the need to "keep the lights on" to one where the demand for energy is determined primarily by the need to decarbonise, then a mixed approach to the adoption of RE is required.

While a lot can be done with on-site solar PV, space constraints for businesses in an urban location make it virtually impossible to decarbonise completely unless the adoption of off-site sources of renewable energy in addition to on-site solutions are explored. Moreover, curtailment becomes an issue for larger on-site systems, which represents an economic loss, reinforcing the argument for a policy framework that supports a mixed approach to RE adoption.

In the context of industrial policy, therefore, clear policy support is needed to help businesses procure/install PV and a BESS. Setting aside the space constraint, the upfront cost of investing in a system (with or without a BESS) remains the primary barrier for Small, medium and micro enterprises (SMMEs) to the adoption of RE. The accelerated depreciation tax incentive certainly improves the economics of procuring on-site PV. However, the expanded incentive is temporary and applies to investments brought into use for the first time between 1 March 2023 and 28 February 2025.[14]

While the lifting of the licensing requirement and the launch of the energy one-stop-shop clearly unlocks pathway #3, more effort should be directed at initiatives and schemes to strengthen the business case for the procurement of off-site RE (pathway #2). A coordinated policy response is required from different ministries, including dtic, to:

1. Expand and strengthen energy trading in the South African energy sector. Energy traders procure RE from one or more IPP using Eskom and municipal networks and sell it on to a number of off-takers in the mining, commercial and industrial sectors. In short, energy traders provide an aggregation service allowing generators/IPPs to benefit from economies of scale and smaller consumers to gain access to RE on a larger scale. A key advantage of energy traders is they are able to decouple supply from the underlying asset and therefore provide better terms and more flexibility to commercial and industrial customers. They also play an important balancing role and allow for a greater number of IPPs to connect to the grid. The Electricity Regulation Amendment Bill, approved by Cabinet on 29 March 2023, broadly allows for trading in the day ahead, bilateral, and reserve markets. However, energy traders need to be strongly capitalised and carry significant exposure on their balance sheets. Thus, systemic measures to support the creditworthiness of traders without reducing market discipline should be investigated.
2. Accelerate the establishment of a national wheeling framework, harmonised municipal wheeling mechanisms, and regulations to facilitate wheeling across municipal boundaries, including

[14] The Minister in The Presidency responsible for electricity has recently indicated that his department is pushing for the incentive to be extended to include inverters and batteries (Omarjee, 2023).

establishing integrated metering and billing systems capable of handling wheeling via both Eskom-to-municipality and municipality-to-municipality wheeling.[15] Current wheeling frameworks and models are not fit for purpose and pose significant challenges to distributed generation expansion and the uptake of pathway #2. A recent paper by Meridian suggests that implementing an Electricity Credit Token system could overcome many of the challenges inherent in wheeling power from off-site RE systems and unlock much greater distributed generation investment in South Africa. (Steyn et al., 2023).

3. Encourage municipalities in which there are significant concentrations of industrial activity to think about how they can attract investment in RE into their areas, increase their portfolio of RE assets, and dependably provide RE to their industrial customers from off-site sources. This includes ensuring energy security for customers located in industrial parks as part of a broader value proposition to attract investment into these areas (see point 5). A policy framework that actively encourages the procurement of off-site RE from a municipal-owned (if not managed) system may also: (i) reverse the erosion of the cross-subsidising benefit municipalities have hitherto derived from the sale of electricity by the increased installation of commercial and industrial rooftop PV; and (ii) disincentive municipalities from increasing the fixed charge component of the municipal electricity tariff, which would reduce the savings businesses derive from adopting RE and lengthen the payback period of the investment in on-site PV installations.
4. Support the roll-out of RE in South Africa by supporting local manufacturers to improve their capabilities and competitiveness and secure local supply. This could include establishing local content targets and criteria for future public and private procurement programmes, establishing a dedicated skills matching platform for the RE value chain, and establishing an original equipment manufacturer (OEM)-led cluster platform linking the different parts of the value chain (OEMs, Tier 1 and Tier 2 companies) to enhance transparent communication on OEM specifications/expectations and well as supporting the upgrading of local manufacturers' technical capabilities and quality standards (including technology transfer).[16]
5. Drive collaboration between public and private stakeholders – Eskom, municipalities, property managers, owners, body corporates, financial institutions – to accelerate the roll-out of PV systems and BESS in industrial areas (dedicated industrial zones as well as areas of concentrated industrial activity) and thus provide low-carbon, energy security for industrial activities. This should include collaborative initiatives to:
    a. Simplify SSEG tariffs by Eskom and all municipalities to improve the business case for PV adoption by SMMEs.
    b. Develop concessional financing mechanisms for SMMEs and grant financing for local enterprises.
    c. Improve the availability and flow of information on traders, installers and technologies to facilitate more informed decision-making.
6. Reinvigorate the REI4P and provide returns to developers that are at least as attractive as the returns they can achieve elsewhere. The public procurement of RE has faced significant challenges since 2015 and, even considering existing and upcoming procurement processes, grid carbon

[15] Municipalities that develop robust and transparent wheeling regulations and frameworks sooner than other municipalities are likely to attract industry into their boundaries from other municipalities that are slow to develop frameworks for wheeling. This is likely to result in increased concentration of industrial activity over time in those municipalities that develop effective wheeling frameworks with potential implications for the spatial distribution of industrial activity and municipal solvency.
[16] South African Renewable Energy Masterplan (SAREM) (draft version), 1 December 2023.

neutrality will not be achieved in a timeframe that would make a meaningful reduction in companies' carbon tax liabilities here or abroad. If REI4P stalls, then the cost of pathway #1 unambiguously rises relative to pathway #2 and pathway #3. It will also negatively impact the creation of new value chains for the manufacture and assembly of utility scale RE technologies in South Africa.[17]

5.3 Conclusion

In conclusion, mitigating the effect of power outages (loadshedding) is important but adopting RE to decarbonise and realise significant savings that could be invested in strengthening firm-level capabilities should be regarded as longer-term objectives by small and large businesses alike. As such, space constraints for businesses in an urban location make it virtually impossible to decarbonise completely and realise significant savings on their electricity bill unless the adoption of off-site sources of renewable energy in addition to on-site solutions are explored.

It is therefore imperative that an appropriate policy framework that supports a mixed approach to RE adoption – i.e., that supports both on-site and off-site PV adoption – is developed. Moreover, a co-ordinated and collaborative approach is required from all stakeholders, public and private, to achieve this successfully. National government departments such as the dtic need to work with all stakeholders to ensure that PV and BESS are widely adopted as a basis for preserving long-term manufacturing capabilities within the country.

[17] If REI4P is reinvigorated but the green energy produced by the programme is auctioned off via a first-come, first-served allocation system then firms at the back of the queue that do not acquire RE by other means will, all other things equal, be worse off due to a worsening national grid emission factor.

ANNEX 1: INPUT VALUES

For completeness, the full list of input values used to generate the results are shown in the tables below:

Size 1: 194kWp installation (75% of NMD)

NMD before PV installation[18]	**259**
PV installation size (kWp)[19]	**194**
Feedback (% of NMD)[20]	**75%**
Battery capacity (kVA)[21]	**0 (no battery) otherwise 48**
Battery Energy (kWh)[22]	**0 (no battery) otherwise 144**
Battery round trip efficiency[23]	**0 (no battery) otherwise 90%**
Replacement time for inverter (years)	**11**
Replacement time for battery (years)[24]	**0 (no battery) otherwise 6**
% green electricity on grid (BAU)[25]	**5%**
Growth rate of green electricity on national grid (BAU)[26]	**1%**
Growth rate of green electricity on municipal grid (BAU)[27]	**2%**
Purchasing price from external company per kWh (SSEG)[28]	**R0.90**
Purchasing price from external company per kWh (off-site)[29]	**R1.00**
Eskom green tariff or equivalent[30]	**R0.05**

[18] Notified Maximum Demand before PV installation (default is NMD plus 10%).
[19] PV Installation size measured in kWp for three different sizing options (75% of NMD, 100% of NMD, 100% of energy per year).
[20] Feedback limited to 75% of NMD in the base case. (If the company is on a shared feeder, then feedback should be limited to 25% of NMD. If the company is in an area that does not allow feedback, then feedback should be set to zero.)
[21] Battery capacity (kVA) – The size of the battery in kVA is assumed to be 25% of the installation size measured in kWp. For the purposes of this study, it is assumed the battery is used to optimise solar usage instead of loadshedding.
[22] Battery energy (kWh) – How long the battery can run at full capacity. (For example, if the battery is 50kVA battery and you want to be able to use it for three hours at full load, then the energy utilisation will be 150kWh.)
[23] Battery round trip efficiency – The energy lost by charging and discharging the battery. This is probably about 5% in each direction, resulting in a total loss of 10% (i.e., 90% efficient).
[24] Replacement time for battery (years) – Batteries are guaranteed for an amount of time or number of cycles, whichever comes first. Since BESS is included for pathway #3 only, an assumption is made regarding the amount of time instead of number of cycles.
[25] % green electricity on grid (BAU) – Amount of "green electricity" is already on the grid in Year 1. Estimated at 5% for base case but will be less if RE available to the grid is allocated as green certificates or sold directly to customers.
[26] Growth rate of green electricity on national grid (BAU) – % by which green electricity on the national grid increases year on year. Estimated at 1% for base case but will be less if RE available to the grid is allocated as green certificates or sold directly to customers.
[27] Growth rate of green electricity on municipal grid (BAU) – % by which green electricity on the municipal grid increases year on year. Assumed to be slightly higher than national grid growth rate in the base case.
[28] Purchasing price from external company per kWh (SSEG) – In the case of on-site RE adoption, this is the purchase price/tariff per kWh when an external company owns the power plant and the factory only pays the tariff per kWh (i.e., no capital expense). Assumed to be lower than the purchasing price for off-site RE.
[29] Purchasing price from external company per kWh (off-site) – this is the purchase price/tariff per kWh when buying from a generator or trader and the electricity is wheeled. Assumed to be higher than the purchasing price in the case of on-site RE due to additional connection and distribution charges.
[30] Eskom green tariff or equivalent – This represents the tariff charged by Eskom to customers wishing to procure green electricity directly from Eskom's own sources of RE (e.g., Sere wind farm).

Installation cost for PV system per kWp (SSEG)[31]	**R15 000**
Installation cost for PV system per kWp (off-site)[32]	**R15 000**
Battery cost per kWh[33]	**0 (no battery) otherwise R7 000**
Maintenance cost per year (% of CapEx[34]	**1%**
Y1 carbon tax (domestic)[35]	**R190/R462**
Y1 carbon tax (export)[36]	**€90**
Exchange rate (EUR/ZAR)	**R20**
Interest rate	**11%**
Loan repayment (years)[37]	**10**
Current grid emission factor (kg carbon per kWh)[38]	**1,04**
Carbon intensity of PV kg per kWh	**0**
Tax rate[39]	**27%**

Size 2: 259kWp installation (100% of NMD)

NMD before PV installation	**259**
PV installation size (kWp)	**259**
Feedback (% of NMD)	**75%**
Battery capacity (kVA)	**0 (no battery) otherwise 65**
Battery Energy (kWh)	**0 (no battery) otherwise 195**
Battery round trip efficiency	**0 (no battery) otherwise 90%**
Replacement time for inverter (years)	**11**
Replacement time for battery (years)	**0 (no battery) otherwise six**
% green electricity on grid (BAU)	**5%**
Growth rate of green electricity on national grid (BAU)	**1%**
Growth rate of green electricity on municipal grid (BAU)	**2%**
Purchasing price from external company per kWh (SSEG)	**R0,90**
Purchasing price from external company per kWh (off-site)	**R1,00**
Eskom green tariff or equivalent	**R0,05**

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[31] Installation cost for PV system per kWp (SSEG) – Full capital cost per kWp for an on-site PV system, excluding a BESS.

[32] Installation cost for PV system per kWp (off-site) – Full capital cost per kWp for an off-site PV system.

[33] Battery cost per kWh – Measured in energy and not capacity. Battery cost differs widely according to size and manufacturer (and guarantee).

[34] Maintenance cost per year (% of CapEx) – Annual cost of maintaining the PV system if self-owned.

[35] The Y1 domestic carbon tax is estimated for two rates: R190/t CO2 emissions is the rate of domestic carbon tax for 2024 as per the Taxation Laws Amendment Act No 20 of 2022 and R462/t CO2 emissions is the rate of domestic carbon tax for 2030 as per the Taxation Laws Amendment Act, 2022 (Act No. 20 of 2022)

[36] The International Energy Agency (IEA) considers carbon prices for developing countries including South Africa of US$90 in 2030 rising to US$200 in 2050 for a global net zero scenario (IEA, 2023a.

[37] Loan repayment in years – Period over which annual payments are made to pay back the loan if the investment is financed by debt (determined by the interest rate).

[38] Current grid emission factor (kg carbon per kWh) – Assumed to be 1.04 in base case as per Eskom's 2022 Eskom Integrated Report (Eskom, 2022).

[39] Tax rate – The company tax rate in South Africa is 27%. This is relevant because the PV installation can be claimed as a tax expense under section 12B of the Income Tax Act No. 58 of 1962. The temporary enhancement yields a (close to) upfront saving of almost 34%. (Under the enhanced incentive, businesses will be able to claim a 125% deduction in the first year for investments in new renewable energy assets between 1 March 2023 and 28 February 2025. This means that for a business with positive taxable income, the deduction will reduce its tax liability to the South African Revenue Service. Moreover, if a taxpayer sells a renewable energy asset on or before 1 March 2026, only 25% of the amount recovered or recouped shall be included in the taxpayer's income under enhanced renewable energy tax incentive.)

Installation cost for PV system per kWp (SSEG)	**R15 000**
Installation cost for PV system per kWp (off-site)	**R15 000**
Battery cost per kWh	**0 (no battery) otherwise R7 000**
Maintenance cost per year (% of CapEx)	**1%**
Y1 carbon tax (domestic)	**R190/R462**
Y1 carbon tax (export)	**€90**
Exchange rate (EUR/ZAR)	**R20**
Interest rate	**11%**
Loan repayment (years)	**10**
Current grid emission factor (kg carbon per kWh)	**1.04**
Carbon intensity of PV kg per kWh	**0**
Tax rate	**27%**

Size 3: 585kWp installation (100% annual electricity consumption)

NMD before PV installation	**259**
PV installation size (kWp)	**585 (Gauteng Province – GP) or 663 (Cape Town – CT)**
Feedback (% of NMD)	**75%**
Battery capacity (kVA)	**0 (NB) otherwise 146 (GP)/166 (CT)**
Battery Energy (kWh)	**0 (NB) otherwise 438 (GP)/498 (CT)**
Battery round trip efficiency	**0 (NB) otherwise 90%**
Replacement time for inverter (years)	**11**
Replacement time for battery (years)	**0 (NB) otherwise 6**
% green electricity on grid (BAU)	**5%**
Growth rate of green electricity on national grid (BAU)	**1%**
Growth rate of green electricity on municipal grid (BAU)	**2%**
Purchasing price from external company per kWh (SSEG)	**R0,90**
Purchasing price from external company per kWh (off-site)	**R1,00**
Eskom green tariff or equivalent	**R0,05**
Installation cost for PV system per kWp (SSEG)	**R15 000**
Installation cost for PV system per kWp (off-site)	**R15 000**
Battery cost per kWh	**0 (NB) otherwise R7 000**
Maintenance cost per year (% of CapEx)	**1%**
Y1 carbon tax (domestic)	**R190/R462**
Y1 carbon tax (export)	**€90**
Exchange rate (EUR/ZAR)	**R20**
Interest rate	**11%**
Loan repayment (years)	**10**
Current grid emission factor (kg carbon per kWh)	**1,04**
Carbon intensity of PV kg per kWh	**0**
Tax rate	**27%**

In addition to the above the following points should be noted:

- All numbers are nominal – The calculator does not take inflation into account or different rates of inflation for different costs. This is the same as assuming that everything increases at the same rate as what they are discounted at so NPVs are just the sum of income and expenses. While there is good reason to believe the utility rate (electricity tariff) will increase faster than the consumer price index (CPI) and the cost of PV and batteries will increase at a lower rate than CPI, this is not necessarily the case, and these rates of increases can change over time. Increasing everything at the same rate (say, CPI) will also not change the relative costs of each pathway.

- Future costs are often discounted at a cost of capital that is higher than CPI. However, in the case of RE investments, the investment is typically constrained by access to capital/debt and not on the minimum internal rate of return required.
- Curtailment (reducing energy consumption during peak hours by influencing the behaviour of users) is only a factor for on-site RE (pathway #3). When the installation size is large and the BESS is small or zero or when feedback is 0%, then more electricity will be curtailed, which represents a cost to the business and has zero carbon benefits.

ANNEX 2 – PLANNED RE DEPLOYMENT IN SELECTED METROPOLITAN MUNICIPALITIES AND STUMBLING BLOCKS

The main initiatives by municipalities include:

Ekurhuleni Municipality	• The municipality first launched a programme to obtain private sources of electricity in 2017. As a result, 47 agreements were signed to address the energy challenges from embedded IPPs with a capacity of 5MW and above.[40]
	• The municipality has developed a wheeling framework to integrate Distributed Energy Resources and has registered more than 200MW of embedded generators (SSEG). This approach presents new revenue streams for the municipality through Distribution Use of System charges.
	• Regarding SSEG systems below 1MW, Ekurhuleni uses simplified connection criteria (NRS097-2-3) to assess low voltage SSEG systems. (City of Ekurhuleni, 2023). Customers can install a SSEG up to the size of their Notified Maximum Demand, with export limited to 25% (shared) or 75% (dedicated feeder). For applications above 1MW, the municipality generally requires applicants to conduct grid impact studies and ensure compliance with grid code requirements.
City of Cape Town	• In February 2022, the City released a tender to procure energy from independent power producers, aiming for an initial capacity of 300MW. The draft Energy Strategy of Cape Town sets a goal of adding 650MW of new independent generation within five years, with the aim of protecting the city against up to four stages of loadshedding by 2026.
	• In 2023, the City approved 15 commercial electricity suppliers to wheel electricity to 40 customers over its grid as part of a pilot project. (Fokazi, 2023).
	• Recently, NERSA and the National Treasury authorised the City of Cape Town to pay power sellers at a feed-in tariff rate of 78.98c/kWh, with the city adding a 25c/kWh incentive tariff.
	• To further promote SSEG installations, the City aims to remove regulatory restrictions such as net consumption requirements currently in place under the Electricity Supply By-Law of the City of Cape Town which applies regulations to systems with a generation capacity less than 1MVA connecting to the City's distribution network.
eThekwini Municipality	• On March 1, 2023, eThekwini Municipality's Mayor, Mxolisi Kaunda, announced the municipality's plan to procure an initial 400MW of electricity generation from independent power producers. This includes 100MW from solar photovoltaic and 300MW from gas-to-power. The projects are expected to achieve commercial operation in 2025 and 2026.
City of Johannesburg	• In November 2022, City Power issued Requests for Proposals for Short-Term Power Purchase Agreements, aiming to secure energy from independent power producers for up to 36 months. In parallel, the City underwent an approval process for Ministerial Determination to procure power from Independent Power Producers on a longer-term basis. The goal was to procure an additional 500MW of electricity to offset up to Stage 5 loadshedding. In additional, the City of Johannesburg planned to recommission the two existing Open Cycle Gas Turbine Stations at a cost

[40] City of Ekurhuleni, 2023.

	of R20 million. This would require the city to procure and burn diesel, adding 74MW to the network when needed.
	The City of Johannesburg has also approved generator-use-of-system tariffs (wheeling tariffs) to transition from a strictly electricity distribution entity to an energy solutions service provider. Third-party generators seeking to supply customers within the City Power network will need to apply for third-party access, subject to compliance with safety requirements. (City of Johannesburg, 2023.)

It is important to note that plans and strategies can be subject to political changes and shifts in council leadership in Ekurhuleni and Johannesburg may impact the implementation of these initiatives.

Further, an arduous external regulatory approval processes through NERSA and National Treasury exists for municipal-owned or IPP power purchase initiatives.

NERSA has granted feed-in tariff approval to municipalities in the Western Cape, Eastern Cape, Gauteng and KwaZulu-Natal, however, the administrative burden surrounding NERSA approval and registration for connections has resulted in limited uptake. NERSA has further approved a net-billing tariff framework – to qualify, customers must enter into a connection agreement with the distributor, install a renewable energy system that complies with NERSA standards, have a bidirectional meter installed, and comply with all technical requirements of the net-billing system.

Municipal initiatives must also adhere to the competitive requirements outlined in the Municipal Finance Management Act No. 58 of 2003 (MFMA). (Botha,2023; National Treasury, 2023). Any power purchase agreement with a duration longer than three years must comply with the MFMA Section 33 processes. This includes fulfilling requirements for public notices and consulting relevant national and provincial government departments. Distributor supply chain policies may also impose additional conditions in this regard. Expenditure by municipalities must align with sound procedures and be included in council-approved budgets, considering both capital and operational costs. Unsolicited bids are evaluated based on the criteria specified in Section 113 of the MFMA and Regulation 37 of the Municipal Supply Chain Management Regulations. Specific Distributor Supply Chain Management Policies may contain provisions that are pertinent to such procurement activities. Lastly, in accordance with the Preferential Procurement Policy Framework Act No. of 2000, and associated regulations, procurement should incorporate considerations of Broad-Based Black Economic Empowerment (B-BBEE) and local content provisions. This ensures compliance with the overarching framework for preferential procurement in South Africa.

SSEG is seen as an opportunity for municipal networks (Goode, 2020). Municipal distributors are prevented by regulation from engaging in a wider range of energy services, but they can potentially benefit from SSEG through peak shaving, load balancing, and building blocks towards future smart energy grids. Municipalities like Johannesburg could help develop the SSEG market by making it viable for property developers to build generation facilities and assist in wheeling power to adjacent customers.

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