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Smart Grid and Net Metering for Grid-Interactive Distributed Generation for the City of Ekurhuleni

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Architecture in Sustainable and Energy Efficient Cities.

2022

DECLARATION

I, Alfred Phiri declare that this research report is my own unaided research, except where acknowledged. It is submitted for the Degree of Master of Architecture in Sustainable and Energy Efficient Cities at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Signature of Candidate

Date: 26th April 2022

ABSTRACT

Increased frequency of electricity outages due to load-shedding coupled with escalating tariffs is forcing customers of municipal electricity utilities to venture into Distributed Generation (DG) technologies. These trends pose major infrastructure-reliability and revenue-erosion risks for municipal utilities which further impair quality of service to their customers, mainly as a result of dilapidated grid-infrastructure which contributes to escalation in distribution losses.

With City of Ekurhuleni (CoE) as a case study, the research applied a qualitative approach to investigate the relevance of smart grid and net-metering systems as a response mechanism towards promotion of DG while also facilitating operational viability of the municipal utility. Primary data collected through interviews with electricity-sector experts as well secondary data from diverse sources were used to derive the key findings and conclusions of the study. Experiences from other countries such as Germany show that smart grids have also been pivotal towards harnessing renewable energy through DG and would therefore be critical towards addressing the prevailing distribution grid challenges within municipal authorities.

In contrast, study findings indicate a steady increase in DG installations within CoE as commercial and industrial customers pursue their goal of energy security at lower costs. However, the utility has not effectively transformed the DG opportunity to cheaper electricity due to inhibitive regulatory and policy framework which also raises the risk of revenue erosion posed by DG. In particular, the overall findings support the working hypothesis which suggest that upgrading grid infrastructure and introduction of a responsive tariff-scheme is key to incentivise the adoption of grid-interactive DG within its jurisdiction. Given the qualitative focus of the study on smart grids and net metering, one of the key recommendations would be political mobilisation across all departments in CoE to provide input towards solving prevailing grid challenges and as well as evolving a responsive business model to facilitate transparent participation of small-scale generators through DG.

Keywords: smart grid, net metering, distributed generation, policy and regulatory framework

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LIST OF ACRONYMS AND ABBREVIATIONS

ACR: Automatic Circuit Recloser

AES Eletropaulo: Brazil Distribution Power Company

AfDB: African Development Bank

Alcatech GmbH: German technology and Engineering Institute

AMEU: Association of Municipality Electrical Utility

AMI: Advanced Metering Infrastructure

AMR: Automatic Meter Reading

BNetZA: Bundesnetzagentur (German Federal Network Agency)

CEA: Consumer Electronics Association

CEB: Central Electricity Board (Mauritius)

CENACE: Centro Nacional de Control Energia

CFE: Commission Federal de Electricidad

CoE: City of Ekurhuleni

CPP: Critical Peak Pricing

CRE: Commission Regualadora de Energia

CSIR: Council for Science and Industrial Research

CSP: Concentrated Solar Power

DBSA: Development Bank of Southern Africa

DG: Distributed Generation

DLR: Dynamic Line Rating

DoE: Department of Energy

DOEMR: Department of Energy and Minerals Resources

ECCS: Energy and Climate Change Strategy (Ekurhuleni)

EE Publishers: Energy Efficiency Publishers (Magazine)

EEDSM: Energy Efficient Demand Side Management programme

EEG: Erneuerbare Energien Gesetz

EIL: Electrical Industry Law

EISA: Energy Independence and Security Acts of 2007

EPP: Electricity Policy Plan

EPSM: Energy and Public Services Ministry

ERA: Electricity Regulation Act

ERC: Energy Regulatory Commission

ERC: Energy Research Centre

ESTA: Energy Strategy and Technology Associates (International Smart grid Consultants)

EU: European Union

FEG: German Future Grid

FERC: Federal Energy Regulatory Commissions

FIR: Fourth Industrial Revolution (4IR)

FIT: Feed in Tariff

GBI: Generation Based Incentive Scheme

GCF: Green Climate Funds

GDS: The Growth and Development Strategy

GHG: Green House Gas Emissions

GIZ-ZA: German Internationale Zusammenarbeit and South African Economic Cooperation

IBRD: International Bank for Reconstruction and Development

IBT: Incline Block Tariff

ICT: Information and Communication Technologies

IDP: Integrated Development Plan

IEA: International Energy Agency

IEE: Industrial Energy Efficiency

IFPRI: International Food Policy Research Institute

IG: Indian Government

INEP: The Integrated National Electrification Programme

IoT: Internet-of-Things

IPP: Independent Power Producer(s)

IRENA: International Renewable Energy Agency

IRP: Integrated Resource Plan

ISGAN: International Smart Grid Action Network

ISO: Independent Systems Operators

KFW: German State-Owned Developed Bank

KWh: Kilowatt-hour

Landis+Gyr: German Smart Metering Company

LCOE: Levelised cost of electricity

LED: Light Emitting Diode

LREIPP: Local Renewable Energy Independent Power Producers

LTE: Energy Transition Law

MARENA: Mauritius Renewable Energy Agency

MEPU: Ministry of Energy and Public Utility (Mauritius)

MFM: Municipal Finance Management Act

MME: Ministry of Mines and Energy

MOE: Ministry of Energy (Mexico)

MOP: Ministry of Power (India)

MSBM: Modified Single Buyer Model

MSDF: Metropolitan Spatial Development Framework

MSDG-NM- Medium-Scale Distributed Generation-Net Metering Scheme

MSDP: Municipal Spatial Development Plan

MSDP: Medium-Scale Distributed Production (Mauritius)

MVA: Mega Volt Ampere

MW: Megawatt

MWh: Megawatt-hour

NAM-POWER: Namibian National Electricity Utility

NCPC: National Cleaner Production Centre -South Africa

NECB: Namibian Electrical Control Board

NERF: Namibian Energy Regulatory Framework

NERSA: National Energy Regulator of South Africa

NGOs: Non-Government Organisations

NMBM: Nelson Mandela Bay Municipality

NMD: Notified Maximum Demand

NNSM: Nerhu National Solar Mission

NSGM: National Smart Grid Mission

NTPC: NTPC Vidyut Vyaper Nigam (Indian Largest utility company)

OGEMP: Off-Grid Energisation Master Plan

OPEX: Operational Expenditure

OUTA: Organisation Undoing Tax Abuse

PPA: Power Purchase Agreement

PPP: Public Private Partnership

PRODESEN: Programme for Development of National Electric Systems

PTR: Peak Time Rebates

PV: Photovoltaic

PWC: Price Waterhouse & Cooper (Account & Auditing Firm)

RAP: Regulatory Assistant Project

RE: Renewable Energy

REFIT: Renewable Energy Feed in Tariffs

REIPPPP: Renewable Energy Independent Power Producer Procurement Programme

RET: Renewable Energy Technologies

RPS: Renewable Portfolio Standards

RSDF: Regional Spatial Development Framework

RTP: Real Time Pricing

SAGEN: South African German Energy Programme

SAIPPA: South African Independent Power Producers Association

SALGA: South African Local Government Association

SANEDI: South African National Energy Development Institute

SAPVIA: South African Photovoltaic Industry Association

SASGI: South African Smart Grid Initiative

SEA: Sustainable Energy Agency

SEN: National Electrical Systems

SENER: Federal Secretariats of Energy

SG: Smart Grid

SMMES: Small, Medium and Micro Enterprises

SONA: State of National Address (South Africa)

SRF: Solar Revolving Fund

SSDG-NM: Small-Scale Distributed Generation-Net Metering Scheme

SSEG: Small-Scale Embedded Generation

ToU: Time of Use

TV: Television

UK: United Kingdom

UNFCCC: United Nations Framework Convention on Climate Change

UNIDO: United Nations Industrial Development Organisation

USA: United States of America

USDTA: United States Trade and Development Agency

WB: World Bank

1 INTRODUCTION

1.1 Introduction and Background of the Study

Globally, electricity markets are experiencing transformations that entail upgrades of interconnectivity across diverse modes of generation, transmission, and distribution to accommodate non-conventional generating technologies (Kakran and Chanana, 2018). It is therefore critical to understand the impacts of this transition in the different spheres of the South African electricity market, especially within municipal and Eskom distribution systems which form a crucial part of the market. Eskom has been in existence since 1923 as a vertically integrated monopoly (covering electricity generation, transmission and a proportion of distribution). It supplies 96% of the electricity to South African municipalities who then distribute/retail to customers within their jurisdictions. Municipal authorities serve about 60% of the electricity end-users whilst Eskom serves the remaining 40% directly (Eberhard et al, 2014).

The South African electricity market/sector is experiencing various challenges that include an acute drop in electricity supplies due to rapidly ageing grid infrastructure and delays in setting up new and energy efficient generation at Eskom and CoE. This has resulted in frequent, rolling blackouts and high distribution losses across the country. There is therefore an urgent need to improve on electricity generation capacity as well as manage end-user electricity demands in a sustainable manner that ensures the reduction of greenhouse gas emissions (GHG) as pledged at the UNFCCC Paris Agreement adopted on 12 December 2015 (Chiroro, 2012, p 8). Resolving these challenges requires the integration of renewable energy technologies as one of the strategies towards enhanced capacity for cleaner and more affordable generation and supply. This would thus offer solutions to current electricity supply constraints at lower GHG emission intensity in South Africa (Bello et al., 2015).

Nevertheless, there has been limited progress in policy and regulatory support for renewable energy technology deployment by authorities so far despite the high resource potential across the country. However, end-users are increasingly looking to invest in alternative energy sources such as solar photovoltaic (PV), wind power, small hydropower and energy storage facilities mainly in response to rising electricity prices imposed annually by Eskom, perennial electricity shortages and decreasing cost of renewable energy generation technologies. This development is mostly visible through the growth of rooftop solar PV installations across all customer segments (including industrial, agricultural, commercial and residential) in South Africa (see

Figure 1.1). In light of these developments, municipal distributors are likely to experience declining revenue generation from electricity sales, thereby negatively affecting available cash flows to fund other social development programmes (Baker and Philips, 2019).

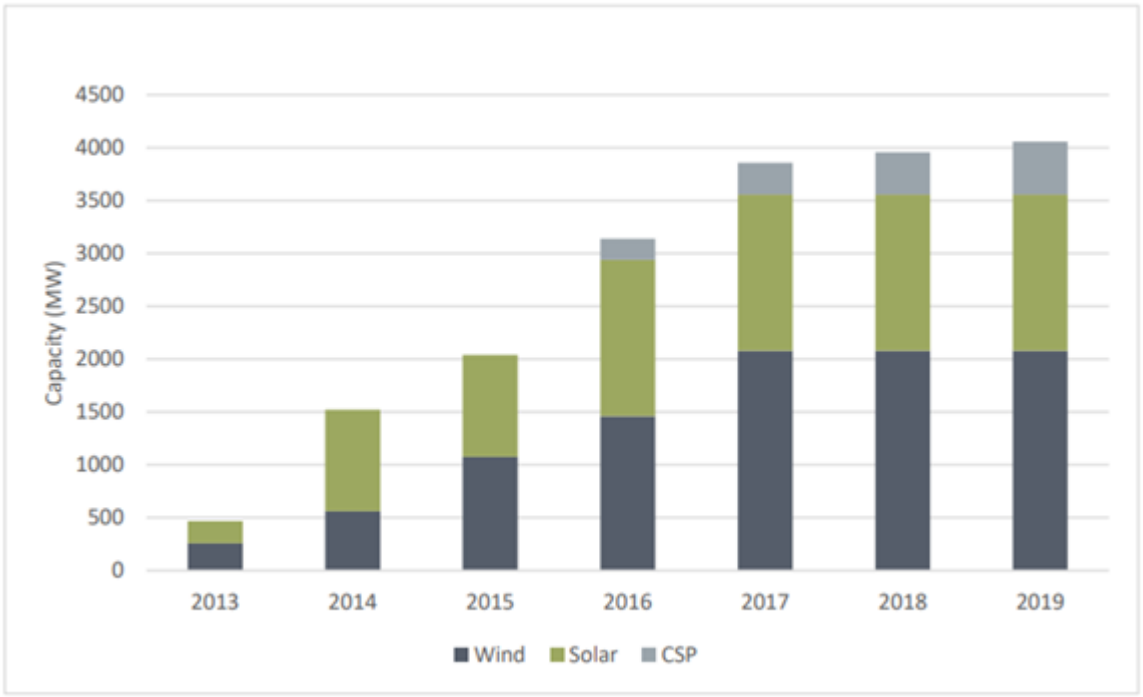

Figure 1.1: Installed capacity for solar, wind and concentrated solar power in South Africa (Source: Renauld et al., 2020, p 4)

As the primary case study for the research, CoE is adversely affected by chronic electricity shortages due to uncertainty of supplies from Eskom. In response, since 2017, CoE embarked on a program to pursue localised power generation of 200MW within its jurisdiction by signing contracts with Independent Power Producers (IPPs). Power generated by the contracted IPPS will be distributed through CoE's distribution network which will further strain its aging grid infrastructure. The study is centred on investigating the electricity infrastructure challenges in relation to the increasing adoption of DG within CoE's jurisdiction.

Faced with these two issues, the study examines how modernization of infrastructure (through the adoption of smart grids and net metering infrastructure) could improve electricity supplies within South African municipalities. The development of the enabling regulatory frameworks can also be used to address both issues for the benefit of CoE as one of the major municipalities that is contributing significantly to GDP in South Africa. CoE is also designated as the country's manufacturing hub with a massive demand for electricity.

In 2015, CoE distributed 2 600 MVA to its consumers, which was equivalent to the combined total demand for Botswana, Lesotho, Zimbabwe, Mozambique, and Namibia (CoE, 2016). This underlines the importance of adequate power supplies to the sustainability of socio-economic activities within CoE. Guided by its Municipal Spatial Development Plan (CoE, 2015, p 109), CoE prioritised sustainable access to electricity especially for the informal settlements as well as harnessing of renewable energy to augment the current demand-supply gap. This was also projected to contribute towards reduction in energy losses through illegal connections and meter-bypasses mostly occurring in the informal settlements. Additionally, aging and obsolete infrastructure have resulted in high distribution cost and revenue losses which in turn necessitate high maintenance costs. A bold decision was therefore made to upgrade its municipal distribution network in order to resolve the electricity challenges. The United States Trade and Development Agency (USTDA) was engaged in 2013 to conduct a feasibility study on smart grids and propose recommendations that could reduce losses (non-technical and technical) and potentially attract investments for distributed generation.

The adoption of favourable policies is vital for transforming the utility market in a manner which is conducive for all participants (Kakran and Chanana, 2018). In view of this need, this this study explores smart grids and net metering policies as potential mechanisms for adapting to the changing utility market. In the absence of such policies and their systematic implementation, it becomes increasingly problematic to attract investments in the electricity sector in order to ensure enhanced supply services. This requires integrated and responsive policies as regulatory frameworks that mutually benefit all parties in terms of social, environmental and revenue aspects. Given these issues, CoE has not been at the forefront in promoting distributed generation especially in terms of compensating prosumers for surplus power exported to the grid, responsive policy for financial support to local IPPs and opening access to the grid for third party access/use.

1.2 Distributed Generation Transition and Status Quo

Increasing demand for energy coupled with environmental concerns have become a priority for many governments intending to optimise electricity generation from renewable resources as well as achieve gains from demand-side strategies which guarantees both energy savings and low-carbon growth strategies by consumers (Baker and Philips, 2019). This also falls in line with South Africa's 2020 Budget Statement and State of the Nation Address (SONA) 2020 that proposed measures to open the electricity market by allowing municipalities in good financial

standing to directly procure their supplies from Independent Power Producers (IPPs). The government is also promoting the growth of small-scale embedded generation (SSEG) below 100MW for self-consumption and acknowledges the role it can play as an alternative source of supply for municipalities. As a follow-up to this commitment, the government has called for public comments on amendments to the Electricity Regulation Act to increase the threshold of licensing exemption for SSEG generating capacity from 10MW to 100MW in (see appendix 9.11) (DME, 2021). This policy facilitation would contribute to reducing frequent power outages by injecting 500MW of additional SSEG capacity into the grid on yearly basis (see appendix 9.2). While this pronouncement is welcome, it falls short in incentivising consumers generating surplus power to feed into municipal grids in order to expedite adoption of DG.

With the increasing trend in adoption of DG, CoE has facilitated the integration of landfill gas generation, roof-top solar PV and energy efficient initiatives to offset its energy costs as well as ensure energy security. However, some installations have become dysfunctional due to lack of technical and operational capacity for monitoring and maintenance, especially in context of its conventional grid infrastructure. In contrast, smart grid and net metering upgrades would have facilitated for higher operational efficiency that would have allowed the DG plants to be utilised at their optimum generation capacity. In view of these challenges, CoE estimates that an investment of R62 billion would be required for infrastructure modernisation and facilitating the incorporation of responsive policy and regulatory frameworks (CoE, 2019). Key to achieving the growth of DG depends on the promulgation and systematic implementation of smart grid and net metering policies as argued in Brown and Zhou (2013).

This study is therefore influenced by the delay in policy formulations and enactment of regulatory frameworks to accelerate the growing demand for DG in South Africa, especially within municipalities which operate the major portion of the country's distribution networks. It sought to understand how prioritisation of smart grid and net metering policies could become a catalyst towards widespread adoption of grid-interactive DG technologies in CoE where, despite the USTDA (2013) feasibility study on smart meters and smart grid, the municipality has been sluggish to respond towards preparedness for smart-grid and net metering infrastructure upgrades.

The significance of smart grid and net-metering infrastructure is not only limited towards enhancing revenue collection by improving operational efficiency, reliability and resilience, but also contributes towards catalysing integration and adoption of distributed energy resources

(DERs). Increasing presence of renewable generation and the proliferation of customer- and IPP-owned DERs are introducing greater levels of variability and uncertainty in both electricity supply and demand. Generation and load profiles which have been predictable in the past can now vary instantaneously depending on the behaviour of the consumers who also have DER-installations. This calls for improved visibility of resources not owned by utilities in order to control and coordinate the increasing number of assets and endpoints along grid systems to readily adapt to changing conditions within sub-second timeframes.

In 2013, the United States Trade Development Agency (USTDA) in partnership with CoE and Department of Energy (DoE), commissioned a study to evaluate the technical, financial, environmental and other critical aspects of implementing advanced metering infrastructure and smart grid technologies in CoE's distribution grid. The scope of the feasibility study included the development of a smart grid implementation roadmap and the design of a smart metering pilot project. As the contractors appointed by CoE for the study, Xtensible Solutions (US) and Aurecon (the local partner) conducted the study and prepared the roadmap for implementing a smart grid system as part of their recommendations. However, the findings and recommendations of the study have not been implemented so far.

This study was therefore motivated by the need to understand the significance of smart grid and net metering systems in facilitating expedited adoption of DG as well as the responsive infrastructure policy and regulatory frameworks. Following the declining cost of most renewable energy technologies (and hence decline in related Levelised Cost of Electricity – LCoE), grid-interactive DG now offers affordable electricity for both large scale and small-scale embedded generators who are forced to rely on storage facilities (at additional costs) due to inhibitive grid connectivity regulations. The availability of smart grid system would therefore guarantee safe and reliable connectivity of DG while also mitigating intermittency commonly associated with renewable energy technologies, especially due to variable weather conditions such as periods of sunshine or wind and other feed stock (Brown and Zhou, 2013).

1.3 Research Problem

CoE is faced with increasing difficulties in meeting the demand for electricity due to constrained supplies and this has also affected its ability to ensure quality of services. This also leads to increased costs in provision of services and a backlash from consumers who are dissatisfied with ongoing power outages. Consequently, customers have been defecting from the grid as they seek alternative options to ensure energy security thus leading to revenue

erosion. The problem within the municipality revolves around lack of any coordinated response and direction towards investing in grid improvements that would mutually benefit the municipality and its customers, especially with regard to DG.

Besides the inadequate grid infrastructure, absence of feed-in-tariffs constitute a severe constraining factor for consumers hoping to export surplus generation into the grid. Municipalities therefore need to create a level playing field to boost electricity supply from renewable energy generation. In addition, addressing climate change requires rapid reduction in use of carbon-based energy sources supported by policy development to encourage investments in clean energy resources such as solar, wind and waste-to-energy as key resources. With responsive infrastructure and policies favouring net metering technologies and smart grid, end-users can contribute to system optimisation while also enjoying greater flexibility towards managing their own electricity consumption not only as an energy security measure but also as mitigation of climate-change impacts.

Arising from this context and motivation, the study aimed at establishing the significance of smart grids and net metering systems towards the promotion of DG solutions by addressing the following issues as the core priorities:

- Shortage in electricity generation and supply versus rising electricity demand in the country
- Shortfalls in prevailing grid infrastructure in relation to envisaged scale-up of DG from renewable resources as related technologies become more reliable and affordable due to declining costs
- Addressing shortfalls in electricity infrastructure, policies and regulatory frameworks, especially in relation to scale-up of smart grid and net metering systems in support of DG

1.4 Rationale of the Study

CoE is classified as the manufacturing hub of South Africa and is often referred to as “Africa's Workshop” due to numerous factories located within its jurisdiction. As an key industrial and logistical centre within the Gauteng Province, CoE is an intensive energy user and ongoing chronic power shortages are forcing its diverse customer base to opt for alternative energy sources to insulate themselves from the risks posed by power outages. This scenario also poses serious economic challenges for CoE as a municipal distributor and has created urgency for a

transformed electricity market which systematically supports economic development while also integrating renewable energy technologies at scale (Bello et al., 2015). With this shift in the electricity market, there is urgent need for municipal utilities in South Africa to demonstrate readiness of adopting smart systems to improve grid reliability, revenue collection and minimise electricity losses (*ibid.*).

CoE is lagging behind other municipalities such as Nelson Mandela Bay and Cape Town that were proactive in development of renewable energy resources by implementing attractive export tariffs for prosumers. In addition, delayed implementation of USTDA 2013 recommendations on the feasibility of smart grids by CoE demonstrates unpreparedness and unwillingness on infrastructure modernisation. This triggered the study towards an understanding of the nature of existing bottlenecks holding back the implementation of recommendations from the USTDA feasibility studies report. This study explores this critical issue through a focus on smart-grid and net-metering policy frameworks in relation to development of green energy targets, feed-in-tariffs for renewable energy (RE), soft loans, grants, tax breaks, carbon credits and Renewable Electricity Portfolio Standards (REPS) which would facilitate the scale-up of grid-interactive DG among its customers. The study also identifies other steps such as open access to the grid to integrate SSEGs and power generated purchased by municipal authorities at a predetermined tariff for a given period.

1.5 Research Aim and Objectives

The study aimed to assess the significance of smart grid and net-metering technologies among other interventions towards promoting grid-interactive DG in South Africa's municipalities based on a case study of CoE. The supporting objectives are to:

- Elaborate on prevailing electricity distribution challenges faced by municipal utilities and the possible range of solutions available or applied
- Appraise available infrastructure and capacity to support the integration of DG technologies for CoE and prosumers
- Explore a common ground for municipality and the prosumers to address issues of revenue erosion and grid defections
- Enquire why CoE has not prioritised smart grid systems despite seeming readiness and pilot projects efforts in DG
- Appraise international case studies towards the promotion of renewable energy and grid-interactive DG through the implementation of smart grid technologies

- Derive conclusions and recommendations towards future infrastructure development and overall policy/regulatory framework reforms.

1.6 Research Question

The study was guided by the following research question:

- What is the significance of smart grid and net-metering technologies towards the promotion of grid-interactive DG for CoE?

The main research question was addressed through a consolidation of sub-findings on the following sub-questions:

- What are the key constraining factors inhibiting the adoption of DG within CoE?
- What is the significance of smart grids and net metering systems towards addressing CoE's distribution challenges while also facilitating the adoption and actualisation of DG?
- What infrastructure policy and regulatory frameworks can be implemented to facilitate scale-up of grid-interactive DG (connection of prosumers) as well as mitigate concerns over revenue erosion in CoE?

1.7 Working Hypothesis

The critical challenges facing CoE's distribution grid infrastructure as well as the growing number of its customers opting for self-generation poses severe risks in terms of grid stability and revenue erosion while also inhibiting expedited adoption of grid interactive DG towards mitigation of GHG-emissions and climate change. The study envisaged that upgrade to smart grid and net metering technologies coupled with implementation of responsive policies and regulations would be the most significant response towards addressing the two critical challenges facing electricity distribution sector in CoE and other municipal distributors in South Africa. Smart grid and net metering technologies have the potential to solve grid infrastructure problems and spur increased adoption of DG in CoE.

1.8 Overview and location of CoE (the case study)

As shown in Figure 1.2, CoE is located in Gauteng Province of South Africa and borders the City of Tshwane to the north and the City of Johannesburg to the West. CoE is a category "A" municipality accounting for nearly a quarter of Gauteng's economy and the latter contributes over a third of South African Gross Domestic Product (GDP).

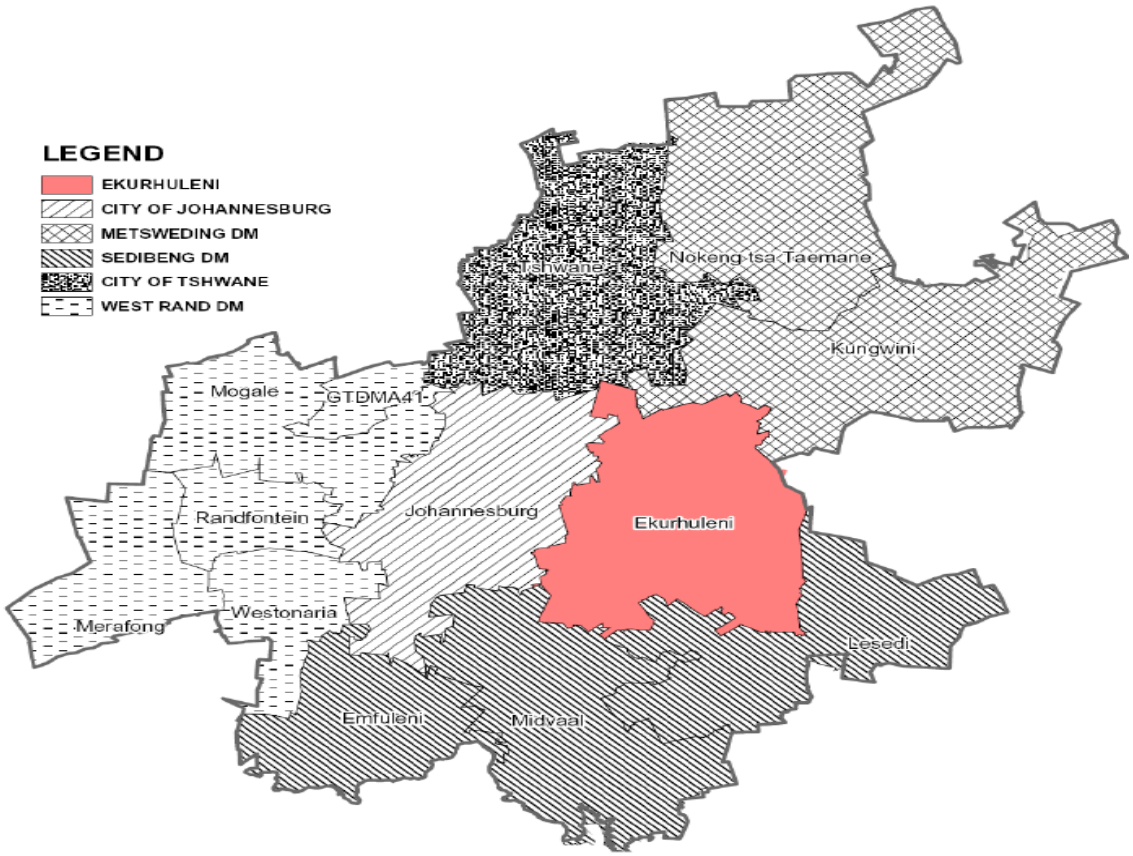

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Figure 1.2: Map of Ekurhuleni metropolitan area indicating its location within Gauteng Province (Source, Payne et al., 2008, p 4)

The city was established in 2000 and had 2 million inhabitants. The population has since grown to around 3.5 million (CoE, 2019) with the majority living in agglomerations within nine townships namely Germiston, Boksburg, Kempton Park, Nigel, Springs, Benoni, Brakpan, Alberton, and Edenvale whilst others live in informal settlements with low electrification rates. The municipality operates under South Africa's constitutional system of three spheres of government (national, provincial and local authority) where its executive and legislative authority is governed by the Municipal Systems Structures Act 32 of 2000.

CoE is currently experiencing challenges in the provision of electricity services due to generation and supply constrains faced by Eskom (the national electricity utility) as well as antiquated grid infrastructure which in turn negatively impacts on socio-economic activities within its jurisdiction (CoE, 2019). Mainly as a result of growing population and urbanization, there is increasing consumption and industrialisation which is driving up demand for electricity. In order to address the rising concern of power shortages, CoE has awarded tenders

to Independent Power Producers (IPPs) to invest in generating capacity of at least 680MW using renewable energy resources.

Customers are also investing in DG installations (mostly based on roof-top solar PV) for energy security (CoE, 2019). According to Filipova and Morris (2018, p 6), CoE had the highest DG installations, followed by Cape Town and Johannesburg. The current developments in CoE therefore provide a platform for other municipal utilities to explore and follow on the importance of upgrading grid infrastructure to implement a smart grid which is also necessary towards promotion of adoption of DG and which would thus mitigate prevailing grid supply gap.

1.9 Definition of Key Terms of the Study

Blockchain entails public digital ledgers that uniquely capture and record online activities such as transactions among various parties. They are evolving to be critical components of the proper functioning of smart grids mainly through ensuring traceability and security of transactions between the utility company and its customers. In particular, blockchain is envisaged to become an authoritative and trustworthy tool towards encouraging grid-interactive DG.

Centralised generation denotes electricity generation carried out from large-scale generation plants commonly located far-off from key points of consumption which thus requires bulk-transmission coupled with breaking-bulk for distribution closer to key centres of consumption followed by retail to the end-users. Even though the three-stage model (generation, transmission, and distribution/retail) remains relevant today, it is losing its appeal because of the rapid diffusion of DG technologies which are rapidly becoming more efficient and affordable.

Distributed generation (DG) is small-scale electrical power generation units (normally at less than 10MW) linked directly to the distribution networks or located on the consumer side of the meter. DG is emerging as a viable alternative to centralized generation primarily because the emerging generation technologies allow for the exploitation of a broad range of renewable energy sources at affordable levels of investments.

Energy policy is a course or principle for action as adopted by either the central government or local authority advocating for a coherent approach towards developing energy resources and markets of the respective country or local authority. For example, in South Africa, the energy policy has prioritised the reduction of coal consumption as a primary source of energy in line

with the country's strategy towards climate change mitigation. Instead, the policy aims at increasing renewable energy share in the total generation mix by 2030 (DoE, 2019, p 10).

Incline block tariff (IBT) is a tariff-scheme that sets electricity tariffs on a consumption-block basis such that the tariff price for each block increases progressively in line with levels of monthly-consumption. Each month is re-set to zero-consumption at the beginning of the month in order to allow for a fresh block-start at the lowest-block level for all customers on that tariff-scheme.

Internet of things (IoT) is the networked online interactions of our everyday manufactured objects which come with a capacity for online connectivity through the internet. This results in highly distributed device networks that communicate with humans as well as other gadgets. IoT is the pillar of smart grid systems that facilitates connectivity and interactions of users and their appliances (including on-site generation) with the grid in a manner which facilitates real-time monitoring and automated responses to system changes within the grid network.

Levelised cost of electricity (LCOE) is a benchmarking indicator which allows for a comparative view of cost-efficiency across multiple electricity generation technologies and resources. It is derived as the cost per unit of energy (kWh) produced over the whole lifetime of the generating technology when all applicable costs are included. It therefore serves as a crucial parameter in facilitating policy and decision-making in relation to the choice of technologies and resources from a range of available options.

Net metering is a billing mechanism that credits distributed DG systems (such as roof-top solar energy technology) owners for the net-electricity they supply to the grid normally at the customer retail tariff or otherwise as set by the distribution grid operator. This allows residential and commercial customers who generate electricity from DG to sell surplus electricity back to the network and simplifies the measurement of energy either supplied to the grid or drawn from the grid by the distributed energy generator connected to the grid. Net metering schemes and grid feed-in tariffs encourage consumers to invest in grid-interactive DG while exempting them from the requirement of obtaining a generation license provided the generation remains below a specified capacity threshold. It also facilitates for DG without the need for battery storage, especially with areas with stable grid supply (with minimal supply interruptions due to load-shedding).

Notified maximum demand is the maximum energy demand agreed between the bulk supplier (Eskom) and the municipal distributor (CoE). The maximum value is determined by the utility's requirements and allows the bulk supplier to plan for the provision of new generation capacity as well as overall operational efficiency.

Prosumers are grid-connected users of power who also generate their own electricity on-site and have options to export surplus electricity to the grid if they are interactively connected. For instance, when generation from their units is low, they are consumers from the grid. However, they act as producers when they generate more than they consume and export the surplus to the grid. Given that prosumers are incentivised by the expanded options to buy, shift-consumption, or generate (for own-consumption or grid-supply), without reliable and efficient monitoring systems such as the smart grid, utilities are unlikely to achieve the necessary capacity for managing the dynamics and complexity of such demand-variability on the grid.

Small scale embedded generation (SSEG) is a regulatory term used in the South African context to refer to DG facilities that are embedded to a municipality's distribution network (connected to the local distribution grid).

Smart grids denote the integration of information technologies, power and communications systems towards improved grid operations especially because it allows for bi-directional flow of information from consumers to the utility company and vice-versa, which in turn facilitates reliable and cost-effective energy management. A smart grid can integrate DGs using renewable energy technologies to reduce the environmental impact of generation based on fossil-fuel resources.

1.10 Delimitation of scope of the Study

This study was limited to CoE as the case study in order to identify challenges associated with the current electricity business model and the disruptive effects of DG on municipal distributors in South Africa. It further investigated the possibilities and feasibility of facilitating grid interactions based on smart grids and net-metering technologies within the current infrastructure and regulatory policy frameworks. The choice of limiting the study to photovoltaics-based (solar PV) technologies was influenced by the solar potential of South Africa and falling costs which are driving the rapid adoption of such technologies towards small-scale generation within CoE and South Africa in general. Solar PV technologies are

prioritised by customers due to lower installation costs (when compared to other alternatives) and are therefore rapidly becoming the widely available self-generating technology globally.

This study explored the significance of prioritising smart grid and net metering systems as enabling factors in mitigation of current grid network challenges faced by CoE as well as paving the way for the scale-up of grid-interactive DG. However, the study does not investigate the extent of financial losses attributable to the aging and obsolescence of the grid network but instead focuses on the limitations of the current grid in relation to accommodating the adoption of DG.

Findings substantiate the importance of adopting different responsive policies tools and investments in infrastructure upgrades to ensure surplus power from small-scale generation exported to the grid. Further, the scope of this study neither assesses the amount of energy that can be harnessed from increased DG adoption nor technical frameworks nor endorse any specific policy interventions to be adopted by the municipality. Policy delineation, standards and implementation strategies are adopted from the Department of Energy and Minerals (DME) for use by municipalities (DME, 2013:14). Through its various policy and strategy documents, CoE has acknowledged the current level of grid infrastructure decay as well as the need to invest in modern and intelligent grid infrastructure. Additional benefits for promoting RE through smart-grid and net-metering renewable energy (such as climate change mitigation, green jobs and boost to local economy) have not been extensively addressed in this study and would thus require separate investigations as noted under recommendations in Chapter 7.

1.11 Outline of the Report

Guided by the study objective on the relevance of smart grids and net metering systems towards resolving the twin problems of current network challenges and promotion of DG in CoE as the case study, the report is structured into seven chapters as follows:

Chapter 1 is the introductory chapter which presents the background and motivation of the research. It also presents the key research question and sub-questions as well as the study objectives and the working hypothesis, followed by definition of key terms and delimitation of scope of the study.

Chapter 2 presents an appraisal of studies on the core theoretical themes of the study. These include distributed generation, distribution-grid infrastructure policy and regulatory frameworks, smart grids, and net-metering systems. The chapter establishes a link across the

various theoretical themes in order to provide the key insights that guided the rest of the study. The chapter starts with an appraisal of the structure of South Africa's electricity market, followed by appraisal of studies on DG and the range of factors that have driven its adoption in other countries. The second part appraises studies on the concept of smart grids, its various components, and how it can be used to resolve some of the distribution challenges. This sets the platform for a discussion on the possibilities of using smart grids towards the promotion of DG, especially through addressing concerns over security of transactions and the management of demand and supply issues in real time.

Chapter 3 presents the overall research approach and method used to collect both primary and secondary data. It also presents the sampling type used to identify interview participants and the analytical framework employed to derive sub-findings on each sub-question. The chapter also motivates the use of purposeful sampling technique in selecting interview participants deemed to have the relevant knowledge on the subject matter. Primary data were gathered through semi-structured interviews with sector professionals, while secondary data were collected from several academic articles, industry publications and online sources as well as government and other reports in the public-domain.

Chapter 4 presents data and analyses towards sub-findings on the first sub-question which focuses on the constraining factors inhibiting the growth of DG within CoE (mainly economic, institutional, social, technical, and environmental barriers). The chapter concludes by providing a summary of sub findings on the first sub-question.

Chapter 5 presents data and analyses towards sub-findings on the second sub-question which focuses on the relevance of smart grids in addressing CoE's current distribution challenges and how the adoption of a smart grid network could contribute towards addressing the challenges. Secondary data and analyses on a case study from Brazil were also used to evaluate the relevance of smart grids when faced with distribution challenges and revenue leakages, while a case from India was similarly used to evaluate the importance of using a smart grid to integrate renewable energy resources.

Chapter 6 presents data and analyses on the various policy and regulatory pillars required to support the implementation of smart grids as a crucial facilitation in the promotion of distributed generation. Data and analyses of multiple policies implemented in other countries are presented in order to assess the interventions for their relevance in the case of CoE.

Chapter 7 presents a consolidation of the sub-findings across the sub-questions into the overall research findings, conclusions and recommendations as the overall response to the main research question. The chapter thus concludes by establishing the interconnection between grid-interactive DG, smart grids and net metering systems within municipal distribution grid-networks. The last section of the chapter outlines recommendations for further research, especially those related to addressing the delimitation of scope issues presented in Section 1.10.

Additional information is presented as annexures in the Appendices. Data on South Africa's electricity generating capacity, summary of REIPPPP expressions-of-interest in 2011 and the initial successful bids awarded under REIPPPP as discussed in Chapter 2 is presented as Appendices 9.1 to 9.4. A register of CoE's SSEG installations and results of customers surveys conducted in CoE on SSEG/smart grid implementation as discussed in Chapter 4 are presented in Appendices 9.5 to 9.7. A transcript of responses gathered from interview respondents is presented as Appendix 9.8 (the data were used to derive sub-findings for sub-questions 1 to 3 as presented in Chapters 4 to 6). The outcomes from the 26th -28th Energy Storage/ Smart Grid Conference proceedings is presented as Appendix 9.9 and the draft regulations on raising the limit on SSEG from 1MW to 100MW is presented as Appendix 9.10 and Appendix 9.11. This announcement is necessary to allow companies to build their own generating capacity as well as reducing the burden on the Eskom grid. With no licensing requirements by NERSA, however generating facilities will still require NERSA registration and Eskom grid connection approval. The recommended fixed charges for SSEG in CoE and the Ethics Clearance Certificate (discussed in Chapter 3, Section 3.8) are presented as Appendix 9.12 and 9.13 respectively.

2 LITERATURE REVIEW

2.1 Introduction

This chapter presents an appraisal of published studies on the role of smart-grid and net-metering technologies towards facilitating wider adoption of DG. The first part is based on a review of the structure of the South African electricity market highlighting barriers and challenges that inhibit the growth of DG. The structure of the market also helps in understanding the critical role of municipal distributors across the electricity value chain. The second part presents appraisal of studies on various factors influencing growth of DG including the relevant local and international policy instruments supporting renewable energy technologies. The third part reviews studies on smart grids in order to deepen understanding of key concepts and benefits of related technological interventions towards facilitating grid-interactive DG. It also presents the supporting elements of a smart grid such as the internet of things (IoT) and blockchain (cryptocurrency) currently driving the ongoing transformation of electricity generation, transmission and distribution.

2.2 The Structure of the South African Electricity Market

The South African electricity market is undergoing a transformation primarily aimed at addressing ongoing power shortages and mitigation of greenhouse gas emissions. These two key drivers have provoked the government to promote energy efficiency and renewable energy through promulgating a set of new policies aimed at effecting change towards a new electricity market (Bello et al., 2015). The policy shifts are also a continuation of prior initiatives to provide universal access to electricity which was first introduced through the White Paper on Renewable Energy of 2003 (DoE, 2003). The white paper sought to change the basic framework on the generation, sale and trading of energy to a sustainable, non-subsidized renewable energy sector anchored by private sector-led investments. Bello et al. (2015) noted that the policy shifts on electricity markets, including DG in the power pool generation mix, had already been embraced by the government at the time of launching the white paper in 2003 (DoE, 2003). DG was then envisaged to reach generating capacity of 17.8GW by 2030 based on a mix of solar photovoltaic (PV), concentrated solar power (CSP), wind power, landfill gas and micro-hydropower. Bello et al., 2015 cites severe challenges affecting most of these DG options especially regarding cost-competitiveness at that time. **Error! Reference source not found.** and Figure 2.2 show the distribution of South Africa's total energy mix and capacity for renewable energy resources in 2020.

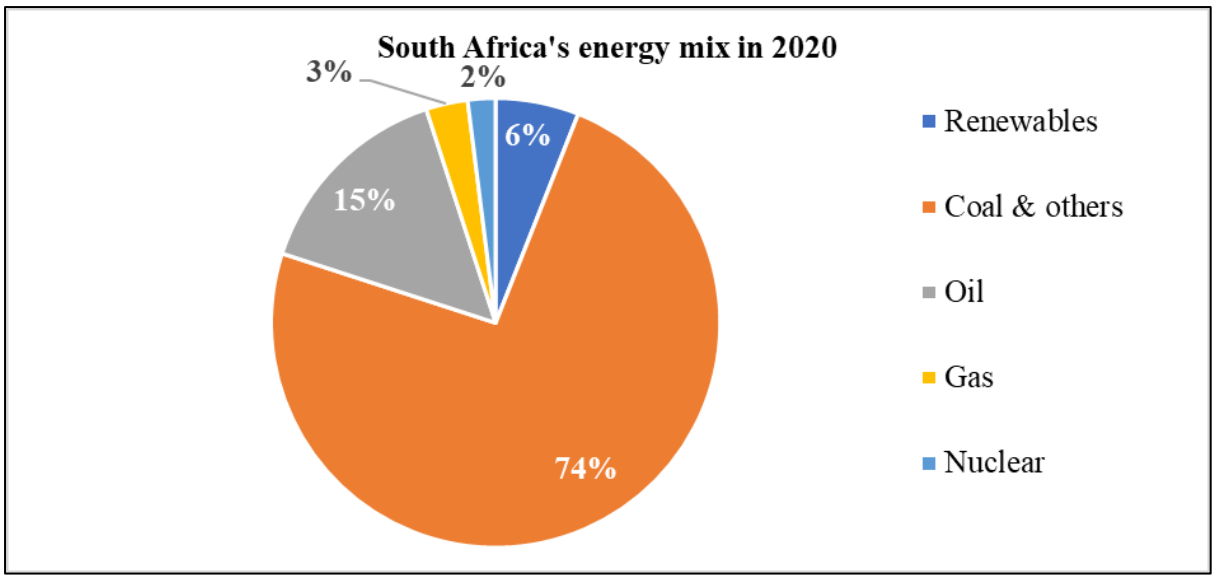

Figure 2.1: South Africa's energy mix (Source, IRENA, 2020a, p 1)

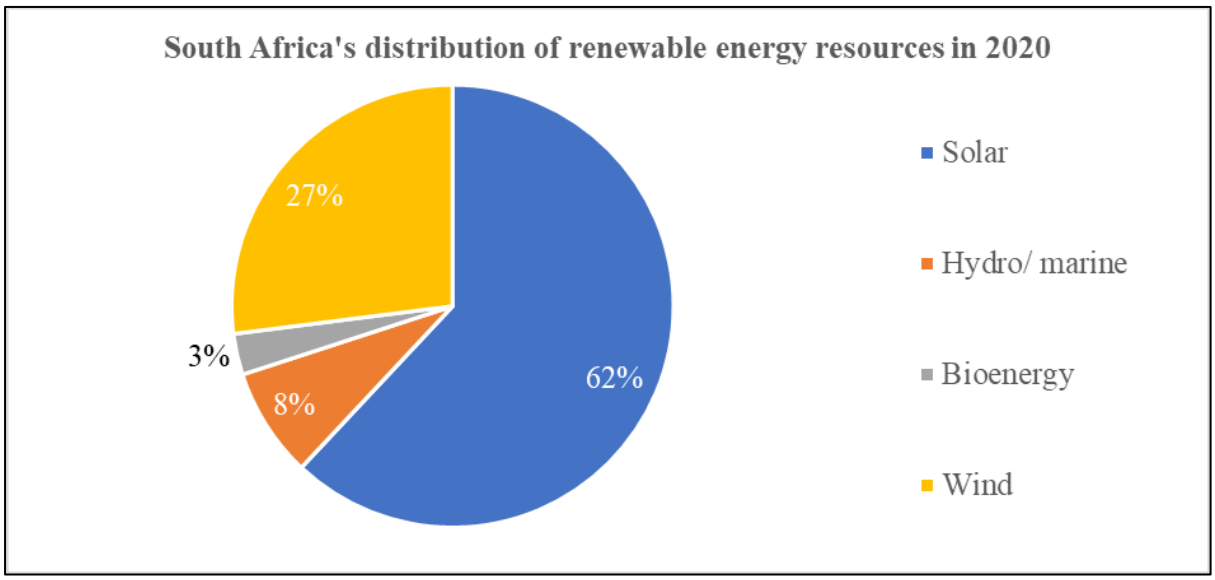

Figure 2.2: South Africa's renewables mix (Source: IRENA, 2020a, p 1)

Between 2014 and 2021, South Africa's electricity tariff increased by 15.06% to R1.59kWh which is noted to have been one of the highest increases globally. Bello et al. (2015, p 3) had envisaged this tariffs trajectory. On the other hand, the average levelised cost of electricity (LCoE) from renewable sources such as solar PV was expected to range from R0.68 to R1.25 per kWh by 2021 (as shown in Figure 2.3). This has made renewable energy more cost-competitive and affordable compared to generation from fossil fuels, and especially coal in South Africa.

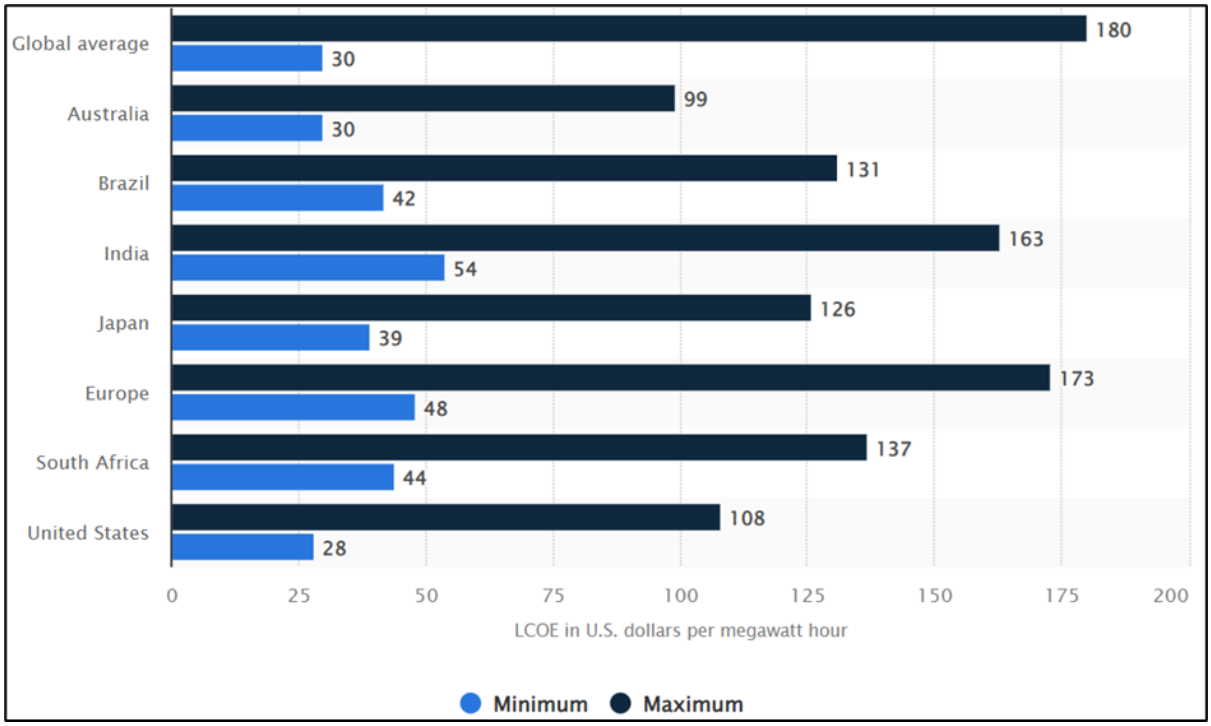

Figure 2.3: Global Levelised Cost for Solar Photovoltaic as of 2021 (USD/Megawatt) (Source: IRENA, 2020b, p 4)

With these challenges, Bello et al., (2015) and Thopil et al., (2018) alluded that tariff increases had attracted public opposition as they were considered a threat to economic development. The rise in energy tariffs therefore required fiscal policy support and coordinated approach towards modernization of power-infrastructure and markets which would in turn expand capacity to accommodate the increasing demand for alternative power sources.

Thopil et al., (2018) estimates that approximately 82% of electricity in South Africa was generated from coal-fired power stations operated by Eskom which had total electricity generation capacity of 44 134 MW, and approximately 37 715 MW of the installed capacity was from coal power stations (including the recently inaugurated Unit 6 of the Medupi power station). Renewable energy plants operated by Eskom have a total capacity of 700 MW which includes hydro stations (600 MW capacity) and a wind farm (100 MW). This means that the country is heavily reliant on coal resources for electricity generation as well as responsible for supplying a significant amount of South Africa's power supply (see Appendix 9.1 for more details on generation capacity).

As of 2019, there were 59 installed renewable energy (RE) generating plants established under the Renewable Energy Independent Power Producers Procurement Programme (REIPPP)

which was at Level 5 bidding window by end of October 2021. These RE plants included 22 wind power with a total capacity of 1,877 MW, 33 solar (PV) plants with a total capacity of 1,502 MW, 2 hydro-power (14.3 MW) and 4 concentrated solar power (CSP) with a capacity of 300 MW (Thopil et al., 2018, p 4). However, these renewable resources only contribute a mere 6% to the total energy mix, which is dominated by coal-based energy accounting for 74% as shown in Figure 2.1.

Despite the country's progress in renewable energy development, the final IRP (2019) was heavily criticised for allocating limited capacity towards renewable energy generation, but instead increased gas-based power and targeted procurement of 1.5GW from newly commissioned coal-fired power stations (Kusile and Medupi). Additionally, IRP (2019) only allocated 33% of RE contribution by 2030 which is still not enough pace to reach its targeted contribution in the energy mix. As government gradually increases threshold for self-generation with renewable resources (currently set at 100MW), the impacts of DG could provide indispensable information to policymakers in setting new and improved standards thus paving the way for an accelerated transition towards a sustainable electricity model for the country (Thopil et al., 2018, p 4).

Eberhard et al., (2014) argues that South Africa desperately needs more electricity primarily in line with its envisaged trends in national socio-economic development. In that context, DoE promulgated Small-Scale Embedded Generation (SSEG) policy that allows NERSA to exempt licensing for self-generation capacities of up to 1MW which was recently lifted to 10MW and subsequently to 100MW (see Appendix 9.10 and 9.11 for related amendments to the regulations).

Within the current policy framework which only allows for Eskom as a single buyer of independently generated electricity (Eberhard et al., 2014), the diffusion of SSEG has mainly been embraced by commercial and wealthy customers, especially those served by the distribution network operated by municipalities. This has provided meaningful benefits to various municipalities through stimulating economic growth, skills development and job creation. However, SSEG installed by these customers reduces electricity sales volumes and subsequently municipal revenues. This places a burden on a reduced consumption base and deprives the municipality of financial resources used for cross-subsiding other social services (DBSA, 2020, p 14).

SSEG is still out of reach of most residential customers and especially low-income households mainly due to high upfront costs of related technologies. This has resulted in the benefits of the SSEG policy generally getting skewed towards wealthy customers who have the means to invest in alternative power sources while the poor are left dependent on an unreliable grid and facing ever-rising electricity tariffs. As a result, low-income customers are carrying the rising costs of cross-subsidy surcharge due to the defection of wealthy customers to SSEG which in turn stifles demand for SSEG. This pattern of SSEG adoption thus constitute a constraining factor for its broader diffusion (*ibid*).

2.2.1 The electricity supply chain framework

The South African electricity market operates on the basis of a single buyer model with Eskom designated as the sole buyer for all utility scale electricity generated by IPPs. Under the current framework, municipalities buy power from Eskom (as the generation and transmission entity) for distribution to final consumers at a margin above the supply-cost (Eberhard et al., 2014). This long-standing model was reiterated through a 2007 Cabinet decision which prioritised the need to ensure security of supply over the development of a competitive wholesale electricity market. As a result, the government and its implementing agencies offer bankable offtake agreements under Eskom in support of scalable private sector-led energy investments. On the basis of electricity sector as a core requirement for socio-economic development (mainly through driving industrialization), government priority for the sector took precedence over all other goals such as creating a competitive/liberalised electricity market.

Eberhard et al. (2014) further argued that the single buyer model is viable as a transitional arrangement and in the case of South Africa, was vital to attract private sector investment into electricity generation prior to satisfying all conditions for a competitive wholesale market model. The one-buyer model has thus helped sustain an integrated wholesale power price as the bulk of electricity is aggregated under Eskom as the sole-buyer utility. This simplified the regulatory process and guaranteed successful investors off-take of their generation at a pre-agreed tariff such that they are not exposed to the forces of demand and supply in an infant market.

The single buyer model is now being criticized for its inherent weakness. In particular, it has perpetuated inefficiencies at Eskom by preserving its monopoly and imposing significant contingent liabilities on the government through take-or-pay quota agreements committed under Power Purchase Agreements (PPAs) signed with IPPs (Eberhard et al., 2014). Besides,

as crucial players in the electricity value chain, municipalities are precluded from procuring supplies directly from IPPs under this model while also bearing enormous negative impacts due to inefficiencies at Eskom. However, sentiments from government provide insights on a possible departure from this model as authorities are now working on a framework to allow municipalities in good standing to procure their supplies from IPPs directly under a Ministerial Determination (SONA, 2020; National Treasury, 2020). The current structure of electricity market is depicted in Figure 2.4.

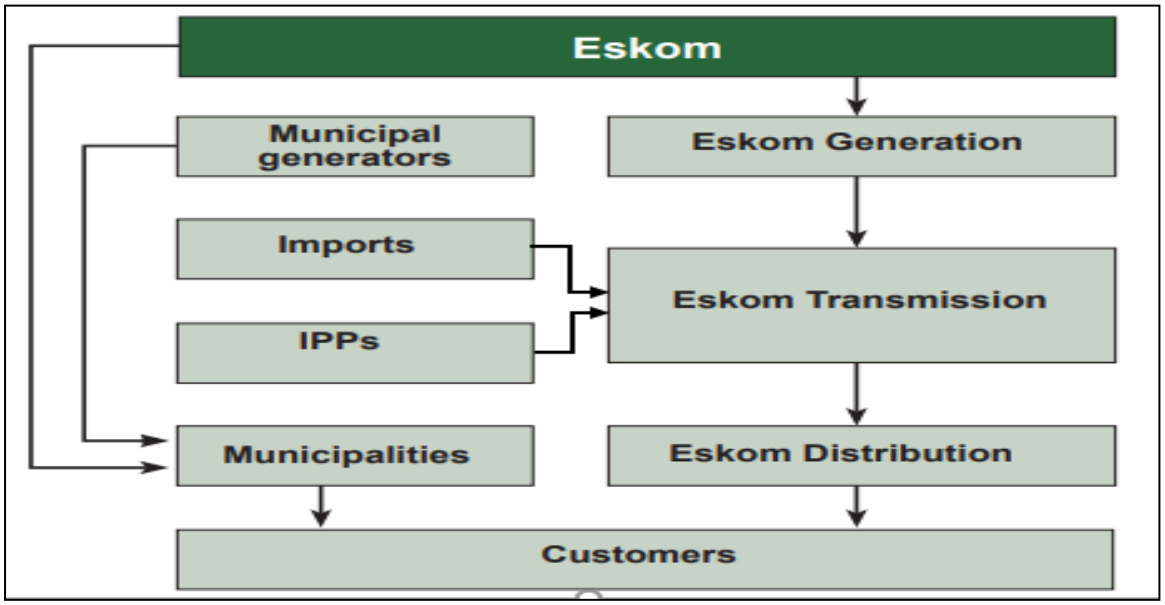

Figure 2.4: Electricity energy flow (Source: DoE, 2018, p 2)

Eskom is currently facing financial and political crisis attributable to decades of mismanagement and state capture. The ripple effects of these challenges (which have also cascaded to electricity distributors) now constitute a national burden experienced in the form of electricity shortages and socialization of costs through rising real tariffs and financial rescue packages for Eskom from the government (Baker and Philips, 2019). As shown in Figure 2.5, over the last 15 years, electricity prices increased by more than four times the rate of inflation. The National Treasury also availed a rescue package of R23 billion in 2019 to finance the reconfiguration of the national utility over three years. The total rescue package was subsequently set at R230 billion to be disbursed over a 10-year period (National Treasury, 2020). The tariff increases and fiscal support are meant to plug holes that have been created by continued imprudent operational and financial decisions at Eskom. Such holes include cost-escalations due to delays at Medupi and Kusile (two new coal-generation plants now at varying stages of construction) with an approximate capacity of 4,800 MW each. The projects were

expected to contribute 56% of the new expansion capacity by 2015 but have suffered from cost overruns and poor performance due to design flaws that have pushed completion dates beyond 2020 (Baker and Philips, 2019).

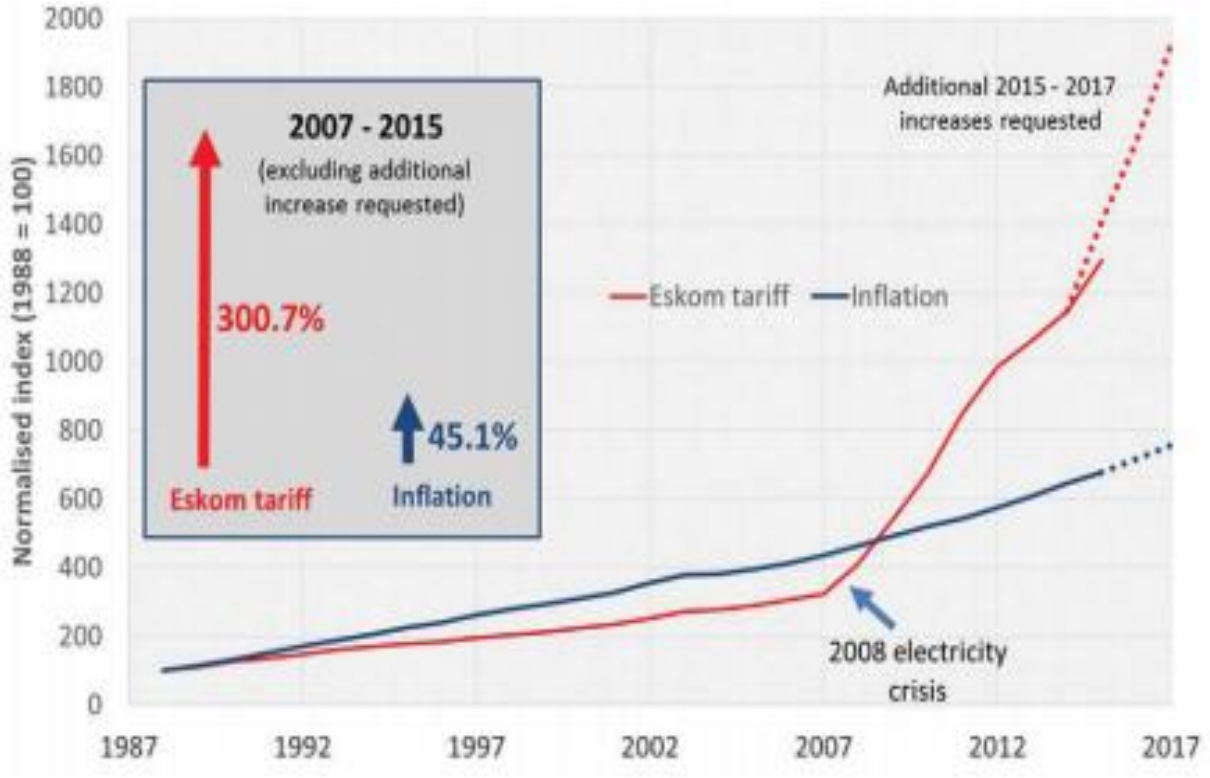

Figure 2.5: Eskom tariff increases vs. inflation (Source, Lutchman, 2019, p 1)

This study has been influenced by growth in self-generation due to supply-interruptions (load-shedding) arising from falling generating capacity at Eskom as well as rising electricity tariffs that force customers to pursue more affordable and reliable power supply options. The study further explored the possibility of implementing a smart grid to accelerate integration of power from self-generation plants into the grid so that it can contribute towards diversifying primary energy resources in the energy mix of the country.

2.2.2 Infrastructure challenges facing the electricity industry

Various academic and industry publications (see for example Bischof-Niemz and Creamer, 2019) have revealed that the critical challenge for electricity generation, transmission, and distribution in South Africa is rooted in ageing infrastructure. This is attributable to years of under-investment across the entire electricity value chain especially since the transition to democracy in 1994. While Eskom is involved in the generation, transmission and some distribution, municipalities are mainly responsible for electricity distribution/retail in areas

under their respective jurisdictions. Both municipalities and Eskom now have to contend with ageing grid infrastructure that is prone to recurring failure thereby disrupting services (Bischof-Niemz and Creamer, 2019).

Bischof-Niemz and Creamer (2019) aver that in the absence of viable alternatives, electricity challenges will continue as an increasing proportion of the current coal-based generating fleet gets decommissioned subsequent to its end of operational life. As shown in Figure 2.6, it is expected that only 10GW of existing generation capacity will be available by 2050. Government is therefore focusing on attracting investments into renewable energy technologies to augment generation capacity in a manner that replaces decommissioned plants as well as meeting future demand and, in the process, reduce the share of coal in electricity generation from 90% currently to less than 65% by 2040. Renewable energy plants have relatively short lead time of about 3 years compared to a minimum of 5 years for thermal power stations (Bischof-Niemz and Creamer, 2019, p 8).

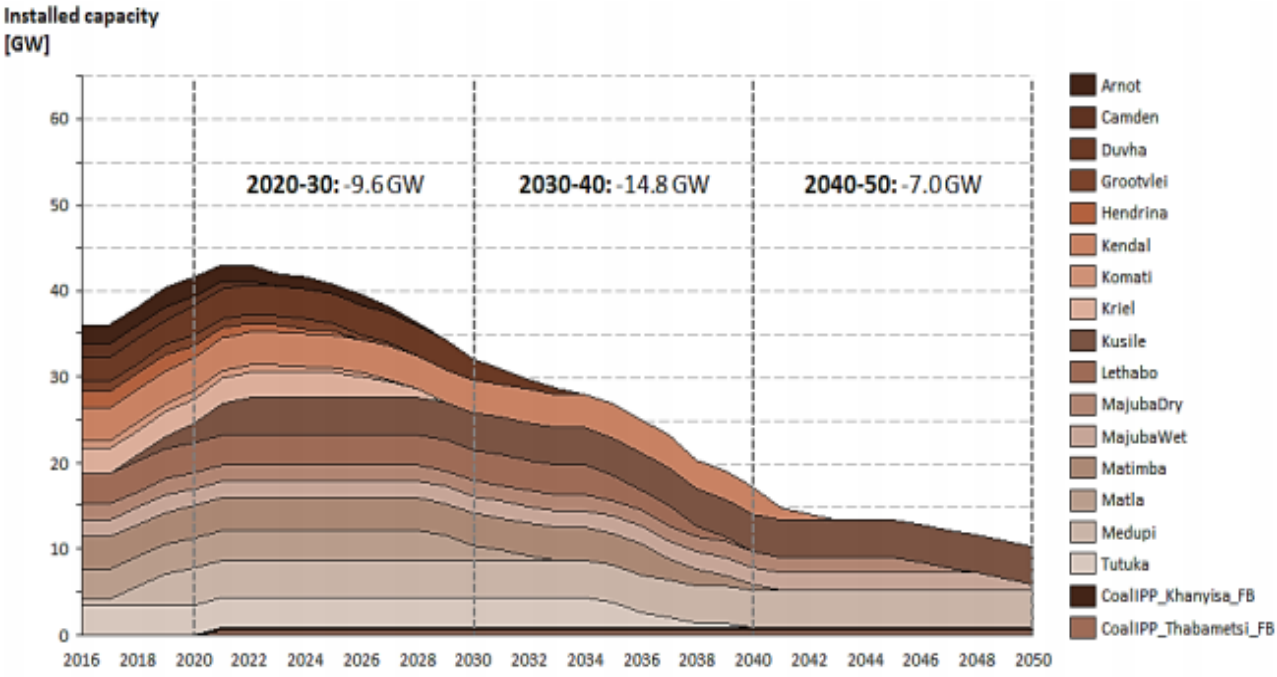

Figure 2.6: Decommissioning schedule for coal-fired power plants (Source, ERC, CSIR and IFPRI, 2017, p 14)

Bischof-Niemz and Creamer (2019) assert that Eskom has been unable to keep the existing plants operating at adequate levels of reliability and therefore continues to suffer from breakdowns in its generation fleet. The constrained generation capacity, coupled with economic growth and rising demand due to the government's extensive electrification programs

since the dawn of democratic dispensation in 1994, have resulted in the country experiencing electricity outages since 2008 when the national utility embarked on widespread (and still ongoing) load shedding to ensure grid stability. Eskom is estimated to be operating at a capacity availability factor of only 66. 8%, against a good-practice target of 80%. This means that generating capacity remains constrained and will not alleviate the challenges of load shedding in the near term.

2.2.3 Role of municipalities in the electricity value chain

Eberhard et al. (2014) observed that municipalities are significant players in electricity distribution in South Africa primarily due to their constitutionally mandated right and authority (under Section 156 and schedule 4B of the Constitution of 1996) to administer electricity distribution within their area of jurisdiction, subject to national and provincial regulation. According to SALGA, 188 municipalities are licensed by NERSA to operate electricity distribution services and they are responsible for retailing about 40% of South Africa's electricity sales. Eskom is responsible for the distribution and retailing of the other 60% directly to consumers in the mining and industrial sectors as well as farms.

However, there have been internal disagreements between Eskom and municipalities over who can distribute electricity in municipal areas. Eskom argues that municipalities do not have an exclusive right. On the contrary, local municipalities accuse Eskom of infringing on their executive authority by distributing electricity within their jurisdictions. This has sometimes resulted in customers within the same area having different tariff structures of either Eskom or CoE distribution network (Eberhard et al., 2014).

According to Baker and Philips (2019), municipalities are responsible for the maintenance of the distribution infrastructure falling under their control, connecting new customers, pricing, and setting minimum service level standards within their jurisdictions. In areas where there is co-distribution of electricity, ownership of the distribution infrastructure is often split between Eskom and the respective municipality.

Another key consideration is that electricity distribution remains a focus area for financial sustainability of municipalities and hence a political battlefield. Approximately 35% of total revenues for the major South African municipalities is generated from electricity sales. Eight metropolitan municipalities (each with more than 850,000 inhabitants) have municipal-management and legislative autonomy within their respective areas of jurisdiction. These

metropolitan municipalities cumulatively account for 60% of total South African economic activity and 42% of the national population. Municipalities are thus a vital cog in the implementation and realization of the national government's energy policies due to their extensive community reach (Baker and Philips, 2019, p 10).

Currently, various municipalities have developed their energy plans in alignment with the national government's thrust on the development of renewable energy to address the twin concerns of climate change and supply shortages (Baker and Philips, 2019). The current trend indicates that some municipalities are taking steps towards developing local policies aimed at attracting private investments for the implementation of their plans.

2.3 Grid-interactive distributed generation

Baker and Phillips (2019) define DG as small-scale electricity generation or storage (frequently varying from less than a kW to tens of MW) that are situated close to the loads (points of consumption) as opposed to primarily supplying to the centralised grid. Whereas there are varied definitions of DG, the underlying feature is that the generation units fall outside the control of the grid operators such as municipal or national electricity utilities (CoE or Eskom as examples in this case). Within this context, this study focuses DG based on rooftop solar PV technologies which customers are now finding cheaper to implement and is therefore rapidly becoming the widely available self-generating technology globally.

2.3.1 Policy and legal frameworks for distributed generation

A wide range of regulations and policies have been touted as the critical factors toward unlocking the full deployment for grid-interactive small-scale embedded generation. Bischof-Niemz and Creamer (2019) acknowledge that although South Africa has promoted the development of renewable energy resources mainly through REIPPP, it has fallen short in extending these policies and regulations to local government structures that run the low-to-medium voltage energy distribution grids which are crucial for grid-connected/interactive DG.

In absence of responsive legal frameworks, Eskom continues in its monopolistic control of electricity and passiveness in generation, transmission and distribution, thus making it difficult for IPP investors to plan and finance projects through "power purchase agreements" at municipal level. The dominance of Eskom in the value chain has often been cited as a sign of weak institutional arrangements which requires government intervention based on a regulatory framework that fosters competition and transparency in grid operations (Bischof-Niemz and

Creamer, 2019). Ongoing cost-decline of solar PV technologies creates the potential for reliable and affordable supplies especially in view of the key elements of the country's national electricity crisis such as diminishing public trust on the grid due to rolling blackouts since 2008 and perpetual increase of tariffs as (Bischof-Niemz and Creamer, 2019).

Various publications have indicated that SSEG installations in South Africa were estimated at more than 200MW by September 2016 in comparison to only 35MW in early 2015. This rapid growth in SSEG has occurred within an environment lacking the relevant supervisory frameworks as well as stiff resistance from municipalities and Eskom. As a result, grid defection of the high-end clients endangers revenue flows of the municipalities and Eskom in general. Bischof-Niemz and Creamer (2019) further point that South Africa provides noticeable contrasts when compared to developed economies such as UK, Germany and Sweden where the introduction of DG was encouraged by deliberate policies such as subsidies and responsive regulatory frameworks. However, Eskom is developing cold feet to push for such deliberate policies because it will lose its monopoly and ultimate control of the sector.

Schelly et al. (2017) postulated that activities aimed at promoting DG were happening at varying levels globally, especially in Europe and the USA, where the focus is to ensure that by 2025 all new buildings should be at nearly-zero energy consumption performance levels. EU member-states found that incentive policies such as feed-in-tariffs and green tax credits are attractive to DG investors. By introducing related incentive-schemes, competitive policy instruments were thus implemented to expedite the diffusion of DG.

As one key example, Greece attracted high investments for solar PV installations from 2012 to 2013 due to its high feed-in-tariffs (Schelly et al., 2017). Similarly, Germany experienced a high increase in DG installations as a result of developing a non-discriminatory regulatory framework (on the part of small generators) that allowed investors to take advantage of the high tariffs offered for surplus electricity exported into the grid. It resulted in renewable energy attractiveness which prompted many residential and industrial consumers to invest in renewable energy generation on-site.

In the US, Renewable Portfolio Standards (RPSs) have been included in the Energy Policy Act of 2005 as specific provisions to encourage the adoption of DG *(*Schelly et al., 2017, p 42.*)*. The study also notes that the RPS policies have measurable impacts on the adoption of DG through exerting significant influence on stakeholders. This included government's promotion

of smart-grid and net-metering (Schelly et al., 2017, p 32). From these case studies, it can be deduced that favourable policy frameworks and incentive programs are a necessary catalyst towards faster adoption of DG.

2.3.2 Fiscal policies for renewable energy and infrastructure development

Rennkamp et al., (2017) notes that incentive schemes addressing market-uncertainties have been some of the significant factors that entice renewable energy sector investments. However, South Africa suffers critical gaps in governance and budgetary policies required to fast-track reforms in support of such developments. Despite embarking on the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) to promote RE, criticism has been on the lack of continuity beyond the five bidding windows implemented so far. Additionally, the overall domestic market size is making investment decision uncertain. Outside the REIPPP bidding procurement approach, implementation of smart metering (as a vital component of the smart grid) continues to be hindered by numerous challenges, especially within municipalities and their respective distribution-utilities (Rennkamp, 2017). Even though a few metropolitan municipalities such as Cape Town, Durban, and Port Elizabeth, now have policy incentives similar to net metering to permit interconnection of residential SSEG units and export of surplus renewable energy to the grid, in most instances, the administrative fees for connecting such DG facilities to the grid are more than the economic benefits that accrue to customers from exporting their surplus power to the grid (*ibid*.).

Lack of funding is also cited as one of the key contributing factors to the ongoing failure to modernize the electricity infrastructure for both Eskom and municipalities (Eberhard et al., 2014). DBSA (2012) noted that electricity distribution infrastructure was estimated to cost a total of R27.4 billion for maintenance and repairs by the end of 2010 (for both Eskom and municipalities and excluding required upgrades to accommodate 21st-century electricity delivery solutions) and the amount was growing at a rate of R2.5 billion annually (Lutchman, 2019). Although the government has supported Eskom financially towards stabilising generating capacity, it has not extended its support to municipalities that own and operate a significant portion of the distribution network which is primarily characterised by high levels of both non-technical and technical losses as well as frequent downtime due to technical failures within the distribution grids (*ibid*.).

Lutchman (2019) attributed the poor distribution network within municipalities to lack of appropriate technical and operational/management as well as politically insulated operational

structures coupled with inability of municipalities to retain suitably qualified personnel to regularly manage and upgrade the distribution system. As confirmed by Development Bank of Southern Africa (DBSA) (2012), lack of funding was also affecting the capacity of municipalities towards resolving distribution backlogs and maintenance within their jurisdictions.

With increased investments in solar PV technologies, the distribution infrastructure is expected to become increasingly unable to accommodate increasing capacity from DGs. Lutchman (2019) argued that politics, through state intervention, can substantially influence legislation and policies to shape grid infrastructure. He established that municipalities in South Africa (including CoE), are failing to resolve electrification backlogs due to funding constraints and infrastructure decay. Continued neglect of this problem will require an overhaul of the whole grid network within the next decade or sooner and may be the catalyst towards investments towards smarting the grid.

Baker and Philips (2019) explained that the continued deterioration of infrastructure has also been accelerated by incidences of tampering, theft and vandalism which in turn contribute to poor service delivery especially in terms of unplanned power outages, poor billing records and faulty meter readings. Both Eskom and municipalities are also confronted by the effects of illegal electricity connections which further escalate the unscheduled power outage crisis. Significant losses are also being noted in generation, transmission and distribution as well as in the actual use of electricity. The distribution grid infrastructure is being pushed to carry more load than it can, given the level of deterioration over the years.

Grid networks require modernisation to make them “smarter” and more resilient through the use of cutting-edge technologies that delivers electricity far more reliably and efficiently. Smart grids also reduce frequency and duration of power outages due to storm impacts on power lines and restore service faster when outages occur. Brown and Zhou, (2013) noted that smart grid technologies improve security by remotely allowing utilities real-time visibility of all activities on the grid.

Eskom estimated that electricity theft was costing the country close to R20 billion annually (Mujuzi, 2020, p 1; Baker and Philips, 2019, p 182). According to SALGA, municipal losses for 2017/18 were estimated at around R9.2 billion and about 10% of this was attributed to theft or non-technical losses (Baker and Philips, 2019, p 180). While such theft has been historically

linked to low-income households in townships and informal settlements primarily as the vulnerable groups are finding it difficult to afford ever-rising electricity tariffs), recent data show an emerging trend where middle-to-high income households in formal suburbs as well as various types of businesses are also engaging in illegal consumption. Such losses could be suitably addressed through investing in infrastructure security under smart grid that can offer real-time monitoring to curb common challenges such as power theft (*ibid.*).

Cases of vandalism and theft can be linked to lack of active community participation in development initiatives due to exclusionary or discriminatory practices. There is therefore a need to incorporate the views of respective communities with regard to investing in modern infrastructure to handle the increasing load demands and offer protection against vandalism on the grid infrastructure (Simon and Wustenhagen, 2006).

Given the prevailing infrastructure and service situation within the distribution network, municipalities are confronted with multiple challenges that include the potential loss of high-end customers due to increasing incidences of vandalism and theft. As cases of vandalism and theft increase, the frequency and impacts of power outages increase leading to wealthier consumers investing in alternative sources of supply based on DG. This would in turn pose further risk of revenue loss and thus contribute to a downward spiral of further deterioration of the grid and service levels.

2.3.3 Impact of grid-interactive DG on municipalities

Increasing diffusion of DG technologies (especially as part of climate change mitigation response) and socio-economic changes have resulted in decreasing costs of self-generated electricity in South Africa relative to the rising tariffs of grid-supplied electricity thus transforming the country's electricity market. Korsten et al. (2017) assert that the expansion of DG is a disruptive force that creates a severe challenge for the legacy business models of Eskom and municipal utilities. In particular, grid-interactive DG has resulted in declining sales and revenues as well as increasing costs for electricity utilities.

Within this scenario, Korsten et al. (2017) investigated the impact of DG on municipal revenues at the household level based on Stellenbosch Municipality as the case study. The study focused on the optimum grid capacities for DG (based on the South Africa's grid standards) relative to individual households with the potential to derive the most monetary benefits from investment in rooftop solar PV. Grid capacity was an essential parameter in the study because it imposed

a limit on the additional surplus energy that DGs could feed to the grid before the Notified Maximum Demand (NMD) could be reached. NMD is the contractual value of electricity that the bulk supplier agrees to deliver to municipal distributor.

The study then explored the impact of solar PV on revenue collection under a conventional business model of municipal electricity utilities. Based on consumption sales and the emergence of DG, the study noted decreasing trend in revenue collection from electricity sales for municipalities. This was further compounded by the fundamental unsustainability of the power rates or tariff designs that are primarily pegged to volumetric sales. Additionally, costs incurred by municipal distributors did not reduce in direct proportions to the reduction in electricity sales, which implied that the savings on the purchase of bulky power from Eskom were proportionately lower than the revenue that would have been generated from lost sales (*ibid*.).

Given optimum grid capacities, Korsten et al. (2017) determined that an optimum number of 2,255 families could link to the grids assuming each family was to invest in a 3kW rooftop solar PV system. This would lead to a 2.4% loss for the municipality based on electricity revenues in the 2013/2014 fiscal year. Grid capacity imposed a constraint and had direct influence on the level of surplus generation that could be fed into the distributor's network by DGs. The second approach focused on 541 homes that would not decrease below monthly usages of 600kWh of power after connecting rooftop PV. Adopting this approach would lead to a loss of 0.6% in total revenues based on the 2013/2014 metropolitan fiscal year. Although the losses seemed negligible then, the rising rate of PV installations means the losses are escalating annually and especially spurred by increasing incidences of power outages.

Korsten et al. (2017) thus conclude that SSEG would largely benefit wealthier consumers who have the means to invest in alternative energy sources due to frustrations with the unreliable grid-supply. On the other hand, low-income households are unlikely to secure alternative energy sources and thus have to continue relying on increasingly erratic and expensive grid supplies. Utilities are also forced to increase their electricity tariffs from the central grid to cover fixed costs as the number of defections grow, leading to a declining trend in municipal revenue collection. As the high-end customers defect from grid-supply and possibly becoming net suppliers themselves, municipalities and Eskom will increasingly be left to serve a higher proportion of indigent customers that do not contribute significantly to sales and revenue.

In a similar study, Mayr et al. (2015) estimated the potential impact of PV penetration up to 2030 based on the City of Cape Town as the case study. It involved categorising the city's customers according to electricity consumption and income levels. The study ran a model-based simulation using hourly capacity profiles and radiation data to estimate each group's electricity bill based on a progressive tariff as it was at the time of the study. The results indicated that based on cost-benefit trends, the bulk of high-income inhabitants would be incentivized to invest in PV-generation by 2020 onwards.

In addition, by 2028, the use of home battery systems will lead to a steady increase in the gaps between revenues and expenditure needs in the budgets of the municipalities. The study suggested that the budget gaps could be minimized by adopting a tariff scheme that replaces the energy-consumption oriented tariffs with revenue-neutral fixed network-installation fees. This is principally important in minimizing incentives to invest in storage such that customers will remain connected and use the grid as their primary power backup infrastructure.

High-end consumers were being affected by the inclining block tariff (IBT) that operates on the principle that the more power customers consume, the higher their tariff rate will be. While higher-end customers have been most impacted by growing electricity bills and are the most likely to pursue more affordable alternatives, the loss of the cross-subsidies that the IBT provides is threatening the revenue base of South African municipalities. This tread can lead to a death spiral and a vicious cycle that can lead to bankruptcy as well as total collapse of the distribution grid networks within municipalities (*ibid*.).

Lutchman, (2019) highlights that despite exponential growth in SSEG, the diffusion has not yet disrupted Eskom's monopoly stronghold on the electricity value chain or the blockages at municipal level. However, it was prudent for municipalities and Eskom to prepare for SSEG's disruptive impact before reaching a tipping point where the transition will be forced on the utility due to changes in market dynamics. In line with that concern PricewaterhouseCoopers (PWC), 2013, p 5) indicated that the electricity market in Germany was already at a tipping point where baseload generation from gas and nuclear was no longer economically viable compared to renewable resource generation.

Lutchman (2019, p 4) suggests measures that could be adopted to protect municipal revenues during the transitional period before reaching the tipping point. The measures include:

- Purchase cheaper electricity (than Eskom provides) from consumer SSEG systems connected to the grid
- Generate own electricity through municipal SSEG systems and must be able to do so at an increasingly lower cost
- Take advantage of the rising SSEG implementation by high-income consumers and change their tariff structure to increase the revenue they receive from a fixed grid connection charge as opposed to electricity consumption tariffs

This study also assessed the relevance of implementing a smart grid network towards facilitating higher adoption of DG which could further facilitate the adoption of dynamic business models for the benefit of municipal utilities. Intelligent components deployed as part of smart grid systems provide information to the grid operator to alter the architecture of the business model to benefit the utility.

2.3.4 Impact of rising tariff on renewable energy-based DG

Filipova and Morris (2018) note that rising electricity tariffs are exerting pressure on consumers and the situation is further compounded by ongoing load shedding aimed at ensuring grid stability in view of the growing demand-supply gap. Their study elaborates on the increases by noting that for residential, commercial and local government, Eskom's real tariff increases for the period between 2003 and 2016 were 46%, 144% and 141% respectively as shown in Figure 2.7. The tariffs remained on an upward trend forcing high-income households to defect from the grid as they bear the most burden of price increases due to the inclining block tariff (IBT) system now in place across the country.

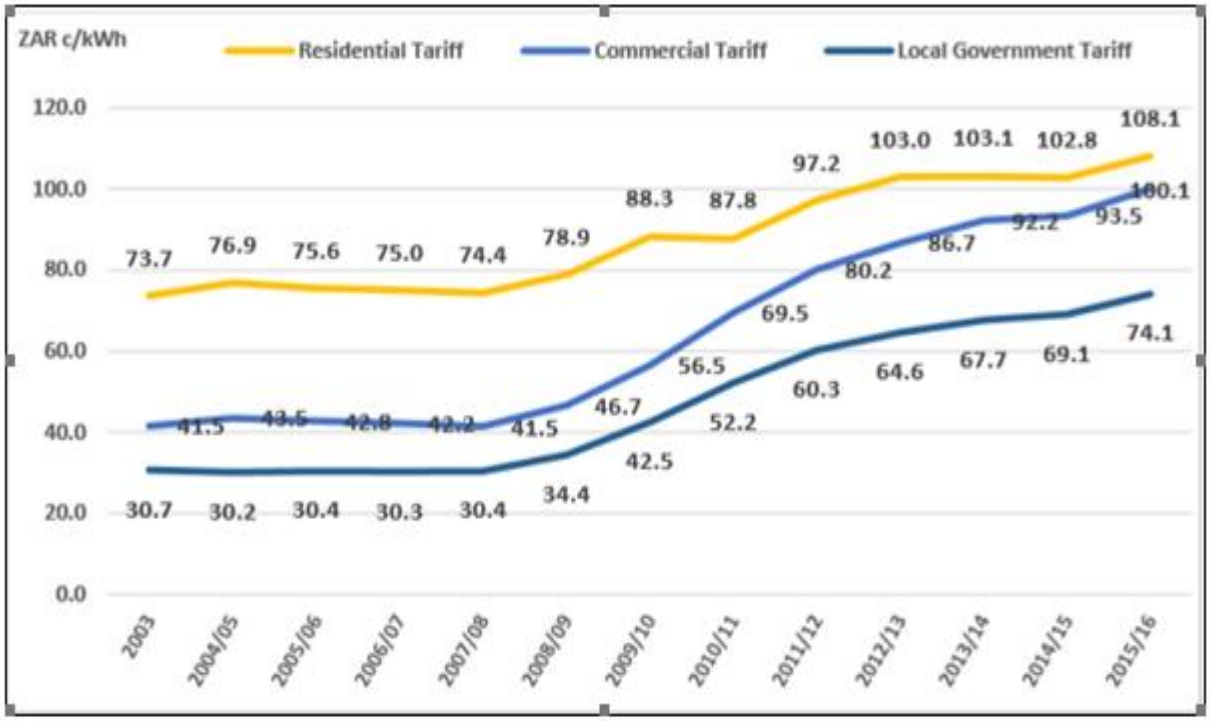

Figure 2.7: Eskom real term tariff increases from 2003 to 2016 (Source, Filipova and Morris, 2018, p 3)

On the other hand, as shown in Figure 2.8, the costs of solar PV-technologies have declined from R3.74/kWh in REIPPPP Bid Windows 1 to R0.62/kWh in REIPP Window 4. Following this trend, Filipova and Morris (2018) corroborates Calitz et al (2017) findings that the levelized cost of electricity (LCOE) for solar PV had breached the grid parity threshold such that generation from solar PV would continue becoming ever cheaper than grid electricity. Filipova and Morris (2018) further assert that a combination of rising electricity tariffs and declining costs of solar PV was encouraging a switch towards solar-based electricity generation technologies as high-end customers opt out of the increasingly more expensive and unreliable grid supplies.

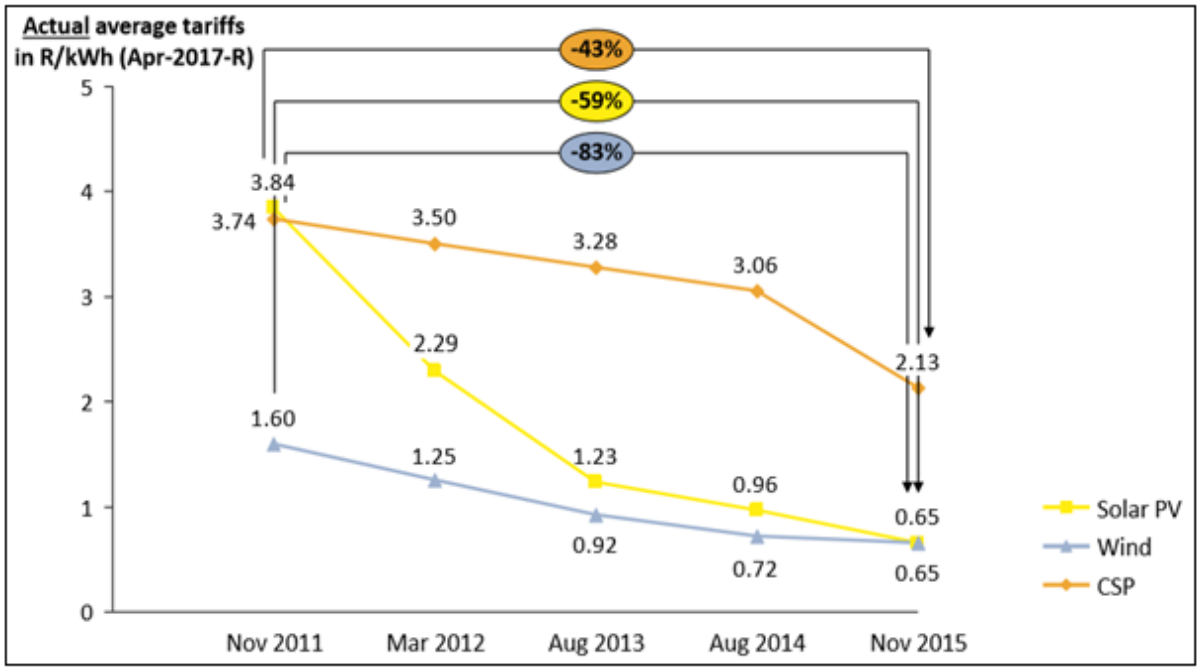

Figure 2.8: LCOE for wind, solar, and CSP, November 2015 (Source, Calitz et al., 2017, p 19)

This transition towards the diffusion of renewable energy technologies has also been made possible by the abundant solar resource in the country where South Africa is ranked as the third most highly endowed solar resource country globally with a mean of 2,500 hours of sunshine yearly and levels of average solar radiations ranging between 4.5 and 6.5 kWh/m² per day (see Figure 2.9). The country can potentially reach solar PV-generation capacity of over 220GW as identified in the Renewable Energy Development Zones (REDZ), where environmental impact assessments have already been completed and another 72GW of solar PV can be harnessed from rooftop PV, especially in urban areas (Jain and Jain, 2017, page 3). Based on this analysis, and coupled with IRP 2019 estimates, SSEG could reach a capacity of 22.5 GW by 2030. This points to enormous levels of connected small-scale PV-generation by 2030. Solar PV-generation can therefore be expected to pick up in demand compared to other technologies because of its relative ease of installation (translates into lower costs and shorter timelines). Despite its intermittency, it can be utilized together with conventional generation/grid supply or with storage-technologies (Jain and Jain, 2017).

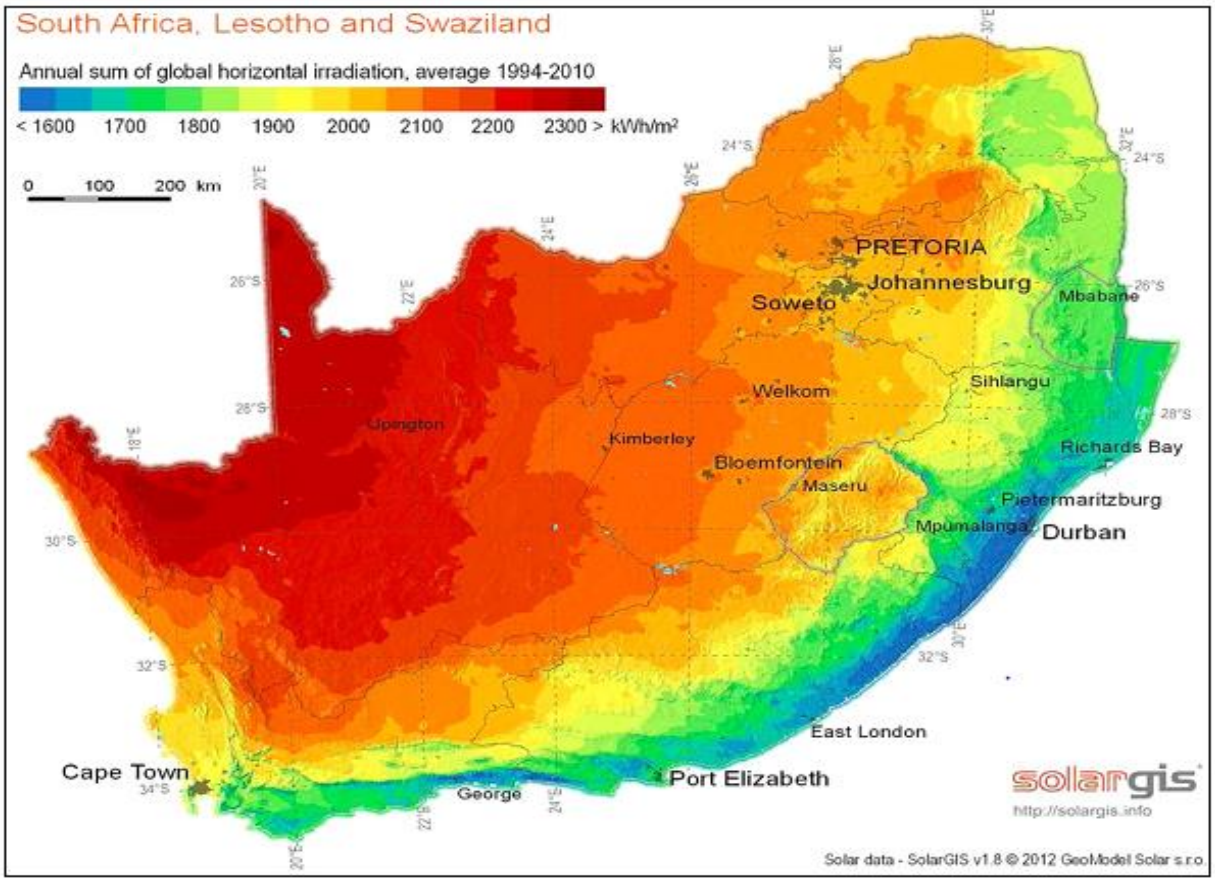

Figure 2.9: Solar resource map of South Africa (Source, Jain and Jain, 2017, p 4)

2.3.5 Barriers to adoption of DG

Policies and regulations communicate the intentions of governments in relation to stakeholder expectations on its implementing agencies. Based on their assessment of regulatory framework, Sewchurran and Davidson (2016) express concern over the low attention given to DG. As a result, the increasing adoption of SSEG across the country is taking place within a context where policy and regulatory framework remains weak, inhibitive and fragmented. In response, their study advocates for the development of regulations towards a more open electricity market in order to encourage investments. However, the study notes that government is unwilling to establish such a new legal and regulatory framework for fear of losing its centralised control on such a critical sector to the private sector. This concern is supported by SAPVIA (2019) which estimated that generating capacity of between 2,500 MW to 3,500 MW from members of the South African Independent Power Producer Association (SAIPPA) was being constrained due to policy malaise. The opportunities lost were inclusive of both small plants (below a capacity threshold of 1MW) as well as larger SSEG projects. The government views

the electricity sector as a key component for advancement of its socio-economic policies and especially in driving industrialisation within the context of a developmental state.

Baker and Philips (2019) also argue that high levels of politicisation of the South African electricity market acts as an inhibitive force towards the adoption of DG. In that context, Eskom and municipalities have had a long-standing and entrenched monopoly that underpins lack of urgency to facilitate the growth of SSEG for fear of losing revenue should the number of prosumers continue to increase. It was pointed out that Eskom has been holding on the right to vital information to prevent new investors from establishing their control over the sector (*Ibid.)*.

Baker and Philips (2019) also note that Eskom refused to support power purchase agreement (PPAs) for 37 ventures in 2015 in defiance of its obligations under an agreed national policy, which stalled progress on the REIPPPP. Such evidence of weak institutional arrangements deters potential investors who may be interested in investing in power generation in the country. Further barriers relate to the lack of power planning structures that afford the essential priorities to municipal distributors and in particular, provisions for fixed generation by municipal utilities.

Another challenge facing growth of SSEG is intricately linked to path dependency of innovation systems and the economics of renewable energy technologies. Pegels (2010) identified that contemporary electricity infrastructure in South Africa has its roots in the apartheid era when autonomy from external energy supplies was a political necessity due to sanctions and energy research continues to be dominated by fossil fuel-based technologies, especially coal. With its extensive monopolistic power still in place continued development of new coal-based generation by Eskom translates into a subsidised electricity market in favour of coal, thus hindering the emergence of a level playing field necessary for the mass rollout of renewable energy technologies and thus exerting heavy investment cost risks on renewable energy technologies. Pegels (2010) identifies some economic and investment features embedded in the Energy Act 34 of 2008 as obstacles to the deployment of renewable energy technologies. The barriers can be categorized into risks and cost factors as shown in Figure 2.10.

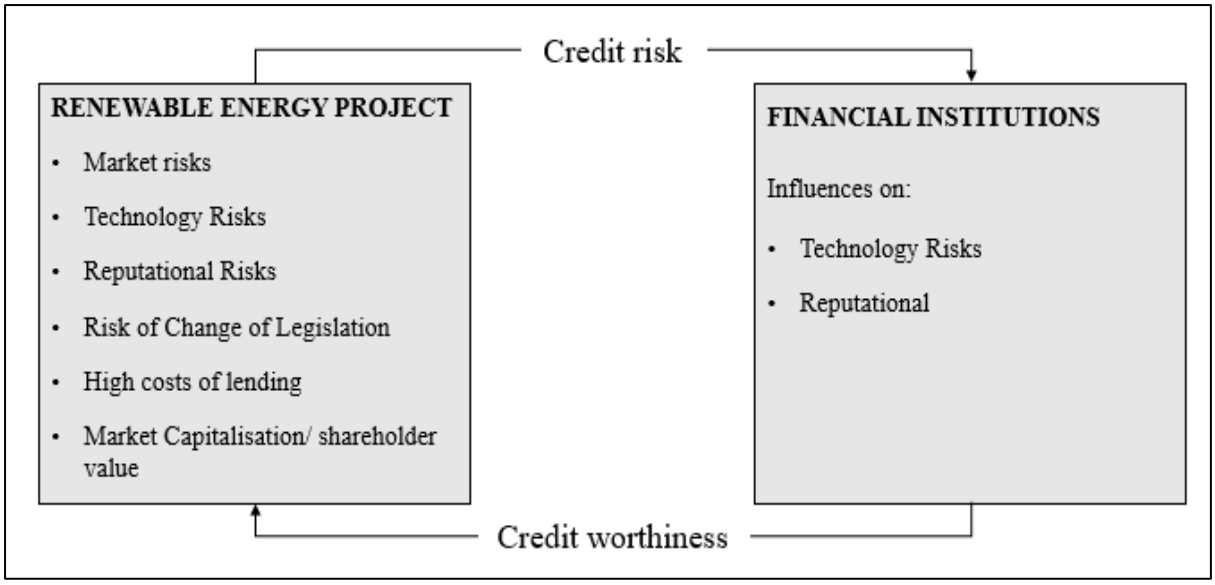

Figure 2.10: Key risks for renewable energy deployment (Source: Pegels, 2010, p 4)

Pegels (2010) cited the high credit risk and low creditworthiness among municipalities being a contributory factor towards the slow uptake of renewable energy projects. This is further confirmed by the number of municipalities in escalating debt for power supplied by Eskom. This is acting as a deterrent to various financial institutions considering funding for development of renewable energy generation both at municipal scale as well as in the form of DG. Investors tend to shun high risk projects and low creditworthiness of parties out of fear that they may fail to recoup their financial investments. Despite RE technologies being sustained by government interventions through programmes such as feed-in tariffs under REIPPP, small scale embedded generation remains limited to self-consumption, thus making it unclear whether changes in regulations and related market liberalisation in favour of DG will materialise soon enough. These uncertainties add to market risks because confidence over feed-in tariffs for DG constitutes a critical factor for the establishment of a reliable market for the investors (*ibid.*).

2.4 Smart grid technologies

Ardito et al. (2013, p 3) defines smart grid technology as a modernized grid network that enables bi-directional energy flows using two-way communication and monitoring competencies that facilitate for a range of new functionalities and applications. As shown in Figure 2.11, a smart grid system facilitates the integration of diverse users and equipment connected to the grid with the primary objective of pursuing overall system-operation

efficiencies especially through matching demand to supply, prioritising green-electricity and mitigation of losses.

Transitioning to a smart grid technology calls for a radical transformation of the energy system from the "business-as-usual model" towards embracing a more efficient and sustainable framework which is adequately adapted to the growing opportunities in DG from the consumers' side. The rapid technological advancements in ICT and 4th Industrial Revolution (4IR) as well as the ballooning shortfalls in centralized generation (especially when based on fossil-fuels) are some of the key factors driving the implementation of smart grids. Such technological advancements underpin the emergence of Advanced Metering Infrastructure (AMIs) within power networks to collect, measure, share and analyse energy usage and production data over two-way communication systems underpinned by progressive meters and the utility's control systems. AMI is just one of the many components that make up a smart grid which affords opportunities for consumers and the utility to interact on a real time-basis (Ardito et al., 2013).

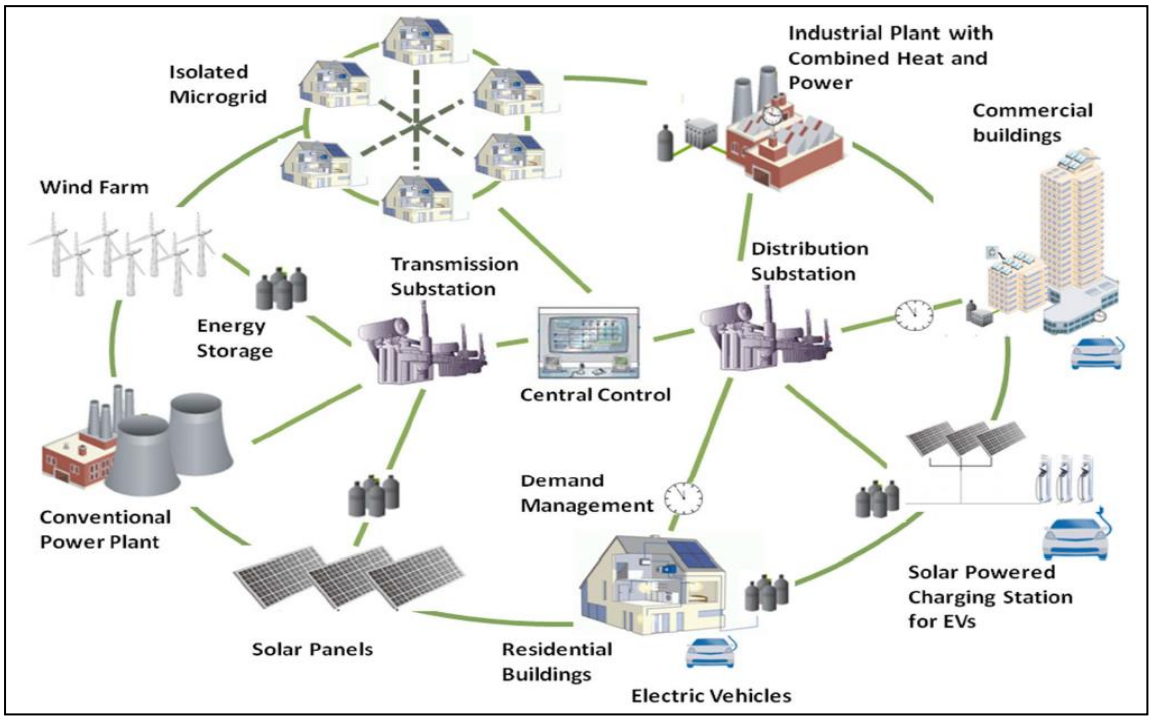

Figure 2.11: Illustration of the smart grid network (Source, Brown and Zhou, 2013, p 21)

One approach of defining the smart grid focuses on a vision that supports and integrates sub-systems, communication, troubleshooting, and various solutions within the electrical network (Brown and Zhou, 2013). Smart grids rely significantly on ICT and 4IR infrastructure to

contribute to the overall efficiency benefits from dynamic pricing as well as allowing incorporation and diffusion of other technologies such as interactive DG, energy storage and electric vehicles.

With regard to the key barriers and problems hindering rapid transitioning to smart grids, Brown and Zhou (2013) highlight that most utilities normally contributing to the crucial policy frameworks for such transitioning are already operating as conflicted monopolies which are biased towards the protection of market features aligned to their status quo core interests. Various governments and regulators are therefore reluctant to implement responsive policy measures which would open up competition in the utility market and thus threaten the interests of incumbent generators, who, in most cases are state-owned enterprises/parastatals.

The study stresses that during the transition, there could be new players, new interaction types, new uncertainty regions and overlapping accountabilities that will have to be resolved. Matters of change management, coordination and agreements should therefore include sharing insights of gains and perils arising from implementation of smart grids as well as the benefit-sharing approaches between players in public and private sectors in order to speed-up its roll-out (*ibid.*). Based on these insights, the study strongly emphasise that technologies are not the only vital aspect. Instead, business models as well as innovative policies and regulations would also be required to incentivize and execute a responsive architecture of next-generation electricity grid system for South Africa.

2.4.1 Smart-grid infrastructure and policy frameworks

Many cities are experiencing an increase in urbanization and population growth which has resulted in escalating energy consumption accompanied by grid-supply constraints as well as price volatility. Given this scenario, there is an expanding customer base as well as a need for diversified generation and distribution options. Such a dynamic scenario should be leveraged to catalyse the adoption of smart-grid technologies which would allow utilities and consumers the agility to adapt to these changing market dynamics.

The changing consumer-needs and requirements therefore calls for radical transformation relating to the way power is generated, transmitted and distributed. Among the multiple benefits of smart-grid, facilitation of scale-up of grid-integrated DG has been identified as one of the key opportunities which prompt many countries to start embracing smart grid technologies. Tomain (2012) notes that smart grids are essential for the future electricity

market, especially because it promises to help many economies transform from fossil fuel-based generation to renewable energy resources.

Tomain (2012) also highlighted that changes in market dynamics are commonly underpinned by changes in supportive policy and regulations. In stark contrast, and especially within developing economies, the emergence of smart grid and net metering has not been effectively embraced due to a critical lag in policy and regulatory reforms.

Tomain (2012) analysed multiple approaches to smart grid development based on two statutes in the US, under the United States Department of Energy (DoE). The two central laws appraised in the study are the Energy Independence and Security Acts of 2007 (EISA) and Energy Policy Act of 2005 which expanded scope of the Federal Energy Regulatory Commissions (FERCs) *(ibid.*).

The principal objective of EISA was to minimize the overreliance on fossil fuels through improved supplies of renewable energy alternatives as guided by an obligatory Renewable Fuel Standards (RFCs) that require transport fuels sold in the US to contain a minimal of 36.0 billion gallons of renewable fuel per year by 2022. These laws are anticipated to reduce emissions of greenhouse gases by 9.0% by 2030 *(ibid.).* EISA further provided for establishment of Smart Grid Task Forces and Smart Grid Advisory Commission within DoE based on the assessment of smart grids as fundamental to the modernization of grid networks and in securing reliable infrastructures for electricity supply in line with future demand.

This mandated the DoE to establish the standards for grid interoperability based on a smart grid pilot project for research and development objectives. The DoE was also tasked with the responsibility of creating matching grants programmes for smart grid investments to stimulate technological investments, especially towards enhancing transmission and distribution, as well as facilitating the scale-up in smart metering, adoption of electric cars, and smart energy efficient appliances/equipment.

The second statute, the Energy Policy Act of 2005, provided the Federal Energy Regulatory Commission (FERC) with a crucial role in smart grid deployment. FERC was responsible for regulating interstate wholesale electricity transactions on issues such as rates, terms and conditions of transmission. In face of mounting electricity challenges, the white paper on smart grid policy was published in 2011 and it called for sharing best practices towards shifting from fossil fuels-based power generation to a DG based RE consumer-driven market (Tomain's

(2012). In line with EISA, the white paper guided the formulation and passing of the Stimulus Bill aimed at promoting cost-effective smart grid investments, innovative technologies and broadening choices available to consumers.

Data related to these findings on policy gaps informed part of the findings to sub-question 1 and 3 in Chapters 4 and 6 respectively. The data were specifically used as secondary data towards analyses of traditional energy policies in relation to smart grid development, the power of incumbency as well as concerns and challenges around grid-interactive DG.

2.4.2 Electric vehicle integration into smart grid infrastructure

The International Energy Agency (IEA) forecasts that oil consumption will rise by 54% by 2035, coupled with a substantial price increase over the next two decades. The transition to electric vehicles and mobility is therefore viewed as a critical intervention to mitigate climate change impacts of transport as well as enhancing energy security and geopolitical concerns over fossil fuels (Mwasilu et al., 2014). Electric vehicles require charging facilities that can be integrated into the grid through residential and commercial buildings as well as parking lots. Mwasilu et al., (2014) further notes that electric vehicles can either absorb the surplus power by DG through different charging schemes or it can deliver power to the grid through vehicle-to-grid network setup. This will put additional pressure on the grid and in turn necessitate responsive infrastructure upgrades.

A smart grid network can therefore be viewed as the contemporary solution that will allow for a diverse range of smart technology interconnections while mitigating the bottlenecking effect. However, South Africa lacks responsive policy framework, attractive incentives or regulatory frameworks to facilitate the required transitioning towards electric mobility. This highlights one of the key constraining factors in the pursuit of low-carbon economy and a smart city agenda. In view of prevailing absence of tax rebates and capital incentives in most countries, it is anticipated that electric vehicle adoption is most likely to follow a similar path to DG integration into smart grid networks and as part of the emerging network of real and virtual power plants (Mwasilu et al., 2014).

2.4.3 Energy storage integration into smart grid systems

Energy storage is a critical component of DG as it improves power management by providing bridging and stabilisation capabilities to intermittent resources, thus acting as a “shock absorber” in the electricity grid. It is also regarded as the major link towards the transformation

of our status quo infrastructure and operations to the smart grid. Sources such as Zame et al., (2018) argue that gaps within the regulatory and policy frameworks have limited the accelerated integration of distributed storage systems into the electricity grid.

The key to energy storage is that it can increase economic benefits similar to generation if offered the status of generation, transmission and distribution services thus enhancing revenue generation status of the underlying assets. One example is where energy storage operators can dispatch to the highest-valued use, thus generating a higher return unlike in the case of serving merely as supplementary energy systems (Zame et al., 2018). In this sense, smart grid and net metering technologies coupled with energy storage, demand side management and interconnection will shape the future outlook of the electricity market towards creating the Internet of Energy (IoE) as a key part of the Internet of Things (IoT). Within this scenario, policy and regulatory frameworks would enable the realisation of value and potential from energy storage by allowing access to ancillary and other markets, thereby acting as a powerful tool to build a storage-based smart grid network (Ferrey, 2009).

2.4.4 Challenges in smart grid deployment

Following on their key observation that widespread deployment of the smart grid is remains highly limited, Brown and Zhou (2013) note that the key challenges to the deployment of smart grids can be linked to ineffective policies that inhibit the smart grid deployment. The upfront cost has been noted to be a major constraining factor to deploying a smart grid, such that the resultant benefits cannot be fully realised for many years (*ibid.*). Without an effective policy to guarantee investment recovery, the adoption process tends to be delayed or non-committal over a lengthy period. Privacy concerns leads to questions over consumer rights protection and developing appropriate policy concerning capture and use of customer data. Policy uncertainties also impact negatively on the willingness to adopt roadmaps to incorporate modern electrical infrastructure networks (Brown and Zhou, 2013).

Verborg et al. (2013) highlight that smart grid implementation has been accomplished in varying forms across countries. This also applies to the way their various components have been incrementally prioritised as part of grid development. For instance, the approaches adopted in the United States have focused on the distribution network and significantly improving the grids and rolling out of smart meters based on collaboration between different levels of government and respective utilities.

On the other hand, the South Korean government and private and national utilities played leading roles in establishing large-scale smart grid demo projects on Jeju Island. Japan's model is characterised as a business-oriented, government-driven and community-led approach. On the contrary, the Chinese government has concentrated on developing fifteen-super-grids throughout China with the support of various electricity power companies. The study also established that a common feature of these models had been the objective of inducing behavioural transformations among household users by using community-led and participation-based models to pilot demand response measures and dynamic pricing systems. The South Korea smart grid (SG) pilot project aimed to visualize electricity usage for users through the applications of government-sponsored programmes on aspects such as demand responses, smart meters, and dynamic pricing (*ibid.*). This shows how government-led initiatives can lead to successful diffusion and adoption of innovative technologies in the electricity market.

2.5 Net-metering systems and policy strategies

Net metering refers to power policies and business models allowing consumers to offset some or all of their electricity use from the grid with self-generated electricity within a grid-integrated DG. Dufo-López and Bernal-Agustín, (2015) note that this is achieved by utilizing a single meter capable of differentiating and capturing bi-directional flow of energy across the meter. Widespread adoption of grid-interactive DG is being implemented and supported globally through the promulgation of different types of tariff policies and incentive programs such as feed-in-tariffs and quota systems (*ibid*).

Their study also notes that the transition towards net-metering has been extremely slow mainly due to the absence of attractive policies and tax incentives for investors, especially on the side of prosumers despite the decreasing cost of renewable energy installations, and especially for rooftop solar photovoltaic. The study further highlights net metering system as the most critical intervention for accelerated adoption of DG as it allows grid-connected consumers to export surplus generation to the grid which is then offset against their electricity consumption from the grid at a set tariff. Given that the set-offs and settlements are done automatically on an ongoing basis (real-time) over the network, it encourages extensive participation of prosumers by eliminating processes that require manual interventions such as reading of analogue meters. Net metering thus allows state utilities to buy back surplus electricity from customers who are interactively connected to the grid.

Dufo-López and Bernal-Agustín (2015) view net-metering as a favourable technological innovation which would help overcome the financial barriers faced by DG stakeholders and investors. It is therefore an integral part of policy formulation aimed at driving the adoption of renewable energy generating plants on a wider scale. Globally, net metering has been implemented over the last two decades as overall costs of renewable energy technologies continue to perform better than centrally-generated electricity supplied from the grid.

Dufo-López and Bernal-Agustín (2015) thus argue that net-metering policy promotes various least-cost technologies and thus helps to bring cost structure down. For example, the US Energy Policy Act of 2005 requires utility companies to adopt net metering and interconnection policies to encourage consumers to become prosumers using various types of distributed energy generation sources. In sharp contrast, multiple studies have noted the lack of net metering policy and regulations in South Africa's municipal policy frameworks and very few of them have implemented measures to compensate for surplus energy exported into the grid from their respective DGs *(ibid)*.

Based on insights from Peru as a case study, Mojonero et al. (2017) concluded that net metering systems provide a strong economic incentive for the installation of PV systems, especially by residential users with higher energy consumption. Their study also found that the use of net metering systems reduced the investment payback period for the system from between 7 and 9 years to 6 years. End-users with low energy consumption demonstrated minimal interests towards becoming prosumers due to the existence of a subsidized tariff. The study confirmed that a well-designed net metering policy provided electricity utilities with additional capacity from small, distributed installations, which reduces capital expenditure requirements for expanding centralised generation capacity. This provides insights into how favourable interactive grid-connection and net-metering policies can encourage the adoption of DG within South Africa's municipalities.

Although net metering has become a widespread policy for supporting distributed PV adoption globally, it is still considered a bottleneck by distribution operators due to uncertainty it can impose on cash flows. Most barriers to net metering are largely attributable to absence of the required infrastructure due to prohibitive costs. Net metering requires fixed investments in building the infrastructure and educating all concerned stakeholders (Darghouth et al., 2016). Many SSEG plants remain underutilized as both customers and utilities are not able to procure the required infrastructure resulting in excess power generated going to waste.

Darghouth et al., (2016) noted that one inherent feature of net metering is that the value of savings enjoyed by prosumers depends heavily on the structure of the underlying retail electricity rate, customer's consumption patterns and PV system installed. Consequently, the value of net metering and the impact of moving to alternative compensation mechanisms can vary substantially from one customer to the next. For these reasons, it is important for municipal utilities to understand how net metering compares to other possible compensation mechanisms on revenue performance in relation to eliminating the critical bottlenecks towards the adoption of DG.

2.6 Cost benefit analysis for smart grid and its application in net metering systems

The review under this section highlights the main concerns around the risk over recouping initial investments on the smart grid. Echeverri et al., (2017) argues that the main driver for smart grid implementation has been its capabilities in helping utilities on energy efficiency management and automation of the distribution network. This results in improved operational and financial performance of utilities thus strengthening their ability to recoup investments made towards the infrastructure upgrades. Echeverri et al. (2017) further identified the positive impact of smart grid and net-metering on socio-economic and the environmental goals such as responsive energy pricing, load and demand curve management, mitigation of energy losses, job creation and reduction of carbon emissions. As observed in the study by Echeverri et al. (2017), job creation will likely increase due to increasing demand for technically superior personnel to oversee installations and development of new technologies. Figure 2.12 shows the cost-benefit factors of smart grid and net- metering systems that can be used to quantitatively evaluate their overall viability.

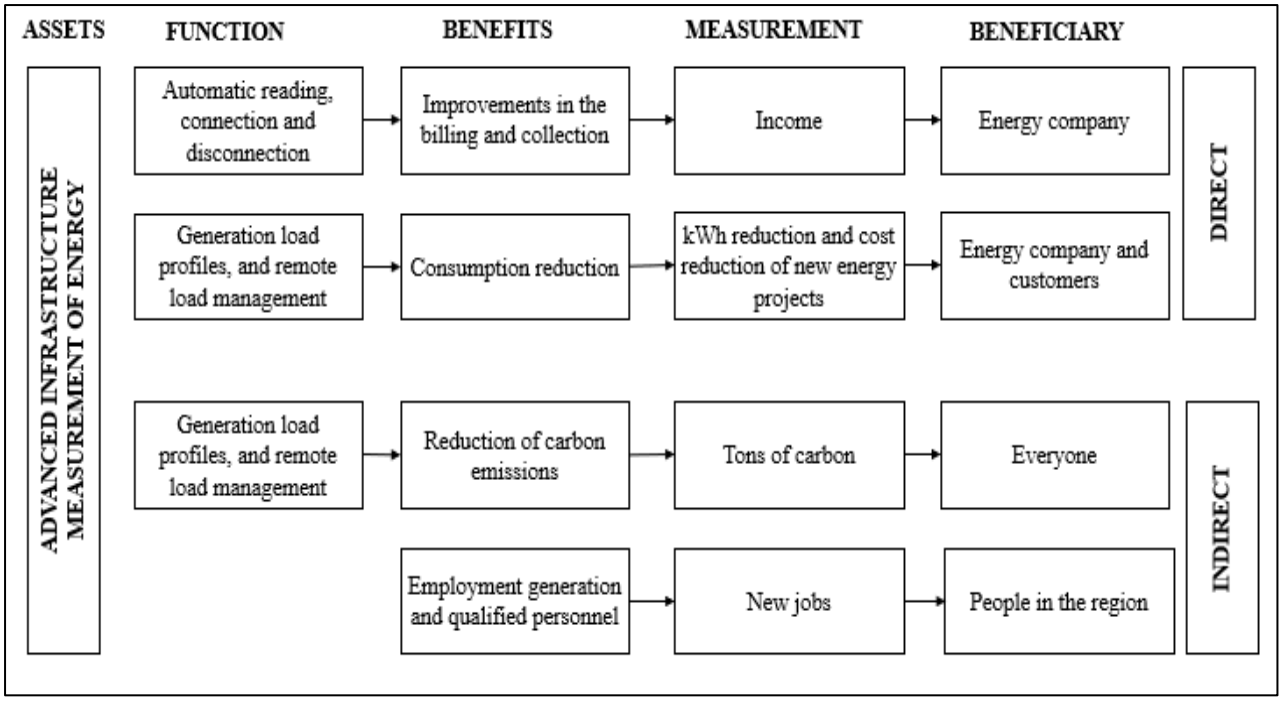

Figure 2.12: Cost-benefit factors for evaluating smart grid and net metering investments (Source: Echeverri et al., 2016, p 32)

The cost-benefit associated with smart grid and net metering applications arise from cost savings due to their capabilities in reading meters remotely as well as automatically connecting and disconnecting users when triggered in the systems. The cost reductions are cumulatively significant on an annual basis and have a direct impact on revenue growth for the municipalities. Echeverri et al. (2016) notes that these benefits could be the likely drivers of the increasing adoption of smart grid and smart metering systems by utilities globally. On the other hand, these systems are also encouraging cost-savings at customer level by providing them with information used in responsive/real-time load-management as well as overall reduction in energy consumption.

One crucial social challenge observed is related to consumer resistance emanating from perceived lack of safety and privacy concerns associated with real-time data collection that tracks and controls consumption (Echeverri et al., 2016). Job creation and new skills development are considered as critical concerns in adoption of a smart grid as it eliminates the well-established manual readings which support direct jobs even though it also contributes to errors as well as increased operational cost for distributors. Reduction of carbon emissions would be one of the key direct benefits for CoE.

2.7 Significance of the Internet of Things (IoT) and blockchain technologies

Arising from the objective of the study to substantiate the significance of blockchain as a disruptor of the conventional business model of municipal utilities, this section focuses on studies exploring the significance and developments of the technology. Al-Ali (2016) notes the critical role of smart grid and blockchain technologies in the scaling up of DG and then highlights the need for new market approaches to manage pricing and other dynamic consumer requirements in the electricity market. The emerging Internet of Things (IoT) is closely aligned with smart grid implementation as both depend on the ever-evolving information and communication technologies (ICT) to provide efficient energy distribution and management solutions in contrast to the conventional grid network.

IoT allows for the bidirectional communication systems in smart grid networks that can facilitate the monitoring of different types of objects based on their respective unique internet protocol (IP) address. Owing to IoT's scalability, loads and consumer-devices and appliances can be integrated into the smart grid using similar principles of bi-directional communications which in turn allows for remote control processes. This entails a significant potential contribution towards incorporating DG such as solar PV, wind power and mini-hydroelectric for the systematic management of power and information exchange (Al-Ali, 2016).

IoT and blockchain thus present immense opportunities for tackling most of the key technical impediments to DG by providing advanced data management and enhanced security tools that are re-shaping the electricity industry (Al-Ali and Aburukba, 2015). Blockchain technology (which underly cryptocurrency operations such as Bitcoin) allows both utilities and consumers to transact over electricity grid without the need for a centralised point of authority, thereby decentralizing the conventional electricity system into a meshed-grid network (*ibid.)*.

Potentially, IoT, together with blockchain, can handle multiple processes and store billions of object-data captured from systems connected to the smart-grid. This is achieved by handling and distribution of DG-related data to allow for the establishment of local energy markets Where consumers (as producers–consumers – prosumers), can trade locally generated renewable resource electricity within their respective communities (*ibid.*). Given the added benefits, there is growing interest in the blockchain technology globally and this is set to open whole new electricity market platforms which will be better positioned to support DG.

Basden and Cottrell (2017) reports on a case study in the New York State of Brooklyn where blockchain technology facilitated buying and selling of electricity among some of the houses. Traders with rooftop solar PV installations were interconnected through a computer with blockchain capabilities which allowed them to sell power to their neighbours in a verifiable and reliable process where blockchain recorded, validated and shared information to minimize downtime or data interferences. This demonstrated the capacity of blockchain-enabled grid networks to manage and record transactions with minimal human involvement.

Basden and Cottrell (2017) also report that similar trends are being seen in countries such as Austria where the largest electricity utility, Wien Energie, is pioneering on blockchain trials to allow trading amongst service providers. Innogy, a power company in Germany is also running a pilot to see if blockchain technology can authenticate and manage the billing process for free electric-vehicle charging stations. Blockchain, together with IoT embedded within smart grid networks, mitigates concerns over variability/unpredictability of supply commonly associated with DG, and thus allow consumers or prosumers to produce, sell, and buy seamlessly at lower costs (especially in financial and operational transactions) across DG-integrated networks *(ibid.).*

2.8 Advanced Metering Infrastructure (AMI)

The development of Advanced Metering Infrastructure (AMI) is regarded as a key element towards grid improvement and the integration of DG. AMI is an integrated system encompassing sensors, information technology and communication systems that detect and read power consumption remotely in real time (Ozbuday and Ozgur, 2018). There are four main components of AMI which includes the meter, Meter Interface Unit (MIU), sensors and remotely controlled variables.

Connected meters report on the flow of information from customers connected to the grid. This is then processed by MIU through signals translated into flow value and then captured into Information Management Systems (IMS). These meters come with sensors that detect and read consumption, pressure, temperature, acoustic signals and electricity quality. This information is incorporated into Supervisory Control and Data Acquisition (SCADA) systems processed and analysed for customer billings with time-based power rates. SCADA is a systems architecture comprising of distributed computers, control, network data and Graphical User Interface (GUI) that gathers data for both utility and customer benefits *(ibid).*

The liberalization of electricity markets has introduced many opportunities such as DG that allow customers to also participate in real-time trading of electricity (Ozbuday and Ozgur, 2018). DG adoption has become a cost-effective way of improving power shortages, reliability and quality. In line with this transition, AMI with connected smart meters enables DG integration into electric grid systems, thus enabling remote reading and automatic meter processing using two-way communication for consumer participation. Given these benefits, AMI can be a good enabler for maximising the value of DG to both distribution networks and utility customers (Khan and Javaid, 2019). To promote AMI, EU commission prioritised it as part of a roadmap towards competitive low-carbon economy by 2050 (EU Commission, 2011). In 2012 most European countries identified AMI as critical element for smart grid development based on increased share for renewable energy.

Ozbuday and Ozgur, (2018) conducted a study on the impact of AMI on the New Zealand electric grid and DG penetration. The study used monthly report data from retail customers published on New Zealand Electricity Authority to perform real-time series and analysed the causality relationship between AMI penetration and DG uptake for four consumer groups (industrial, commercial, residential and small medium enterprises -SME). The results indicated that bidirectional causality between AMI and DG uptake is essential in future value for DG. Further to the findings, responsive policies were found to be pivotal in adding value through promotion of both AMI and DG for mutually benefitting owners of DG and as well as distribution networks. The study thus provided insights on the role of AMI in increasing customer participation through DG programmes (*Ibid*.).

2.9 New business model for electricity utilities

Richter (2013) speculates that the existing power utility business model will radically transform to a point of becoming unrecognizable by 2030. The study highlights that German utilities did not see SSEG as a threat to their business models at developmental stages and therefore lacked alternative models to help them commercialize DG to their benefit. The utilities' reluctance to embrace SSEG at the beginning of the cycle resulted in them losing to competition from private players such that the utilities ended up owning and operating a mere 12% of renewable energy generating capacity while private players took the initiative to invest in renewable energy early on and ended up taking over 88% of the potential market. German utilities thus lost their position in the market, not because of technological changes but because of their insistence to

continue with a business model that was no longer compatible with the diversified market opportunities.

CoE is potentially faced with a similar fate unless the municipality reconfigures its business model to incorporate renewable energy resources and especially through integration of DG. With digital solutions on the rise to incorporate grid-interactive generation with or without wheeling arrangements, municipalities are compelled to transform their business model and related legislative frameworks in response to the growing demand for DG and facilitated by the rapidly evolving technological innovations now diffusing in the electricity market *(ibid.)*.

Based on the German case study, Richter (2013) further explores two business models that can be adopted by utilities in order to remain relevant in the face of disruptive impacts of DG. The models are *customer-side* and *utility-side* renewable energy business models. Both models provide insights on how current business operations can be reconfigured to take advantage of DG. In the proposed models, Richter (2013) does not cover the possibility of municipal utilities playing trade facilitation roles through activities such as wheeling arrangements and aggregation of production from distributed generators (and therefore serve as the wholesaler) for further distribution to consumers. Instead, the models are limited to the participation of the electricity utility in electricity generation.

Figure 2.13 presents a paradigm shift in the new era of a disrupted electricity market where issues of where and how electricity is generated, transmitted, and distributed no longer matter due to technological developments that allow even residential consumers to also turn into generators. Sewchurran and Davidson (2016) highlight the increasing grid defection risk in todays and future economies that aspire to decarbonise, cope with retail pricing evolution, and grid modernization that otherwise would be entirely left to monopolistic utilities. Under such a scenario, CoE is faced with systemic challenges of customers defecting from the grid which thus creates urgency towards framing reforms in electricity tariffs, new business models, and regulatory frameworks crucial for integrating various self-generation technologies at diverse capacities and scales.

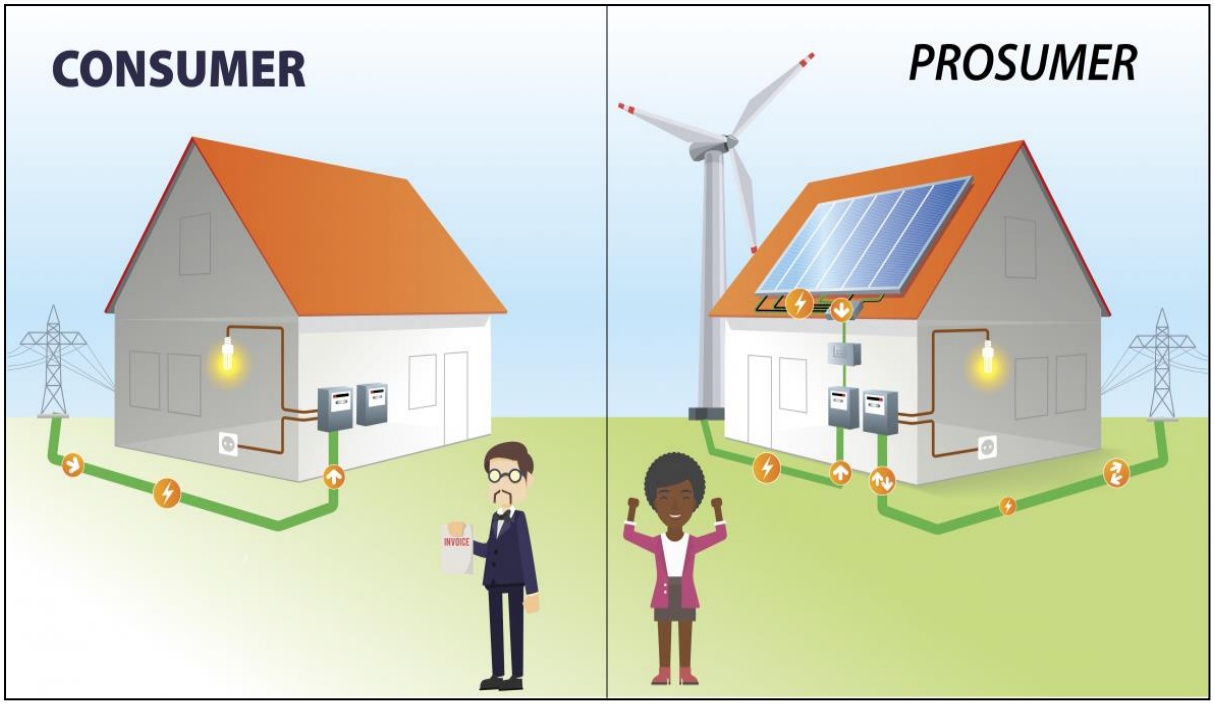

Figure 2.13: Evolving electricity market from utility versus consumers to prosumers (Source: Hittinger, 2019, Online page)

2.9.1 Customer-side business model

Richter (2013) notes that DG is situated at the client's property and based on technologies such as micro-wind turbines, solar PV and solar water heating. The system usually varies from a few kW to about 1 MW. Value proposition by the utilities can cover services such as simple consulting to full-utility packages including asset operations, financing, and ownership. Municipal utilities such as CoE, would fund and own the asset situated at premises of the customer. Municipal revenues would then come from utility charges and returns on investment, while they incur costs originating from system operation, management and connections (Richter, 2013). The electricity produced by the distributed plants would be sold to the consumer and the utility has an option to feed the surplus into the grid at a lower cost compared to grid/Eskom tariffs.

2.9.2 Utility-side renewable energy business model

Richter (2013) suggests that an alternative approach would entail utilities investing in extensive projects of renewable energy at varying scale from 1 to 100MW projects with technologies ranging from solar thermal electricity, biomass, offshore and onshore wind plants. Power from these plants is fed into the grid with wheeling arrangements where necessary. Client interfaces consist of electricity buying pacts on business-to-business model instead of relationships with

the end-users. Such ventures would be more like conventional centralized electricity distribution than customer-side business models. They are also likely to be closer to the status quo core competencies of utilities with regard to services as well as asset operations and management (*ibid.*). For CoE to implement such a model, it would require a generation license from NERSA, possibly on a case-by-case basis.

2.10 Literature review insights and conceptual framework

The studies appraised in this chapter yielded critical insights on the core themes relevant to the study, which in turn facilitated for the conceptualisation of the theoretical framework as shown in Figure 2.12. The theoretical themes appraised include status quo architecture of South Africa's electricity market, infrastructure challenges faced and their impact on service provision, main drivers promoting the growth of SSEG and the importance of implementing a smart grid to allow grid-interactive DG. Studies on case studies from other countries have revealed that the key to the deployment of a smart grid lies in developing supportive policy instruments as well as the necessary investment-funding. The various strategies and policies to unlock the potential and realize the benefits of DG include:

- Encourage investments by compensating them for surplus electricity exported to the grid
- Smart grid technologies to facilitate procurement policy and programmes which allow utility companies to buy at wholesale and run DG in areas that are not connected to the grid
- Regulatory frameworks that enforce standards and procedures permitting customers and micro-generators to trade with each other without the involvement of the utility companies (decentralised markets)

The adoption of solar and other renewable energy resources as well as their related technologies is expected to accelerate in future and municipal customers are increasingly taking advantage of the declining investment costs to secure their own energy-supply. Governments, regulators and utilities need to move with speed in incentivising electricity end-users towards grid-interactive generation and thus mitigate grid defection. Many customers are already seizing the opportunities of being prosumers even under the prevailing scenario of inhibitive policies/regulations and absence of fiscal incentives by government or the relevant utilities.

Based on CoE as the case study, these insights were applied towards developing the conceptual model adopted for the study, with a focus on substantiating the significance of a smart grid in the promotion of DG as well as resolving distribution-grid operation challenges such as high distribution losses and recurring power outages. The theoretical framework shown in Figure 2.11 demonstrate the interrelationships across the key elements underpinning the study in response to the overall research question as articulated in Chapter 1 (see Section 1.6).

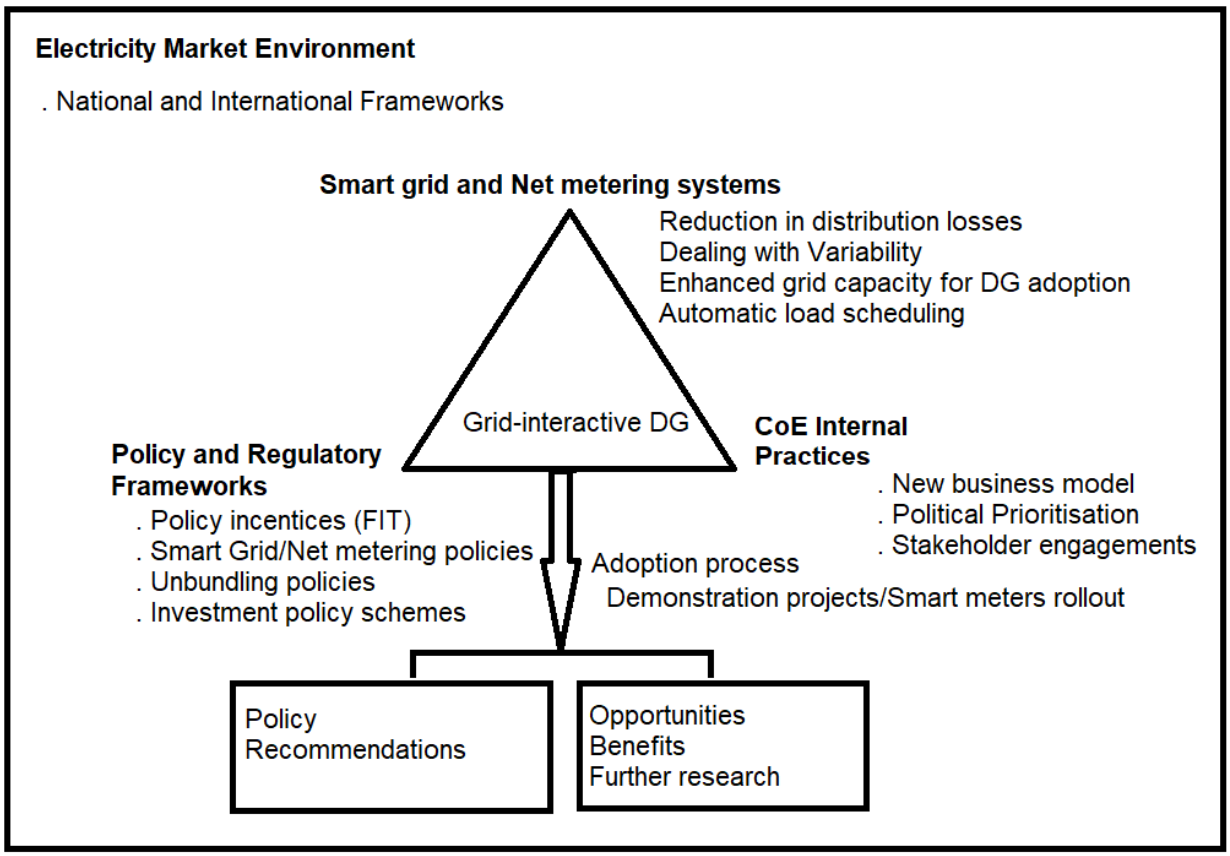

Figure 2.14: The conceptual framework

Figure 2.14 shows a conceptual framework with multiple dimensions. The interplay of technology, policies, and organisation as the key internal factors presents opportunities and potential benefits. The conceptual framework reinforces the three dimensions of smart grid and net metering, CoE internal practices, and policy frameworks as enabling factors for scaling up grid-interactive distributed generation. In the framework, smart grid and net metering represent capabilities and flexibility to close the gaps in CoE's electricity distribution challenges. Based on insights from shifts in international and national policies reviewed in this chapter, policy and regulatory frameworks are instrumental in delivering expedited DG through the implementation of smart grid and net metering systems. In contrast, CoE internal practices

require change in line with new electricity distribution models supported through political prioritisation of smart grids in collaboration with various actors across the electricity value chain.

3 RESEARCH METHODOLOGY

3.1 Introduction

The chapter presents the process and tools used for data collection and analyses in substantiation of the sub-questions and overall research question guiding the study. The first part provides details on the research design employed to ensure clarity of the research process. The second part focuses on data collection techniques for primary and secondary data on the respective sub-questions, while the third section summarises the overall relationship across the key themes and parameters with the respective data as captured in Table 3.1. The fourth section presents an overview on data presentation, analyses and interpretation as executed in subsequent chapters, while the fifth section presents limitations in data collection, analyses and interpretation stages of the study. The last part appraises the ethics considerations of the study in relation to data collection, analyses and reporting.

3.2 Research design

Research design addresses the systematic plan relating to procedures employed in conducting a study in order to answer the research question or meet the key objectives of the study. Creswell (2014) notes that research design entails a framework which guides the investigator through data collection, analyses and interpretation stages of the study. It is a logical model that allows the researcher to ultimately draw inferences concerning causal relations among the critical elements/units of the study.

The study adopted an inductive, qualitative, case-study approach to conduct an inquiry on the significance of smart grids, net-metering systems as well as the aligned regulations and policy frameworks towards the promotion of DG within a real-life context of CoE. An inductive study refers to an observation of causal factors operating relative to the case study and how these variables interact within available conditions that activates it and revealing unexpected aspects of causal mechanisms (George and Bennett, 2005). Creswell (2014) notes that inductive qualitative research inductively analyses data on how individuals or group of people understand and make meaning about the phenomenon defined in the study. This was achieved through the collection and analyses of primary and secondary data from diverse sources.

The use of the case study approach allowed the study to contextualize and deepen overall understanding on pertinent issues on smart-grid and DG as a rapidly evolving field of renewable energy, energy security and mitigation of climate-change (Yin, 1994). The approach

focused mainly on the "what" question in order to arrive at an initial working hypothesis and propositions to guide the inquiry (Sarantakos, 2005).

The selection of CoE as a case study among other municipalities was primarily influenced by the fact that it had already conducted a feasibility study on smart grid implementation, but there was no urgency or clear road map in implementing the recommendations. Secondly, CoE was also one of the very few municipalities amongst its peers (such as Cape Town, Nelson Mandela Bay Municipality, City of Tshwane and City of Johannesburg) which had not implemented mechanisms to compensate prosumers exporting surplus energy into the grid. The study thus sought to understand the factors holding back implementation of the smart grid recommendations and lack of feed-in tariffs for prosumers in order to promote grid-interactive DG within CoE. It thus served a complementary role of providing explanatory information towards an intensive evaluation of smart grids and DG within the distribution model of a municipal electricity utility as commonly applied in South Africa. Lastly, CoE's proximity to the researcher offered convenience of access during data collection stage of the study.

The research question was structured into three sub-questions focusing on factors inhibiting the growth of DG within the case study municipality, the relevance of prioritising smart grids and net metering systems towards eliminating prevailing challenges in CoE's distribution network and the alternative regulatory and policy scenarios that could spur infrastructure development and DG growth in CoE as an exemplar case among distributor-utilities in South Africa.

The study followed a four-stage process as shown in Figure 3.1. The scope involved an appraisal of CoE to understand the status-quo of DG and the various factors constraining its growth. The first step involved reviewing the electricity distribution business model of the municipal utility, the challenges and barriers within the distribution network, infrastructure, and regulatory policy framework at the municipal level in order to establish the status quo compared to the benchmarks set in the smart grid readiness feasibility report (USTDA, 2013).

The study gathered primary data from purposely identified participants relevant to the study while secondary data were abstracted from various published academic journal articles, industry/conference reports and proceedings as well as government documents. Among the policy and regulatory documents reviewed were the Integrated Resource Plan of 2018 (DoE, 2018a) and SANEDI (2017) that addressed the small-scale embedded generation (SSEG)

policy framework and regulations in South Africa, CoE's annual reports from 2015 to 2019, and the Smart Grid 2030 Vision being championed by SANEDI.

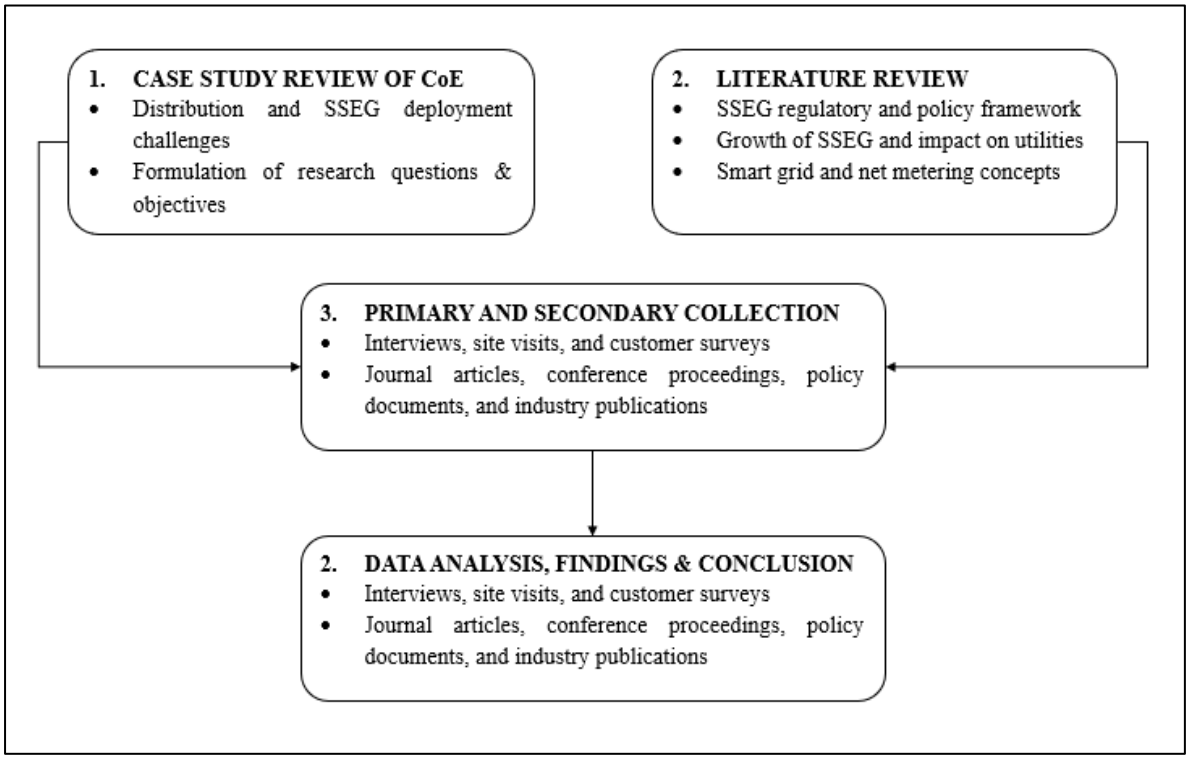

Figure 3.1: The research design framework

The second stage involved identifying and reviewing literature from multiple sources to guide understanding of experiences on the evolution of DG as well as relevance of smart grids and net metering technologies towards facilitating grid-interactive DG. The review derived insights from other regions such as Europe and the Americas, as well as other African countries. The insights were also used to identify the theoretical research themes and data parameters applied in formulation of data collection tools as guided by the research question.

Interviews with industry experts, site visits, direct observations, and training-seminar presentations were used to collect primary data specific to municipalities and CoE case study in particular. The primary data were analysed according to data themes established for each sub-question and the insights that emerged were linked systematically to the conceptual and theoretical framework derived from the literature review.

The fourth stage was the inductive analyses and interpretation to derive the research findings and conclusions through consolidation of the sub-findings. Data from the various sources within CoE and South Africa were thematically analysed based on the established parameters

to obtain sub-findings on each sub-question. Secondary data from case studies in other countries were used to contextualise the analyses within a broader context.

3.3 Data collection tools

Primary data collection was based on semi-structured interviews and direct observation of purposely selected cases of DG-installations by CoE and its customers. Semi-structured interviews allowed the researcher to pose follow-up questions for further clarification or guidance on additional participants and secondary sources. Secondary data were collected from various national government and CoE policy documents and reports, as well as academic publications, and conference proceedings on smart grid implementation and SSEG. Table 3.1 presents a summary of the data collection methods and how primary and secondary data were analysed.

3.3.1 Primary data collection

Participants were purposely selected based on the primary or complementary roles of their respective organisation in the fields of energy, finance and regulatory issues as they relate to the overall electricity markets and sector. Interviews were conducted with officials from CoE and other industry experts from South African National Energy Development Institute (SANEDI), the South African Local Government Association (SALGA) and the Development Bank of Southern Africa (DBSA), the Organisation Undoing Tax Abuse (OUTA), Sustainable Energy Africa (SEA) and the National Energy Regulator (NERSA). The most critical aspect for selecting these organisations was to facilitate a comprehensive view on CoE's electricity distribution network as well as gather insights from other critical stakeholders on the changing dynamics of the electricity market within South African municipalities (including the regulatory and policy framework). The interview questions and respective participant-responses were presented in relation to the specific sub-question as shown in Appendix 9.8.

For ensuring participant-anonymity, respondents' personal details were not captured in the data presentation and analyses. Instead, interview participants were identified according to the respective institutions they are based at in order to give context to their responses and experiences. Interview responses were transcribed into summaries and were analysed according to the adopted themes under each sub-question.

The interview data were complemented with data gathered from direct observation and customer surveys of the installed rooftop solar PV systems on some of CoE's customers and

CoE's own installed Solar PV. On CoE installations, site visits to selected rooftop solar PV plants and the waste-to-energy generation plant (Simmer and Jack landfill site) were conducted in order to gain first-hand experience on scale as well as operational challenges experienced by the plant operators. Customer perceptions and performance experiences with their DG systems were also collected from owners of purposely selected installed Solar PV systems. Data collected on these parameters are presented and analysed in Chapter 4 in order to identify status quo challenges to the adoption of DG in CoE.

3.3.2 Secondary data collection

Municipal policy and financial documents such as IDP 2018/2019 (CoE, 2018a), Growth and Development Strategy 2055 (CoE, 2007), CoE Cost of Electricity Service study (CoE, 2018b) and the feasibility study report on smart metering and smart grid for CoE (USTDA, 2013) were reviewed to extract secondary data on municipal policy framework. National publications on policy framework and programs on the electricity market (such as the South African Smart Grid draft policy vision 2030 - SANEDI, (2018), Integrated Resource Plan of 2019, and SSEG policy draft of 2018) were also reviewed as secondary data sources. CoE's Municipal reports and policy documents provided insights on the scale of challenges it faces on its distribution network, the scale of DG installations as well as updates on planned infrastructure development to encourage increased adoption of DG.

Data on formally-reported rooftop solar PV installations were obtained from the CoE database (CoE, 2021) which covered the number and size of registered installed SSEG systems only (it is estimated that there are other unregistered installations) for domestic and commercial buildings as presented in Appendix 9.5. Additional secondary data were collected from presentations at the South African Energy Storage, Small-Scale Embedded Generation (SSEG) conference held on 22nd to 23rd October 2018 and Electricity of the Future conference organized by EE publishers (a local energy and engineering news firm) held at Emperors Palace in Johannesburg.

3.3.3 International case studies

The study also used data to review the effectiveness of multi-policy options adopted in Brazil, India, Mauritius, Namibia and Mexico in order to drive insights on promotion of DG through infrastructure policy reforms. The case studies are presented at a national level to provide an overview in terms of implementation and enforcements towards achieving desired objectives. Farmer (2021) aver that national and local governments engage each other in a broad set of

complicated interdependent relationships and it is these assertions that influenced the selection of these cases based on multilevel governance relationships. Additionally, the policy reforms focused on improving efficiencies of the distribution network and this makes them comparable to the case of CoE as it also operates in the distribution value chain and has constitutional right to administer the reticulation of electricity within its jurisdiction as explained in Section **Error! Reference source not found.**. The rationale for choosing cases from these countries were as follows:

- **Brazil** is justified because the electricity distributors were facing similar distribution problems like CoE, which inherited an ageing grid from colonial masters. The rehabilitation projects resolved the challenges which were being faced along the distribution network. CoE has started implementing some of the measures (such as AMR) to improve efficiencies within its distribution network.
- In **Mexico** the restructuring and creation of a competitive wholesale market is similar to the proposed creation of a wholesale market under LREPPPP. Mexico's reform agenda was based on winning the trust of powerful political coalitions to harness its high potential for renewable energy resources and in South Africa, vested political interests have also been cited as a stumbling block towards reforming the energy sector.
- In **Germany,** the review focused on the impact of 20-year fixed feed-in tariffs, the liberalisation of generation activities and promotion of an "open grid" policy. The actual implementation was achieved through 900 municipal utilities that operate distribution networks. As one of the early forerunners in decentralisation of the utility market, Germany presents unique lessons on how the pluralistic structures of electricity markets can be pivotal in creating competitive and innovative energy markets.
- In **India**, the review provides vital lessons on the need to understand customers' concerns in the deployment of technologies. Whilst the prioritisation of a smart grid can be pivotal in managing the negative consequences of grid-interactive distributed generation, it may fail to achieve intended objectives if there is no acceptance by customers.
- Namibia and Mauritius are two regional countries with similar ambitions as South Africa (and CoE in particular) to encourage renewable electricity generation by customers. The two countries also have similar climatic conditions, demographic/culture and political environment but differences in structure of their electricity value chains. Generation, transmission and distribution activities are all vested in state utilities but their involvement in distribution activities makes them comparable to the case of CoE. Fiscal policy measures

as those adopted in Mauritius are beyond the scope of CoE but have been discussed to demonstrate the impact of harmonisation of regulatory and policy framework in the energy sector.

3.4 Data presentation and analysis

Subsequent to data collection, primary and secondary data were grouped according to relevant themes on issues concerning grid-interactive DG, policy frameworks and compensation mechanisms (feed-in-tariffs), energy efficiency and demand side management, financing and Smart grid technologies. The themes were derived from the sub-questions of the study. Microsoft Word was used to transcribe collected data which involved browsing through transcripts to understand coordinated pattern of responses from respondents as shown in Appendices 9.5 and 9.6. The various themes were used as the basis of data presentation and analyses in the substantive chapters.

Data obtained from primary and secondary sources were presented according to the sub-question being addressed starting from Chapter 4 to Chapter 6. Data and analyses of the factors inhibiting the growth of DG within CoE are presented in Chapter 4 in relation to the key data parameters on the first sub-question. Data on the relevance of smart grids and net metering systems in facilitating grid-interactive DG helped to resolve the second sub-question as presented in Chapter 5. Chapter 6 addressed the third sub-question which focused on insights from various national, regional and international policy and regulatory frameworks used to promote DG. These international and regional case study insights were used to demonstrate the importance of renewable energy policies, implementation of smart grids and net metering systems. The consolidated research findings, recommendations and conclusions were presented in Chapter 7 based on consolidation of the sub-findings derived in Chapters 4, 5 and 6. The study parameters and data needed under each sub-question are presented in Table 3.1.

Table 3.1: Overview on data collection and analysis in relation to the sub-questions

Sub-questions	Data needed and data collection tools	Data processing and analysis
Sub-question 1: What are the key constraining factors inhibiting the adoption of DG within CoE?	**Primary data sources:** Interviews with municipal officials at CoE, and experts from SANEDI, GIZ/SAGEN, SALGA, DBSA, OUTA, NERSA. Direct observations (site visits and photographs of installed distributed generation plants such as waste-to-energy power and solar PV on various municipal sites in order to understand the SSEG trends in the metropolitan area. Municipal workers and customers with rooftop solar PV within the CoE region were interviewed to understand their challenges and success factors, and how to improve the grid system to their advantage. **Secondary data sources:** Notes and leaflets obtained from experts' presentations at conferences on energy storage, smart grid, and small-scale embedded generation. Government regulations, CoE reports and policy documents, academic research journals and industry reports as wells media articles **Data Tools:** An interview guide, note pads, cameras, and recording devices	Primary data were combined with extracts from secondary data covering main constraints (classified as institutional, technical, economic, and social) to understand the current capacity and limitations towards promoting distributed generation within CoE. The challenges and barriers which include distribution losses due to illegal connections vandalism and theft of equipment, aging grid infrastructure errors in billing, and grid destabilization were obtained and analysed. Analyses were based on theory-guided evaluation parameters and sub-findings were derived as presented in Chapter 4.
Sub-question 2: What is the significance of prioritising smart grids and net-metering towards addressing CoE's distribution challenges while also facilitating the adoption and actualisation of DG?	**Primary data sources:** Interviews with municipal officials at CoE, and experts from SANEDI, GIZ/SAGEN, SALGA, DBSA, OUTA, NERSA. **Secondary data sources:** The database of installed SSEG, City of Ekurhuleni policies and programs on electrical metering, USDTA's feasibility report on smart metering, SALGA publications on the bold move towards smart cities, The Integrated Development Plan (IDP 2017/2018) and Growth Development Strategy 2055 (GDS 2025). International case studies from India and Brazil	Primary and secondary data obtained from CoE publications were used to establish the importance of smart grids and net metering technologies to resolve distribution losses and related challenges. Analyses were based on theory-guided evaluation parameters and sub-findings were derived as presented in Chapter 5.

Sub-questions	Data needed and data collection tools	Data processing and analysis
	The documents were formulated and published by CoE. Approved contracts on AMR, informal settlement electrification programs, and other published resources were appraised.	
Sub-question 3: What infrastructure policy and regulatory frameworks that can be implemented to facilitate scale-up of grid-interactive DG as well as mitigate the fear of revenue erosion in CoE?	**Primary data sources:** Interviews with municipal officials at CoE, and experts from SANEDI, GIZ/SAGEN, SALGA, DBSA, OUTA, NERSA. **Secondary data obtained were:** White Paper on Renewable Energy (2003), 4.2 Electricity Regulations on New Generation Capacity of 2009, Integrated Resource Plan 2010 – 2030, REIPPPP, IDP 2017/18, academic journals. International and regional case studies from Germany, Mexico, India, Brazil, Mauritius and Namibia	Data were analysed to determine the extent to which smart grid policies and regulatory frameworks can be used to solve the challenges faced by CoE in its distribution network. The insights obtained from international and regional case studies were also applied towards understanding the success factors. This analysis focused on three crucial variables namely promotion of renewable energy, implementation of smart grid and adoption of net metering policies. The sub-findings are presented in Chapter 6.
Main Research Question What is the significance of smart grid and net-metering technologies towards the promotion of grid-interactive DG for municipal utilities in South Africa?	As presented in Chapter 7, the overall findings were articulated through the consolidation of sub-findings from Chapters 4, 5 and 6. This was followed by derivation of conclusions and recommendations for further studies in line with the limitations captured in Chapters 1 and 3.	

3.5 Data analyses and interpretation

Primary and secondary data were grouped into themes in accordance with the sub-question being addressed and as guided by the critical data parameters related to each sub-question. The analyses were divided along themes such as regulatory and infrastructure policy frameworks, distribution challenges and disruptive effects of DG. Insights from various data sources were used to identify themes and patterns that guided further analyses towards the key sub-findings.

Content analysis was critical to connect the best practices from various parts of the world and linking to policy framework and practices in South Africa (with CoE as a case study). CoE's preparedness for DG, the pockets of resistance and policy misalignment in this context were critical in providing a high-level perspective and objectives towards the future development of CoE's electricity value chain. Contextual analysis of international cases on smart grid developments highlighted best practices that can be adapted to interconnect DG with the grid and promote alternative sources of electricity supply for municipal utilities. Appraisal of the case study of CoE was instrumental towards deriving sub-findings on CoE's and South Africa's regulation and policy successes and failures relative to insights from secondary data on international experiences.

3.6 Study themes and data parameters

Evolution of distributed generation, smart grid development and the supporting regulatory and infrastructure policy frameworks were the key study parameters that influenced the overall direction of the study. The themes were therefore used to establish the relevant data features of the research as well as the formulation of data collection and analyses tools. In the context of CoE, the policy framework on renewable energy development in South Africa was one of the main sources on the full course of action being adopted by the national government towards promoting investments in distributed energy resources. The second parameter focused on the development of distributed generation and entailed appraising inhibiting factors that can be addressed through implementation of a smart grid. The third parameter involved appraising the benefits of a smart grid to resolve the critical challenges associated with infrastructural decay in South Africa. The actual data abstracted from various sources as guided by each theme are presented in Chapters 4, 5, and 6.

3.7 Limitations

Interviews were used to obtain primary data. This entails levels of subjectivity in responses which could lead to biased findings. However, this was mitigated by cross-checking responses

with necessary policy documents and publications used as part of the secondary data sources. Another limitation involved the use of CoE as the only case study, which limits the generalization of insights on the significance of smart grid to encourage DG adoption across South African municipalities. South Africa's eight metropolitan municipalities have semi-autonomous legislative authorities which has often led to variations in regulatory and policy frameworks at municipal level.

However, this was mitigated by use of related secondary data from other municipalities to supplement and verify the insights obtained from CoE. The market for smart grid development is still at piloting stage in South Africa and this made it difficult to quantify the benefits of smart grid implementation in CoE. However, a review of international cases provided the overall perspective on DG adoption as well as key findings on the significance of smart grids to the adoption of DG.

3.8 Ethical considerations

This research was conducted in accordance with the research ethics requirements of the University of Witwatersrand which guides on ethics-issues to be addressed for studies involving human subjects. On specific ethics issues for the study, permission by CoE was granted in writing. The permission authorised the researcher access to their data and use of the municipality as the case study. As a service provider to the municipality, the researcher has business transactions with CoE and had to ensure ethical conduct through the research period, especially with regard to issues such as conflict of interest. All the information obtained was used to fulfil the research requirements and not for advancing professional or consultancy interests with CoE.

To ensure confidentiality of participants, their identity and personal details are not mentioned in the report. Furthermore, all data obtained through the interviews were anonymised before capture, presentation and analyses in the report. Most of the documents obtained from the CoE were already in the public domain and widely accessible on their websites such that any other researcher without any links to CoE could also access the information.

Interview participants were advised of the aims and objectives of the research as well as its academic nature and also notified of their rights to accept or decline participation. All responses from interview respondents were treated as confidential and were used solely for purposes of the study. As an industry expert, I also had to ensure that my position did not influence the

interviews or other data-capture/extraction processes in order to mitigate the risk of biased findings. A copy of the ethics clearance certificate for the study is presented in Appendix 9.11.

4 FACTORS CONSTRAINING GRID INTERACTIVE DISTRIBUTED GENERATION IN COE

4.1 Introduction

This chapter presents data abstracted from both primary and secondary sources to address sub-question 1 on the constraining factors inhibiting the growth of DG within South Africa's municipalities with CoE as the case study. Analyses of the data collected provided insights on the interplay of diverse factors such as infrastructure policies, regulatory frameworks and socio-economic, financial and technical constraints. The findings are consolidated in terms of three key parameters which are internal, national and prosumer-side constraints. Resolving the combined effects of these factors offers an opportunity to scale up DG within CoE.

The first section presents an overview of CoE's electricity value chain as well as an evaluation of the key policy frameworks towards the promotion of grid-interactive DG. Embracing disruptive technologies associated with the growth of DG requires the establishment of enabling and attractive public policies to incentivise stakeholders. In the case of CoE, these policies are crucial in spurring the municipal authority to adopt measures towards modernising the electricity grid such that it is capable of interconnecting self-generation installations of their customers. The second part presents data gathered from CoE customer interviews conducted with a purposely selected sample of rooftop solar PV owners. The interviews provided insights on customer concerns in the local distribution system. Data analyses and derivation of sub-findings on the factors inhibiting DG in CoE are presented as the concluding section of the chapter.

4.2 Data overview

Data were collected through interviewing nine participants from CoE as well as industry experts, direct site observations and an interview with two commercial and three residential solar PV system owners. Secondary data were abstracted from policy documents guided by parameters for sub-question 1. Table 4.1 summarises the respective data parameters and related data sources.

Table 4.1: Summary of Data Parameters and Data Sources

Sub-question 1	**Key parameters**	**Secondary data**	**Primary data**
What are the key constraining factors inhibiting the growth of DG within CoE?	• Identified internal constraining factors within CoE • National-level electricity sector constraints • Prosumer-side constraints.	• Renewable energy (SSEG) development in CoE • Key policy approaches for DG • Funding for SSEG and infrastructure development **Data Sources** • DoE IRP (2019) • CoE Annual Reports (2015 - 2019) • Eberhard (2014 and 2016) • Bischof-Niemz and Creamer (2019) • Baker and Philips (2019)	• Status quo of energy distribution in CoE • Solar PV trend and related constraints **Data Sources** • Interview with CoE officials and other experts in the electricity sector • Interview with SALGA, SANEDI, OUTA, DBSA, SEA, GIZ-SA officials

4.3 Internal CoE related constraints

This section presents data and analysis on factors internal to CoE that are restricting the growth of DG. These factors are within CoE's control and influence, hence can be addressed internally without involvement of third parties.

4.3.1 Lack of political prioritisation

CoE's electricity distribution challenges relate to the inadequate prioritisation within the IDP as well as other plans, policies and regulatory frameworks. The current regulatory guidelines on DG are distributed across a variety of policy documents and pieces of legislation which include the IDP 2018/19, Electricity Regulation 374 of 2006 and CoE's SSEG Policy. This has created multiple instances of regulatory and policy gaps as some of the regulatory and policy instruments differ on implementation mechanism and desired objectives. According to an official from CoE, the municipal authority has been focusing on electrification of informal settlements which is a short-term vision compared to revitalisation of infrastructure and improved service delivery in the long-term.

Secondary data abstracted from the CoE (2018c) highlighted that the medium-term energy plan contains the Electricity Policy Plan where CoE has prioritised the upgrading of conventional metering units to Automatic Meter Reading (AMR) that would subsequently be used as a springboard for the anticipated smart grid system. Additionally, the upgraded metering system would be used for dynamic tariffs (such as ToU), which would be geared towards supporting grid-interactive DG. Focusing on isolated items such as AMR demonstrates a piecemeal and slow-paced approach towards the adoption of DG.

As presented in the IDP 2018/2019 and GDS-2025 (CoE, 2018e, p 45), the current policy framework thus falls short in providing for implementation of grid-interactive DG across the whole value chain. In contrast, the focus on electrification of informal settlements is specifically prioritised mainly due to political pressure for conventional electrification and supply-certainty in face of growing urbanization amidst increasing unemployment and poverty. Secondary data reviewed indicates that population growth is steadily increasing at 3.5% per annum which presents significant challenges for CoE to cope with the resultant electricity demand. This is attributed to an increasing number of citizens looking for better opportunities within the Gauteng City Region (CoE, 2018). As of 2016, the population was estimated to be at 3.5 million, with 81.3% living in formal households whilst 18.7% live in informal

settlements. The increasing population intensifies calls for electrification programs for households and informal settlements as identified in the IDP 2018/2019.

In its IDP 2018/2019, CoE notes that one of the key development priorities is to fast-track infrastructure modernisation and achieve a target of 100% informal household electrification from current level of 88.6%. Responses from CoE respondents (see full transcript in Appendix 9.8) highlight that unemployment, poverty, inequality and financial constraints compounded by aging electricity infrastructure have escalated incidences of meter bypasses and cable theft. In order to meet the electricity demand, a mechanism should be devised to allow excess power from DG to be fed into the distribution grid. In addition, the promotion of DG should have been provided for in the IDP 2018/2019 as the formal CoE master plan which incorporates other policy frameworks such as the Municipal Spatial Development Framework (MSDF).

4.3.2 Technical skills gap

Integration of DG and related technologies into CoE's distribution network requires significant investments in human capital to facilitate knowledge transfer and technical expertise in upgrading electrical infrastructure as well as the development/integration of the relevant ICT systems (see Section 1.4). Investors may opt not to participate or even cancel the business opportunities due to lack of technical ability to sustain projects. SANEDI respondent (see Appendix 9.8) bemoaned the lack of local expertise on smart grid projects across the country which leads to dependence on imported skills. This should therefore become a focus issue as the electricity sector evolves and the demand for such skills triggers supply-side opportunities (trained engineers and managers to bridge the technical gap and develop new skills in research and development, analytics, data management and decision support primarily through technology transfer initiatives). The lack of technical skills within CoE and the industry at large was also confirmed by all CoE respondents who indicated that the prevailing challenges at many of the installed solar PV systems were due to technical skills-gaps of local service providers to maintain electricity infrastructure at DG-scale (see Appendix 9.8).

CoE has installed renewable energy generating plants at various sites as outlined in Table 4.2 and Figures 4.1 and 4.3, and with a combined capacity of 2.95MW. Despite this gesture to demonstrate its willingness to shift towards DG many of these plants were not functioning properly due technical challenges as shown in Table 4.3. The researcher could only obtain performance data of two plants Kempton Park Civic Centre and Simmer and Jack landfill to

energy plant (as shown in Figures 4.2 and 4.4) while all other plants were unavailable due to malfunctioning of online metering systems.

Table 4.2: CoE owned grid-interactive DG-plants (Adapted from CoE, 2018)

	Area	**Off or on-grid**	**Capacity**
1	Boksburg Civic Centre (2016)	On-grid	250kW
2	Kempton Park Civic Centre (2017)	On-grid	750kW
3	Springs Civic Centre (2014)	On-grid	250kW
4	OR Tambo Cultural Precinct in Wattville, Benoni (2012)	On-grid	200kW
5	Alberton Civic Centre (2017)	On-grid	500kW
6	Simmer and Jack Landfill Gas Power Project (2014)	On-grid	1MW
Total			**2.95MW**

The DG plants under REIPP programmes seek to source an estimated 683MW of alternative renewable energy with the aim of reducing overall dependence on Eskom supply (CoE, 2018). Figure 4.1 shows some of CoE's SSEG installations based on rooftop PV which is controlled and monitored using Automatic Metering Reading Systems (AMR). The performance of Kempton Park Civic Centre is monitored through an online system, whose performance data as shown in Figure 4.2 were obtained from a municipal official in the department of energy. One key observation is the absence of orientation-optimisation of the panels relative to sun-angles for CoE's latitude. This happens to be a common experience for retrofitted installations where pre-existing roof profiles influence the orientation in order to balance between minimising installation costs versus compromising performance.



Figure 4.1: Kempton Park Civic Centre Solar PV (Source, Field observation, October 2019)

The Kempton Park Solar PV system provides power to the facilities at Kempton Park and the surplus is exported into the municipal grid, which thus reduces energy costs for CoE.

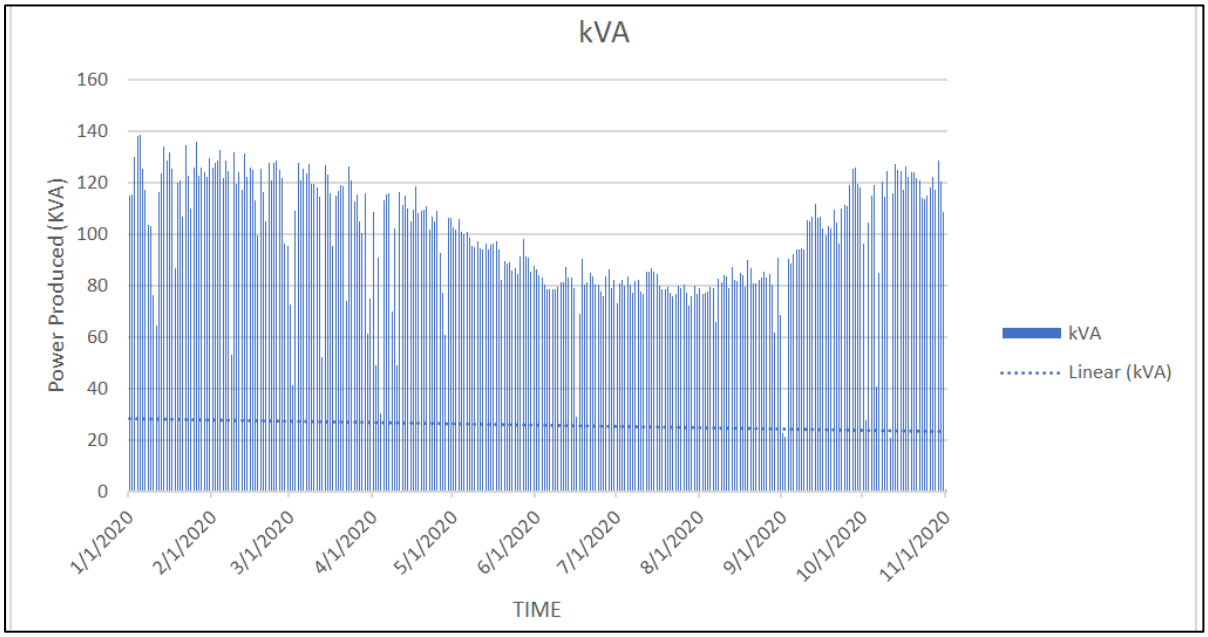

Figure 4.2: Performance data for Kempton Park Solar PV in 2020 (Source: CoE Metering on-line system obtained from CoE officials).

Figure 4.2 shows the trend in power generation at the Kempton Park Civic Centre which has an installed solar PV plant with capacity of 750kW. Although there is minimal variation in energy output as shown by the dotted trendline, the data revealed that overall power output is just below 140kW per day implying that the plant is operating at around 18-20% of its installed capacity. This indicates lack of control and monitoring systems to identify the probable causes of such low generation capacity, especially for January when solar radiation intensity is at its highest levels. In the absence of precise information, the low-capacity utilisation could be due to a combination of unresolved technical failures and weather conditions. The compromised performance leads to a longer payback period for the initial cost investment. However, if the plant had been integrated to a smart grid network, it would have been possible to remotely collect precise information on its performance and use the data to optimise its operational efficiency which would in turn reduce the payback period on the initial cost.



Figure 4.3: 1MW Simmer and Jack Landfill Gas Power Project (Source, Field observation, October, 2019)

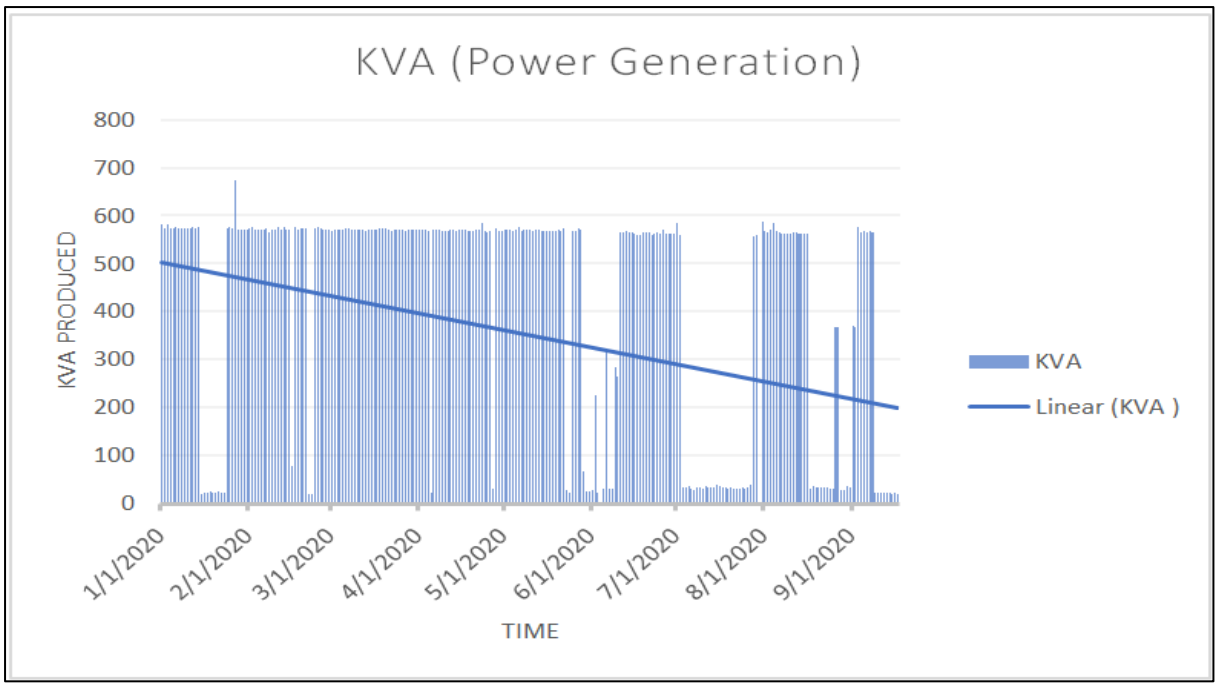

Figure 4.4: Performance data for Simmer and Jack Landfill Gas Plant (Source: Source: CoE Metering on-line system, obtained from CoE officials, 2020).

The Simmer and Jack waste-to-energy gas plant was self-funded by CoE and has a capacity of just under 1MW. It thus qualifies for licence-exemption under NERSA's regulatory framework for SSEG. As indicated in Figure 4.4, generation at the plant ranges between 58 and 60% of the installed capacity. In addition, the interview data obtained from the facility manager from CoE shows a declining trend in power production over the review period. This has been attributed mainly to lack of adequate feedstock (the landfill-gas) and longer maintenance down-times, which is further compounded by lack of technical skills locally to efficiently operate the plant. Based on insights from literature on smart-grid practice globally, it is clear that the challenges posed by the landfill gas plant could be significantly mitigated if it was integrated into a smart-grid distribution network.

4.3.3 Limited grid access and cumbersome application processes

Faced with increasing electricity prices and chronic power shortages, coupled with declining cost for solar modules, many commercial and industrial customers are increasingly investing in self generation (SSEG) particularly with rooftop solar PV with or without municipal approval (Lutchman, 2019). This was confirmed during interviews with the municipal official and other experts in the electricity sector who alluded that various technical issues are brought up when a solar PV is installed without following prescribed grid codes and regulations

contained in the NR097 guidelines. NR097 is related to SSEG installations (Eskom, 2019). These facilities would have been wrongly connected without following set standards as customers were allegedly using cheaper or unqualified installers to save on cost. The municipal official further explained that such installations were posing risk to grid infrastructure and more so to the grid maintenance staff.

A CoE official alluded that there was need for the municipal utility to come up with proactive and appropriate procedures and standards for SSEG integration to avoid unregulated proliferation of installations. One such solution was to replace tedious and cumbersome manual application for SSEG integration with online web-based application of which until now has not been fully implemented. In addition, there was also a need to improve access to the grid and upgrade its capacity to accommodate DG. As noted by Korsten et al. (2017) (see section **Error! Reference source not found.**), the state of grid infrastructure imposes a limit on the amount of DG generation that could be exported into the grid before the Notified Maximum Demand could be reached.

4.3.4 Administrative barriers

Even though the government has increased the threshold for DG installations from 10MW to 100MW in 2021, there are several sticking administrative issues hindering the implementation of such a policy at municipal level. For instance, there are no long-term policies outlining specific targets to be achieved which would have provided guidance on the nature of supporting infrastructure (such as installation of smart meters and improved ICT platforms) necessary for DG integration. Another notable challenge is political interference and prioritisation of budget allocations. Based on responses from CoE respondent, politicians as head of departments make final decisions on which projects to focus on, which may in turn lead to poor service delivery. This narrative agrees with Mgomezulu, (2020. p 2) which noted that political interference in the South Africa's municipality fiscal space was a serious problem contributing to inequality and disparities in service delivery.

4.3.5 Financial barriers

According to Organisation Undoing Tax Abuse (OUTA) respondent, there are several challenges that hamper effective and efficient financial management within municipalities. Some of the challenges include lack of expertise, poor debt collection, rampant corruption and unaligned exorbitant salaries for officials and politicians. To confirm CoE's financial challenges, Moody's rating agency rated CoE as a low sub-grade investment which is reflective

of poor financial status and makes it difficult to raise funding to undertake major capital projects from private and institutional investors. Moody's rationale for down grading CoE was particularly related to deterioration of liquidity as reflected in financial year 2020/2021 and reflects a high probability of inability to meet debt obligations (SABC News, 2021).

In addition, an official from CoE highlighted that the legislative framework under the Municipal Infrastructure Investment Framework (1995) limits the ability of municipalities to borrow freely as there must be concurrence from national treasury as a guarantor. Without broad municipal financing structures and policy uncertainty, market players are unwilling to invest in the municipal sector-controlled infrastructure projects. The absence of attractive policies and regulatory frameworks is creating a vacuum in the market which finally increases financial constraints which threatens various developmental agendas as articulated in the master plan document (GDS, 2055). Although a Development Bank of South Africa (DBSA) confirmed that the institution was facilitating third party funding based on clearly defined rules, the funding models were targeted at utility-scale projects which marginalised residential customers who require funding to acquire and install small generation units.

4.4 Electricity distribution challenges in CoE

Interview with industry experts from SANEDI and SALGA elaborated on the prevailing structural and systemic challenges facing municipalities in terms of electricity distribution. Rising power tariffs (primarily driven by Eskom as it seeks funds to build new generation capacity and high distribution losses) was highlighted as the leading factor forcing high income earners to look for alternative power sources. This is affecting municipal revenue collection and ability to cross-subsidise other social services. Municipal utilities use the inclining block tariff systems which allows them to generate much of their revenue from high-consumption users and use resultant surplus to subsidise services for low-income users (see Sections 2.3.3 above2.3.3 and 2.3.4).

An official from the municipality and CoE (2019, p 156) also confirmed that limited grid capacity and increasing maintenance frequencies are contributing to localised power outages. This is also contributing to loss of sales and revenue which is impacting on the municipality's financial position as well as socio-economic opportunities of residents. Despite these challenges, the municipal authority is targeting to complete the electrification of informal settlements by end of 2021/22 financial year (CoE, 2019, p 156). This is, however, likely to further strain an already ageing grid which could result in increased outages in affected areas.

CoE is also installing prepayment meters to monitor usage in these areas where the grid is most vulnerable due to incidences of vandalism, theft and tampering. These measures were expected to improve revenue collection (CoE, 2019).

As shown in Figure 4.5, CoE's bulk purchases from Eskom and corresponding sales to customers reveal ongoing/perpetual loss of revenue due to a combination of both technical and non-technical losses. The ongoing losses also reflect the fact that it is difficult to increase tariffs beyond a certain level in order to recoup losses as NERSA imposes regulatory restrictions on such tariff increases which effectively limits the level of costs that municipalities can pass on to consumers.

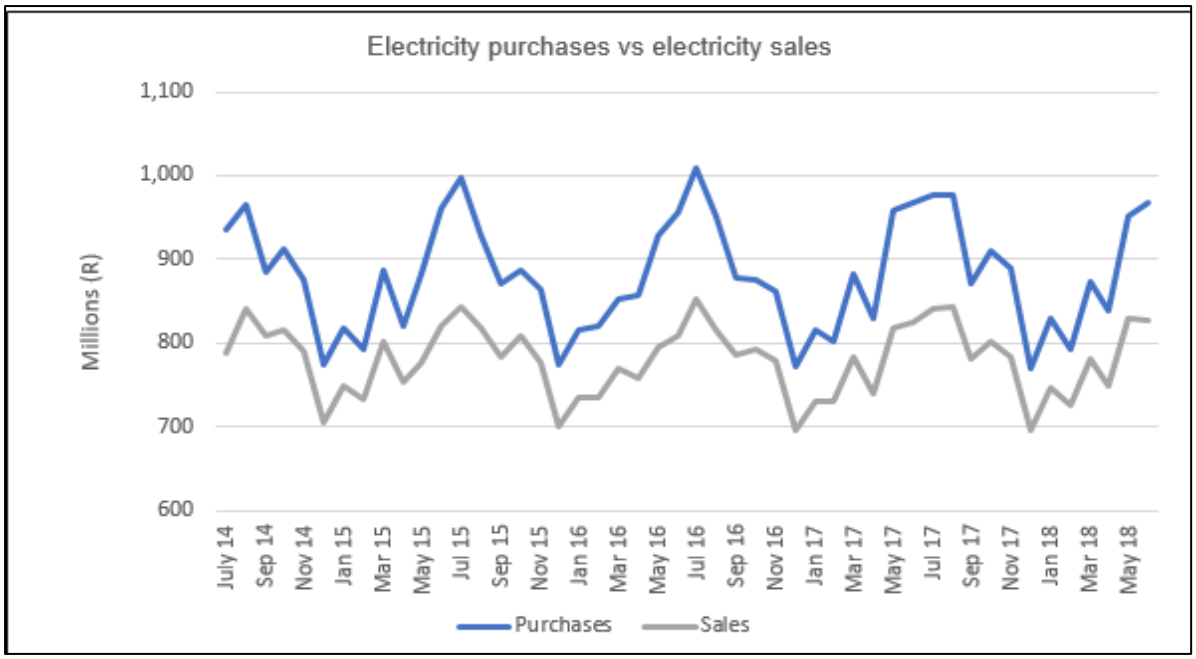

Figure 4.5: CoE's cost of electricity purchases from Eskom versus sales to consumers (adapted from CoE, 2018b, p 29)

Table 4.3 shows that CoE reported total losses of R1.1 billion and R1.2 billion in 2017/18 and 2018/19 financial years respectively. In relative terms, the losses were steady at around 12% per annum over the 2 years. The technical losses increased to R584 million in 2018/19 from R543 million suffered in the 2017/18 financial year, which thus reflects increasing grid inefficiencies. Over the two years, non-technical losses increased from R533 million to R599 million due to increasing cases of electricity theft through illegal connections and bypassing or tampering of meters (CoE, 2019). Overall losses increased by 9.9% from R1.076 billion to R1.183 billion and this was driven mainly by non-technical losses which increased by 12.4%

compared to a 7.6% increase in technical losses. This showed that incidences of energy theft, tampering and meter by-passes were increasing within CoE's distribution network despite improvements in security patrols (CoE, 2019).

Table 4.3: Electricity losses in CoE (Source, CoE, 2019 p 53)

	LOSSES (ZAR million)		
Financial year	**Technical**	**Non-technical**	**Total**
2017/8	543	533	1,076
2018/19	584	599	1,183
Annual change	**7.6%**	**12.4%**	**9.9%**

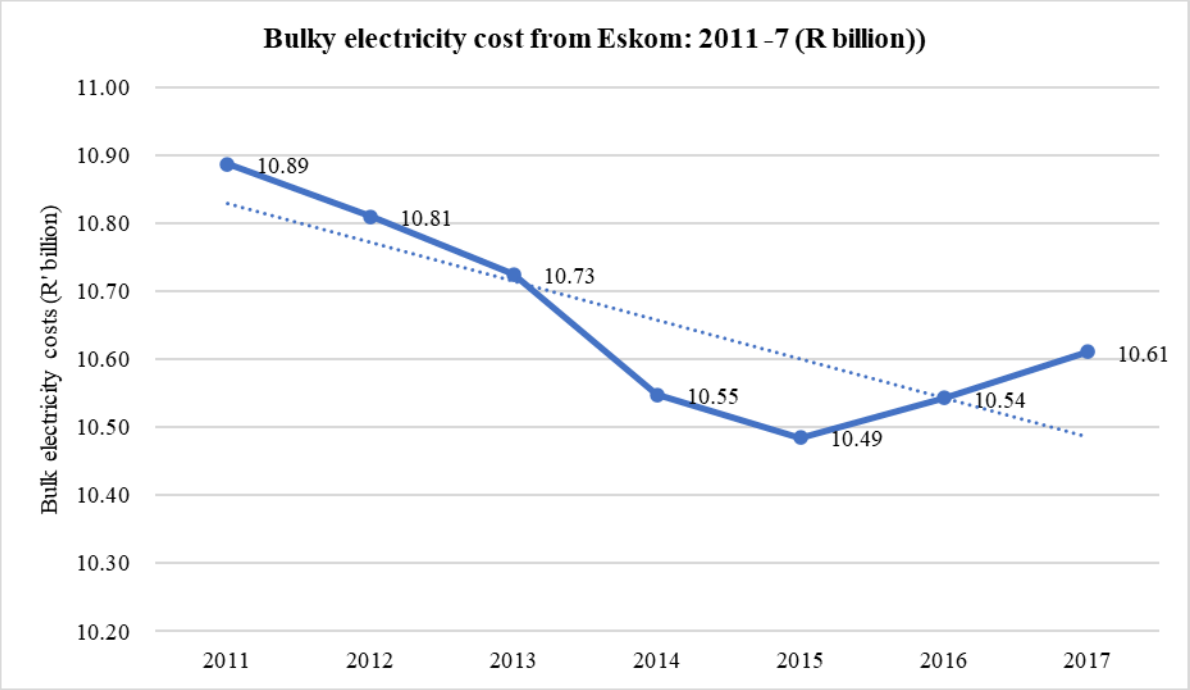

Figure 4.6: Trend for bulk electricity purchases from Eskom (adapted from Thenga, 2019, p 83)

Figure 4.6 shows the trend for cost of bulk electricity purchased from Eskom by CoE for the period between 2011 and 2017. The trend shows that electricity purchases have been declining annually which is a sign of weakening demand arising from either an improvement in demand side management efficiencies or increasing number of DG units. It is however difficult to comprehensively conclude on the reasons in the absence of an analysis by CoE attributing a

specific amount to identified factors. The issue becomes even more complex when one takes into account load-shedding by Eskom (forced under-consumption due to unavailability), which is not identified in the reported data. Cost of bulk electricity supplies fell

Table 4.4: Cost drivers analysis (CoE, 2018b, p 16)

Finance breakdown of costs	Actual expenditure 16/17 (ZAR'm)	Actual expenditure 17/18 (ZAR'm)	Approved Expenditure 18/19 (ZAR'm)
Staff	430.9	468.7	462.1
Consultants	0.5	2.8	10.7
Operational cost	828.2	760.5	621.7
Repairs & Maintenance	603.8	741.6	813.0
Loan repayments	137.0	173.2	220.5
Bad debt	894.9	804.3	872.3
Contractors	29.0	43.5	44.6
Total	**2,924.3**	**2,994.6**	**3,044.9**
Annual increase		2.4%	1.7%

Table 4.4 shows annual operational cost budgets for electricity distribution from 2016 to 2019, where costs increase for 2017/18 and 2018/19 was 2.4% and 1.7% respectively. Operational costs, bad debt and repairs and maintenance were the major cost drivers accounting for more than 80% of electricity distribution costs. Bad debts alone accounted for approximately 30% of the total costs and were the largest expense item in each of the three years and this is reflective of weak revenue collection strategies and politicisation of electricity delivery by the municipal authorities, a point alluded to by an official from CoE (see Appendix 9.8). Due to bad debts, there has been an increase in loan repayments which indicate rising borrowings to cover the cash flow gaps arising from failing to collect billed revenue. Loan repayments increased by an average of 27% per annum from R137 million in 2016/7 fiscal year to R220.5 million by end of 2018/19.

Repairs and maintenance and bad debt costs are largely customer driven costs, which could be mitigated with investments in a smart grid that enhances security as well as providing advanced tools for management of debtors. These costs must be added to the tariffs charged by Eskom to determine the overall cost of electricity in a given period (CoE, 2018b). However, incorporating these costs into the tariff structure would result in a significant increase in

electricity tariffs beyond the reach of many customers and further accelerate grid defection by customers who can afford installation of self-generation equipment.

Secondary data collected shows that CoE has an aging grid infrastructure as evidenced by increasing cost of refurbishments each year (CoE, 2019, p 71). This was also confirmed by an official from CoE who alluded to the continued deterioration of infrastructure since inheriting the grid at independence. CoE is lagging in capital expenditure which has been noted to be negatively affecting the economic life of the assets (CoE, 2018b, p 18). For the utility to remain financially viable into the future, the assets need to be maintained at a level that ensures reliability of supply for all customers. An official from CoE confirmed that the municipal was short of financial resources to invest in the grid hence its continued deterioration.

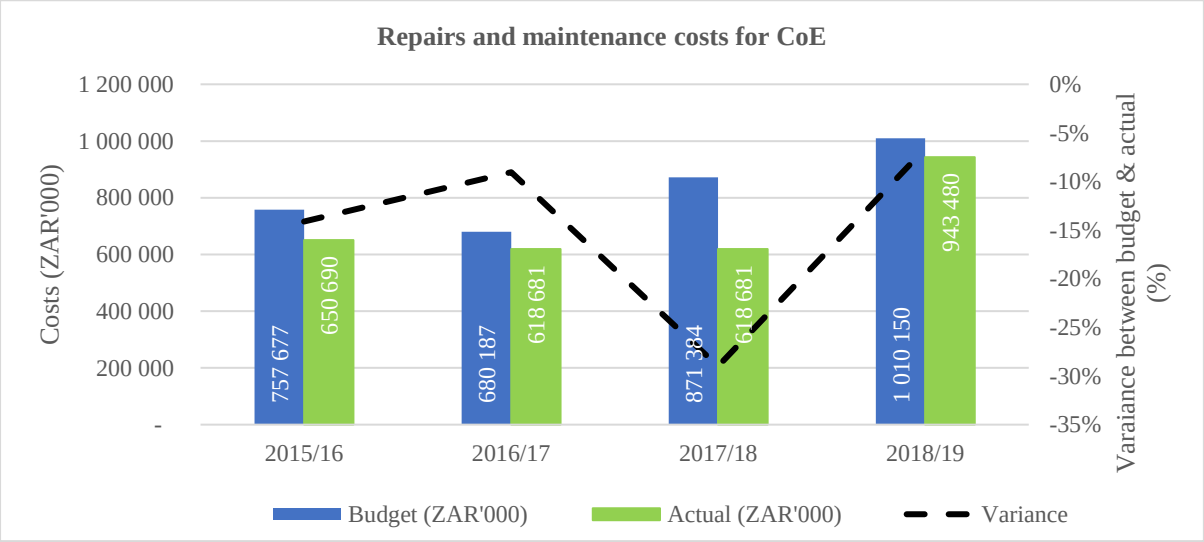

Figure 4.7: Trend in repairs and maintenance costs for CoE (Source, CoE, 2017; CoE, 2018; CoE, 2019 and CoE, 2020)

Figures 4.7 and 4.8 shows that resources allocated for repairs and maintenance as well as capital expenditure on electricity projects are consistently falling lower than required which is accelerating the deterioration of the infrastructure. From 2015 to 2019, actual funds spent on repairs and maintenance have been on average lower than budgeted by 15% annually due to financial constraints associated with low collections rates on revenues from electricity consumption.

This impairs capacity to undertake crucial works on the network. As highlighted in the infrastructure maintenance and capital expenditure rollout plan, performance of the

infrastructure cluster has been consistently falling below targets by an annual average of 10% over the past 5 years. (CoE, 2019). The compounded effect of these deficits confirms that repairs and maintenance work as well as capital investments on the distribution network are lagging. Despite these challenges, CoE managed to keep downtime network availability at 0.58% but resolving the issue of unaccounted electricity remains a serious challenge (CoE, 2019).

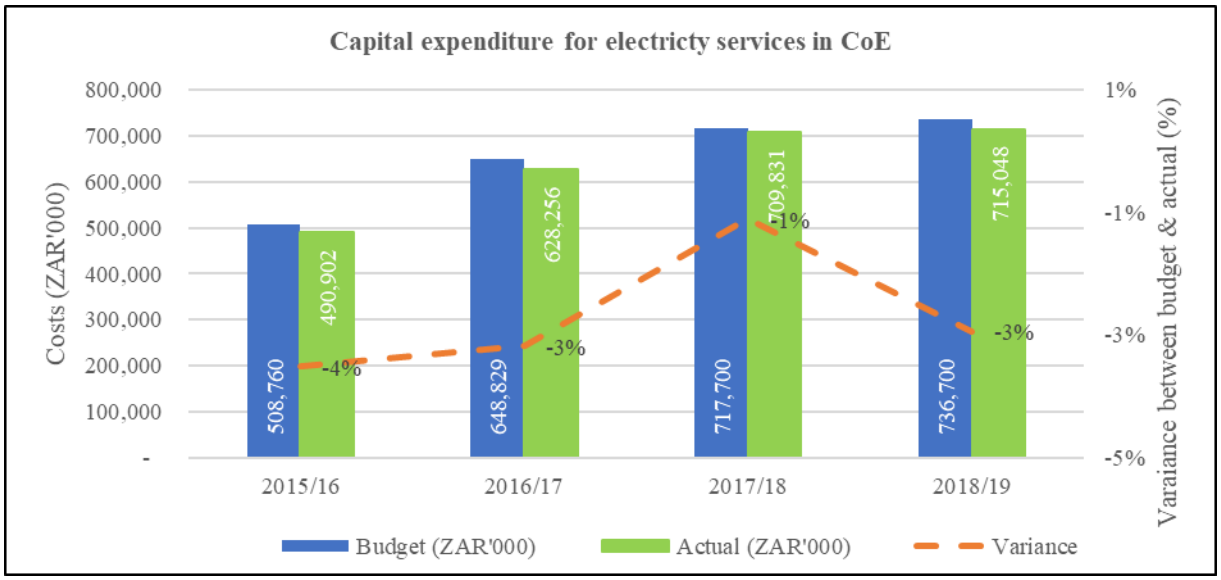

Figure 4.8: Capital expenditure on electricity (Source, Source, CoE, 2017; CoE, 2018; CoE, 2019 and CoE, 2020)

4.4.1 CoE's electricity revenue performance

As shown in Figure 4.9, the increasing trend in self-generation within CoE is cause for great concern mainly because of its impact on municipal revenues due to reduced sales. As noted by Baker and Philips (2019), electricity sales constitute 35% of revenues generated by South African municipalities and the growth of SSEG constitutes a significant threat (see Section **Error! Reference source not found.**). Overcoming the risk of potential revenue erosion would require redesigning a new business model which factors the current electricity market dynamics to ensure that its electricity utility business remains viable.

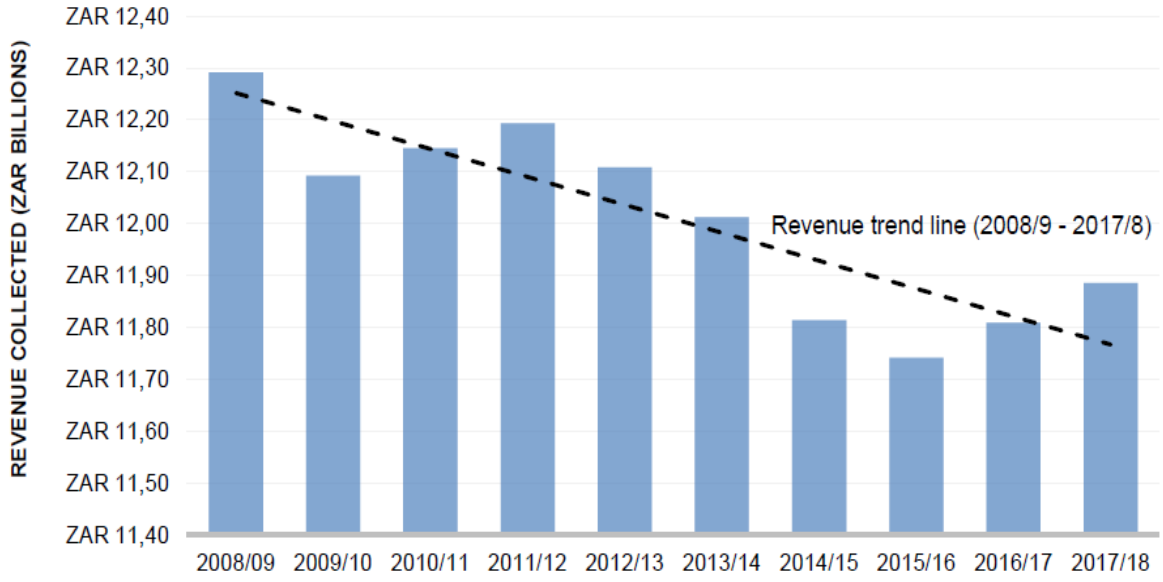

Figure 4.9: Electricity revenue performance trend for CoE (Source: Thenga, 2019, p 85)

The declining revenue trend has been attributed to reduced consumption as a result of load shedding and customers opting for DG to reduce reliance on the unreliable grid as well as ensuring investment return due to declining costs of renewable energy technologies, especially for solar PV. The downward trend in revenue could therefore be indicating growth of DG as an important contributory factor. Revenue has continued to decline despite the imposition of above-inflation tariff increases that were meant to offset the impact of load shedding on revenue (Lutchman, 2019, p 1).

An official from CoE acknowledged the declining revenue trend and indicated that various tariff options were being considered before approvals could be sought from NERSA for implementation. CoE's inclination was towards adopting a net billing system rather than net metering to compensate prosumers for surplus energy exported into the grid. This would be supported by upgrading metering devices to ensure an integrated system since the municipality could not afford significant capital expenditure for investing in a smart grid. In the interim, customers willing to connect their system to the grid were required to pay a fixed fee which would go to the municipality for availing and maintaining the grid infrastructure.

This was also highlighted by interview respondents from SANEDI, SALGA and various experts in the electricity sector (see Appendix 9.8). According to SANEDI respondent, revenue enhancement objective was one of the key components of SANEDI's smart-grid pilot project and this was based on smart metering infrastructure as part of smart-grid pilot project. SANEDI

respondent further alluded that the pilot project revealed serious concerns over municipal revenue erosion and hence the need for smart technology to mitigate the trend and its impact on viability of the utility and the municipality in general. The targeted interventions being proposed by SANEDI would improve network availability, enhance security of the grid in order to curtail energy theft and billing platforms to improve revenue collections. Energy theft, particularly in informal settlements by vulnerable households, has been cited by CoE as one of the leading factors contributing to continued loss of sales and revenue.

This concern was also corroborated by SALGA respondent who alluded that decline in electricity sales could also be attributed to technical and non-technical losses. Due to the aging of the grid, technical losses are high as the distribution grid is no longer efficient. It has also become vulnerable in several regions such as in informal settlements where there have been increased cases of vandalism. Expedited adoption of DG would reduce technical losses given that the loads would be located closer to the generating units. Vulnerability to vandalism can only be cost-effectively addressed through the implementation and operation of a smart grid which can collect information on activities along the distribution network and relay it to the distribution operator in real time as explained in Section 2.4.

4.4.2 Response measures to accommodate DG within CoE

CoE developed a revenue-loss mitigation policy especially in relation to its major-customer base who can be expected to switch from grid-supply to alternative power sources (grid-defection) in response to growing supply interruptions coupled with escalating tariffs. As a policy response, CoE (2018c, p 70) includes adaptive measures to embrace and promote the integration of renewable energy technologies to its distribution grid.

These increasing installations also pose additional grid operation challenges such as difficulties in forecasting demand and ascertaining responsive infrastructure requirements. Given the situation, the demand for improved grid infrastructure to harmonise electricity inputs from the growing DG opportunities is therefore intensifying. A smart grid system would provide information on a real-time basis to CoE (as the distribution system operator) from multiple generating units versus points-of-consumption in order to allow decision-making and optimization of the network on a real-time basis.

Data from the CoE indicates that there has been slow or no response to the recommendations by the USTDA (2013) feasibility study on CoE's readiness for the roll-out of smart grid within

its distribution network. In addition, SANEDI respondent confirmed that CoE had turned down an invitation to participate in SANEDI's smart-grid pilot project in collaboration with multiple stakeholders such as key municipalities (see Appendix 9.8 for review of the SANEDI initiative) The respondent highlighted that a probable reason for CoE declining the invitation was possibly a lack of interest or concern over operational inefficiencies in the municipality. The smart-grid pilot project would have provided a platform and framework for CoE to prototype the incorporation of the increasing demand for grid-interactive DG while ensuring that its revenue base is not eroded as currently evident in the prevailing revenue trend.

4.5 National-level electricity-sector constraints

Under current electricity policy and regulations in South Africa, adoption of DG faces systemic barriers when competing with Eskom as a vertically integrated utility monopoly in the sector. For example, the South African electricity pricing policy subscribes to economic efficiency and cost reflectiveness to inform feed-in-tariff rate setting (Shumba et al. 2018: p 16). In that sense, a municipal utility such as CoE introduces export tariffs based on Eskom bulk purchases. Whereas this approach might become attractive as Eskom tariffs continue to rise over time, it is currently inadequate for incentivising DGs mainly due to the longer payback periods for DG installations.

Currently, CoE does not have a tariff scheme to compensate customers for surplus power exported to the grid. However, as confirmed by CoE respondent, there is a proposal being considered by NERSA for approval. In the absence of nationally supportive regulatory framework for DG, municipalities follow NRS-049 (AMI requirements) and NRS 097-2-1:2017 (Grid Interconnection of Embedded Generation) guidelines for connecting DG units to the grid. This requires compliance with the requirements set out in Schedule 2 Gazette No 43151 of the Electricity Regulation Act (ERA) (Eskom, 2020). The regulations are also in line with NERSA SSEG framework that covers the connection of installations of up to 1MW.

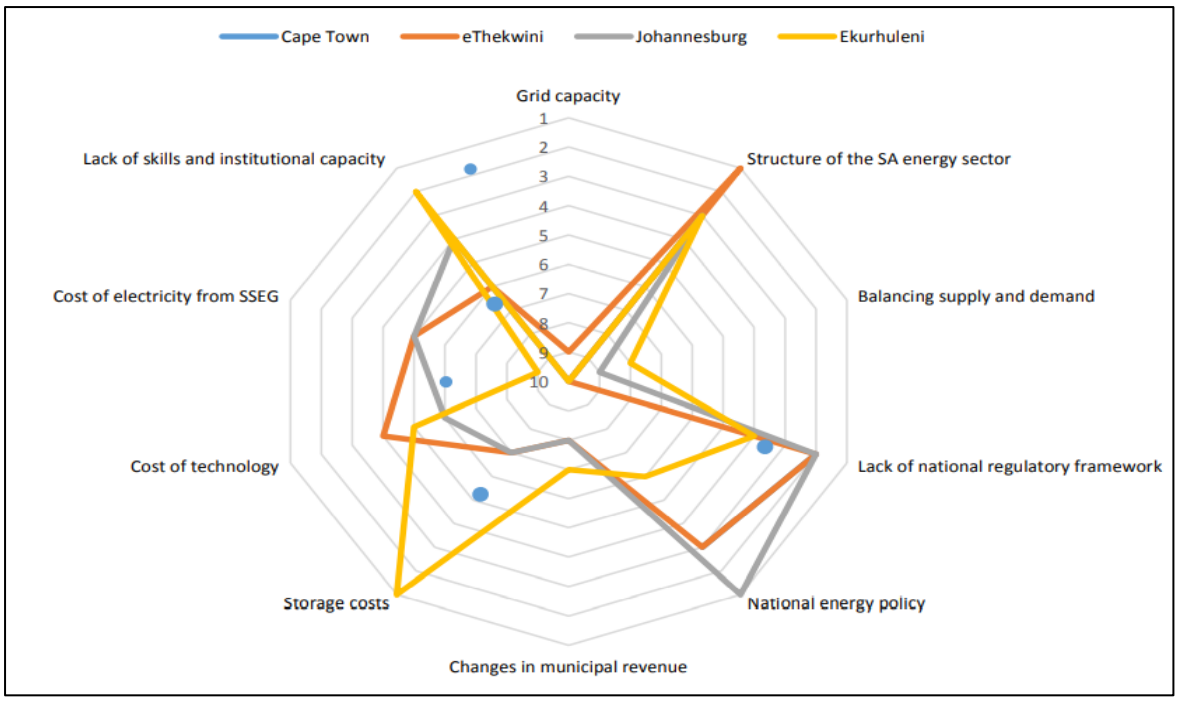

Figure 4.10: Various obstacles in SSEG growth (Source: Filipova and Morris, 2018, p 8)

Figure 4.10 shows common challenges closely linked to national level policy, which is characterized by a focus on large-scale, centralized energy projects such as Kusile and Medupi coal power stations. Given the disruptive potential of SSEG, demand is growing due to technology improvements and steep decline in cost. This should be complemented by increasing grid capacity and open access. Lack of grid capacity to accommodate RE and difficulties of balancing supply and demand features was among the main ten technical barriers and ranked second by Ekurhuleni, fourth by Johannesburg and sixth by eThekwini. This demonstrates the challenges facing municipalities and it is even worse for smaller municipalities with insurmountable financial constraints and limited skills base (Filipova and Morris, 2018, p 6).

The overall electricity sector in South Africa requires transformation towards a supportive regulatory framework aligned to DG as one of the key approaches towards the adoption of renewable energy technologies. At national level, South Africa has refined the compensation mechanism for utility-scale IPPs by migrating from the renewable energy feed-in-tariff (REFIT) that had been developed by NERSA in 2007 to the current competitive bidding process under REIPPPP. Through this policy and regulatory transformation, the government has progressively developed a procurement framework to support large-scale renewable energy-

based power generation while also introducing private-sector owned IPPs in the country's electricity market.

However, such an integrated policy framework does not currently exist among the municipalities who operate the distribution grid. As a result, each municipal authority has its set of policies to suit its unique opportunities and constraints. The most common and probably most effective policy instrument used in support of renewable energy technologies is the feed-in-tariff that guarantees producers fixed tariffs over a certain period. This ensures that prosumers are able to earn an additional return on their assets from surplus generation exported to the grid, which in turn creates a basis for long-term investment planning, since revenues are predictable in advance. The tariff structure must also be designed in such a way that the electricity utilities are able to recover fixed costs for maintenance of the distribution network.

A SALGA respondent (see transcript, Appendix 9.8) noted that out of 165 municipalities, only 41 (25%) allowed SSEG installations and only 25 (15%) had developed SSEG tariffs to compensate consumers who export surplus generation to the grid. CoE was not one of the municipalities with a SSEG tariff as it was still awaiting approval by NERSA. An interview respondent from Sustainable Energy Africa (SEA) also confirmed the low number of municipalities with SSEG tariffs and attributed this to municipalities that perceive distribution generation to be a threat to revenue generation whilst residential prosumers were being deterred from getting connected to the grid by the high cost of metering and absence of feed-in tariffs. However, commercial scale PV was considered a good investment under most current tariff conditions as explained by the SEA representative. This also confirmed the current state of registered installations within CoE.

One of the critical challenges facing DGs is the massive difference in tariffs which can be linked to the absence of a national framework to inform/guide municipal-level feed-in-tariff setting. For example, Cape Town has a feed-in tariff of R0.74/kWh whilst City of Tshwane and City of Johannesburg have feed-in tariffs of R0.10/kWh and R0.53/kWh respectively. The variations are huge and are attributable to the constitutional right given to municipalities to set their own tariff policies. This shows that there is no coordination in pursuit of a common SSEG policy within the local government space where distribution networks are operated. This contrasts significantly from the approach adopted in other countries such as Germany where feed-in-tariff structure is designed at national level and its enforcement procedure at local level included as part of the national regulations (Brunekreeft et al., 2015: p 67).

Technical elements of the programme such as technical requirements, tariff setting, grid code compliance and local ownership conditions for REIPPPP have greatly enhanced attractiveness of funding from financial institutions such as DBSA and others. An interview with DBSA respondent (see transcript list, Appendix 9.8) indicated that local banks are supportive of renewable energy funding instruments backed by national treasury. This contrasts significantly with CoE's LREIPP launch uncertainty since 2016 where continued delays in obtaining ministerial determination as well as compliance with Section 33 (1) (a) of the MFM Act (2003) have created barriers for DG rollout at municipal level.

The lack of funding was also cited as one of the limiting factors towards smart meters that are a key element in integrating DG to the distribution grid. DBSA respondent highlighted that the bank supports and facilitates funding for sustainable technology transitions through various instruments such as debt financing and mezzanine financing in collaboration with various financial institutions such as Green Climate Fund (GCF), AfDB, KFW and World Bank.

Their funding criteria follows various models and structures such as ring-fenced funds used for special schemes (such as feasibility studies, spatial planning frameworks, electrical distribution lines and efficiency challenges such as reducing electrical losses). The DBSA respondent further alluded to the fact that, on availability of funding, no municipality has come forward with a funding proposal towards policy or infrastructure developments. However, it was not clear why municipalities do not make systematic efforts to access such funding in spite of the pressures they face while mainly relying on dwindling treasury grants and other subsidies.

4.5.1 Key policy incentive challenges for DG

As demonstrated in Figure 4.11, one of the critical challenges facing growth in SSEG in South Africa's electricity market is the massive difference in SSEG tariffs across different municipal distributors. This is mainly due to the absence of a central reference point that can be used for tariff design by all municipalities coupled with the constitutional right for municipalities to set their independent tariff policies while bearing in mind NERSA-requirements. The data provided in Figure 4.11 shows that it is attractive for prosumers in Cape Town (either residential or commercial) to connect their generating units because the feed-in tariffs are approximately 8 times and 1.6 times higher than those offered in City of Tshwane and City of Johannesburg respectively. Given that these cities are within the same country, the equipment and installation costs would likely fall within a similar range, which thus creates an unequal playing field for customers keen DG across the various municipalities. The feed-in tariffs

presented in Figure 4.11 would therefore likely lead to higher SSEG penetration in Cape Town followed by City of Johannesburg and City of Tshwane.

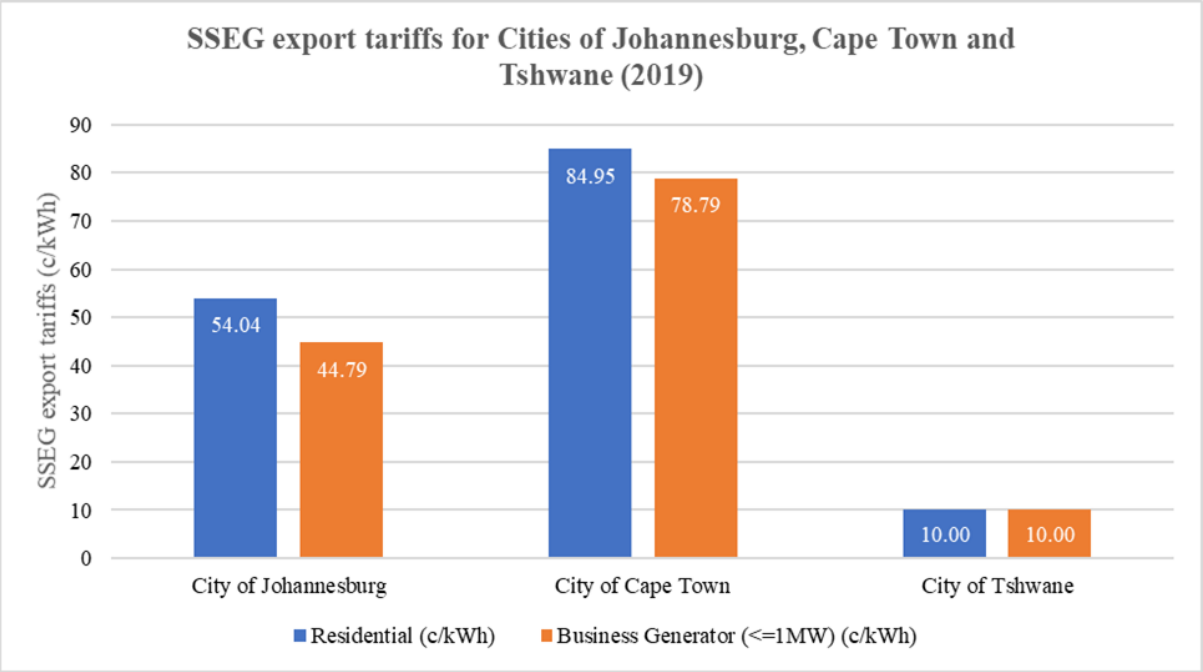

Figure 4.11: Municipal SSEG tariffs for Johannesburg, Cape Town and Tshwane (Source, CoJ, 2019, p 1, CoCT, 2019, p 1 and CoT 2019, p 2)

This was further highlighted by OUTA respondent who noted the lack of coordination across local governments (such as at SALGA level) in policy development and a lack of concern over responsive feed-in tariff structure as a strategy towards incentivising the adoption of DG. This approach differs significantly from the one adopted in Germany where the tariff structure and implementation framework for renewable energy from DG was designed at national level and also incorporated as part of the national regulations for the national electricity sector (Voss et al., 2017). In Germany, the adoption of a 20-year feed-in tariff was considered the most effective policy instrument to support renewable energy technologies as it offered certainty on cash flows to investors over the lifespan of the DG units. It thus encouraged the growth of prosumers, which resulted in private players controlling 50% of the electricity market (Voss et al., 2017).

A SALGA respondent confirmed that for NERSA approval, municipalities can choose either net billing approach (where surplus energy exported to the grid is compensated at less than the utility's retail tariff) or net-metering (off-setting consumption from the grid with surplus exported to grid and the customer gets charged or paid for the difference at normal tariff). CoE

respondent insisted that net metering is not financially attractive in the context of protecting municipal revenue mainly because the feed-in-tariff under net-metering is set to be at the same rate as the utility's retail tariff for the respective customer. This is deemed to be a major drawback for distributors and wholesalers such as CoE as it poses the risk of not covering fixed costs especially in a context of declining revenue-stream.

As a result, most municipalities are opting for net billing. The CoE respondent highlighted that only Nelson Mandela Bay Municipality (NMBM) has adopted the net-metering approach to DG. The participant also noted that NMBM's SSEG policies and objectives were not necessarily driven by revenue or profitability priorities. Instead, they were more aimed at promoting DG primarily for supply-security and resilience through covering some of the customers' costs of self-generation installations.

A CoE participant alluded that implementation of feed-in-tariffs is in progress and is currently awaiting NERSA-approval. As a result, customers do not get any rebate or any financial incentives for feeding excess power into the grid. It is also a requirement for any grid-interactive SSEG-operator to register their systems for safety and planning purposes, but there are no punitive measures yet for non-compliance.

By developing a tariff proposal, CoE is possibly signalling its acceptance of the inevitable dynamics currently underway in the electricity sector and thus preparing for a transition towards a more systematic integration of grid-interactive DG. Operational modalities must be devised to ascertain possible ways of compensating customers, thus strengthening the business case for customers who wish to be prosumers. This would also incentivise prosumers to register their systems with the municipality in order to qualify for such tariffs.

In its NERSA-application, CoE prefers to adopt a dynamic tariff structure (like Real Time Pricing - RTP, Critical Peak Pricing - CPP, and Time of Use -ToU charges) which allows it to purchase and sell power to consumers based on existing demand on a real-time basis. This was highlighted by CoE officials interviewed. The officials further indicated that the adoption of a fixed FIT carries the risk of encouraging consumers to use the distribution grid network merely as a storage facility for their surplus generation during off-peak period and draw it back for use during peak periods much to the detriment of CoE (see Appendix 9.8).

Another alternative suggested was to adopt SSEG tariffs on a net-consumption basis which requires the customer to consume more electricity from the grid than they export over a 12-

month period as way to protect municipal revenues. This approach has been adopted in other municipalities such as the City of Cape Town. Customers are currently liable for payment of a fixed charge to CoE either as a once-off fee on connection or on a monthly basis for access and use of the grid-network.

4.6 Prosumer-side constraints

According to respondent from CoE (see Appendix 9.8), these installations are more widely adopted by the business sector to alleviate the increasing electricity tariffs which are negatively impacting on business cash flow. Installed capacity increased from just 350kW in 2013 to more than 52MW by end of 2021. On average, it meant installed capacity was doubling annually since 2013 to end of 2020 and on the other hand, the number of sites registered also increased from just one (1) in 2013 to 85 in 2020. The data provided by CoE (see Appendix 9.5) showed that over 90% of the registered installations were at non-residential premises, a fact also confirmed by a municipal respondent. This indicates an increasing trend and is predicted to escalate in the next 3 to 5 years as shown in Figure 4.12.

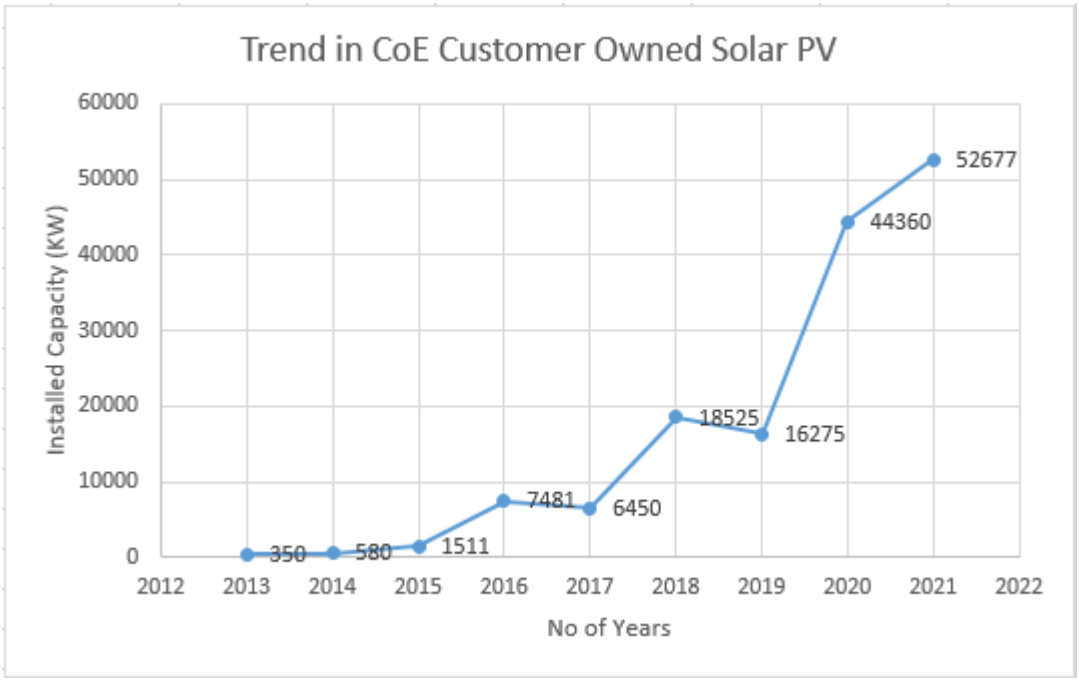

Figure 4.12: Trend in grid-interactive solar PV installations in CoE (Source: CoE SSEG manual database, obtained from CoE official, 2018).

Pandarum (2018) suggests that there has been exponential annual growth in installed capacity of solar PV across the country over the last 5 years to a level of about 285 MW. With installed DG capacity of around 30MW in CoE, this means that approximately 10% of the total

registered installations are in CoE (see Appendix 9.5). The positive correlation in the trends demonstrates that the underlying factors driving DG in CoE are also similar to those prevailing across the country. Pandarum (2018) also indicates that 69.8% of the countrywide installations are under commercial and industrial categories whilst residential and agriculture accounted for 7.7%. These installations are primarily for self-consumption and therefore constitute a particularly valuable option in South Africa where feed-in tariffs offered by municipalities are significantly lower than applicable electricity retail tariffs charged on consumers when using electricity from the municipal grids. Another major factor driving the uptake of embedded solar PV includes the desire for longer term certainty on electricity costs particularly for energy intensive users. Such installations are also facilitated by general access to sizable roof space (in m^2) for commercial and industrial buildings.

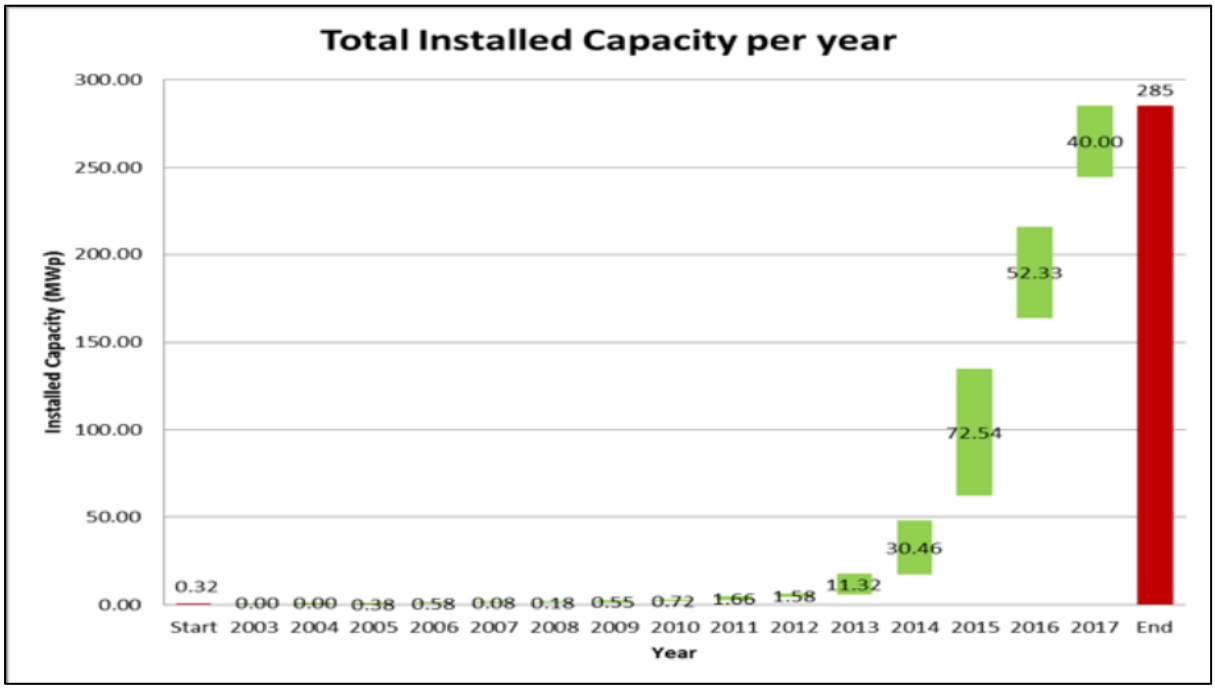

Figure 4.13: Recorded national wide annual total installed SSEG from 2003 to 2017 (Source: Pandarum et al., 2018, p 4)

Figure 4.13 shows the total installed capacity for SSEG per annum. This trend is due to lower feed-in-tariffs offered in the municipalities than applicable electricity rates from Eskom and municipality (Pandarum et al., 2018, p 4). Overall installation trend reflects the slow pace at which SSEG is being adopted across the country. The commonly cited obstacles in the slow

uptake is consistence with the cost of technology and energy storage, national regulatory framework, structure of energy sector and grid capacity.

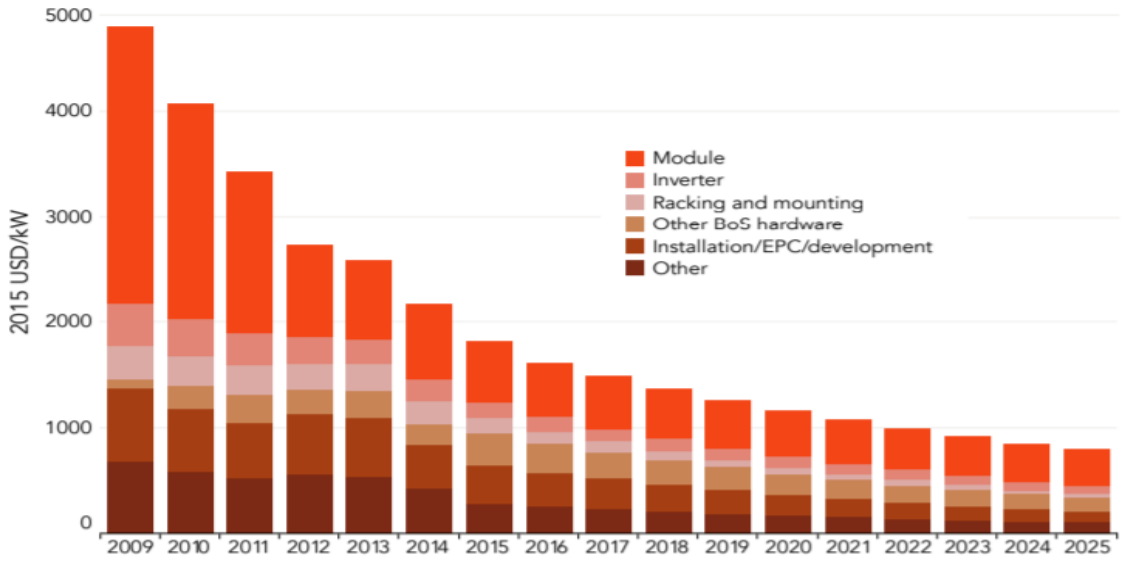

Figure 4.14: Projected decrease in Solar PV costs to 2025 (Source: Eskom, 2018, p 19)

Filipova and Morris (2018) point that a combination of rising wholesale and retail electricity tariffs, declining cost of solar PV technologies and growing offers for feed-in tariffs by municipal distributors are providing the necessary conditions for increased growth of DG over the projected period up to 2025. As shown in Figure 4.6, the declining cost of solar PV technologies will continue incentivising SSEG and thus negatively impact on municipal electricity sales which generates a significant portion of their revenue.

With increasing adoption for self-generation (which transform consumers to prosumers), CoE is witnessing a mild increase in rooftop solar PV installations (see Figure 4.12), which is in line with national level findings (see Figure 4.13). The increase is mainly due to declining cost of solar modules and growing offers for feed-in-tariffs by various municipalities as presented in Figure 4.11.

The increase in self-generation for CoE (see Figure 4.12) is however amplified by an outdated business model based on a centralised system that requires urgent transformation (Baker and Philips, 2018). Inadequate policy and regulatory framework are seen as key municipal level constraints towards faster adoption of DG by prosumers. As shown in Appendix 9.6), the key concerns for generators 1-5 were the absence of compensation on surplus electricity fed to the grid. This could come in the form of incentives schemes, grants, subsidies and feed-in-tariffs.

One of the key findings from the customer-participant interviews is that that CoE prosumers support the rollout of grid-interactive DG accompanied by supportive policy frameworks to guide tariff expectations among other regulatory concerns.

4.7 Key sub-findings and conclusions

Key sub-findings are related to technical capacity, financial barriers and SSEG approvals which accounted for over 75% of all problems affecting DG growth within municipal distribution networks. These challenges revolve around staffing and skills deficit to engage with the newly emergent and highly disruptive SSEG technologies. Capacity of distribution grid network to accommodate DG/SSEG is also constrained. The absence of feed-in-tariff will result in the increase of grid defection as customer find no benefit of paying increasing fixed charges for grid connections. This will result in accelerated erosion of the revenue base in CoE if a responsive business model is not established to accommodate DG promotion as mentioned Section 2.8 and Figure2.10. Political issues are attributed to lack of prioritisation in policy formulation and implementation due to failure to appreciate the impact of SSEG penetration on municipal revenues. Additionally, policy developments have not been matched by promulgation of relevant regulatory provisions to give guidance to municipal distributors on critical issues such as feed-in-tariff setting.

5 PRIORITISATION OF SMART GRID AND NET-METERING FOR INCREASED DG ADOPTION

5.1 Introduction

Insights from studies appraised in Chapter 2 suggest that significant opportunities exist for addressing the diverse challenges of grid-interactive DG through grid-modernization especially towards smart-grid. In view of the aging power grid and increasing electricity demand due to urbanisation and economic growth, modern grid systems are rapidly embracing the integration of automated systems which can also facilitate self-correction based on sensing and communication with integrated DG (Huang et al., 2012).

Guided by these insights, this chapter presents data and analyses on the second sub-question with regard to the importance of prioritising smart grid and net-metering systems towards facilitating DG. The chapter is presented in two parts where the first part covers data and analyses on the range of technical issues affecting CoE's distribution network and the unintended consequences of connecting SSEG to CoE's existing grid. Data collected relates to technical performance challenges of the current grid network as well as potential of smart grid and net-metering towards facilitating incorporation of DG. The second part presents data and analyses on the appraisal of socio-economic benefits related to resolving DG challenges through infrastructure upgrade to smart-grid and net-metering systems.

5.2 Data Overview

The data presented and analysed in this chapter were collected through interviews with CoE officials and industry experts (primary data) as well as from secondary sources based on the data parameters outlined in Table 5.1. The data and related analyses were then used to derive sub-findings on the prioritisation of a smart grid and net-metering systems in addressing DG challenges as experienced in CoE.

Table 5.1: Key parameters that guided primary and secondary data collection

Sub-question 2	**Key parameters**	**Secondary data collected**	**Primary data collected**
What is the significance of smart grids and net-metering systems towards addressing CoE's distribution challenges while also facilitating the actualisation and adoption of DG?	• State of distribution-grid infrastructure in CoE • Needs and effects of grid-connected SSEG on conventional grid	**Adopted themes:** • Technical factors affecting distributed generation • Importance of smart grid in reducing non-technical and technical losses (addressed using a case study from Brazil) • Compensation mechanisms to promote DG • Significance of Smart grid pilot project (SANEDI, 2017) **Key Secondary Data Sources** • CoE annual reports 2017 - 19 • CoE Cost of Electricity Service Study 2018 • USTDA feasibility study (2013)	**Adopted themes** • Electricity distribution challenges • Implications of SSEG on CoE distribution network • CoE responses to distribution challenges • Advanced metering infrastructure (AMI) **Data Sources:** Responses by participants from: • SALGA • CoE • SANEDI • OUTA • SEA • GIZ-ZA

5.3 Challenges faced by municipalities in promoting growth of DG

This section presents data and analyses on the technical issues affecting CoE's distribution network, primarily focusing on operational inefficiencies and increasing demand for grid interactive SSEG/DG. The inability to fully integrate DG within CoE is mostly blamed on the aging grid network. SALGA conducted a survey in 2019 to ascertain the challenges faced by municipalities in accommodating DG/SSEG into their distribution network and the findings are presented Figure 5.1.

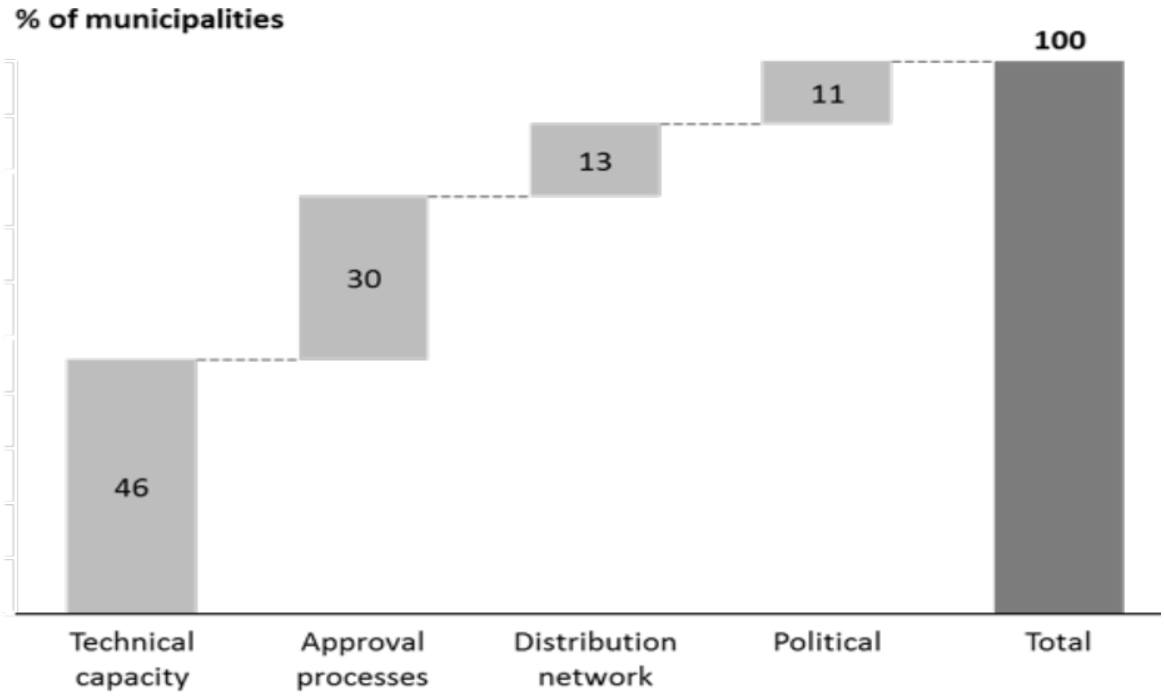

Figure 5.1: Challenges affecting DG/SSEG penetration in the municipalities (source: SALGA, 2020, p 15)

5.3.1 Implications of SSEG on CoE distribution network

DG growth is negatively affected by lack of clear support mechanisms for SSEG in municipalities. The challenges shown in Figure 5.1 are contributing to downtime on the distribution grid operations and planning. The distribution network does not support DG stability concerns and as a result, frequent faults are experienced either on customer premises or nearby substations. These faults arise due to illegal connection of DG units to the grid.

The CoE official further indicated that customers were using unqualified installers and cheaper equipment thus failing to comply with the regulatory framework (see Figure 5.2 on municipal

challenges to promotion of SSEG). Despite the negative impact of SSEG connections, SALGA respondents alluded that SSEG integration into the local grid is a move in the right direction and is aligned with objectives of the IRP of 2019 which recognises the role of SSEG as an alternative source of supplies. It is expected to disrupt the electricity market structure but will also contribute positively to the economy, which is an essential factor for sustainable energy offerings. It is therefore imperative to incorporate the issue into policy formulation at a local government level while also aiming for harmonisation of supporting policies at national level.

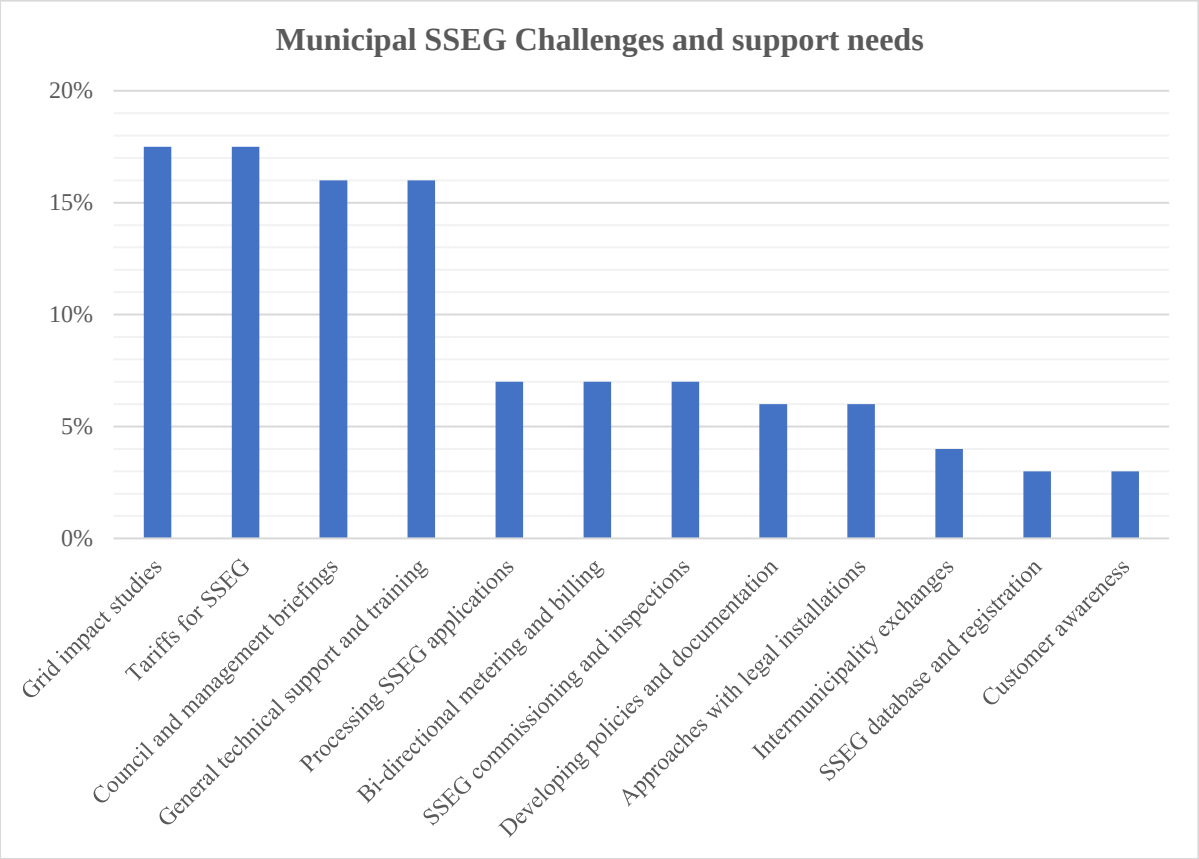

Figure 5.2: Municipal SSEG challenges. (Source: Adopted from SALGA, 2020, p 16)

The city's distribution grid receives high voltage power from Eskom's transmission-lines through a range of distribution points or substations as presented in the Figure 5.3, whilst DGs are connected onsite before CoE's meter.

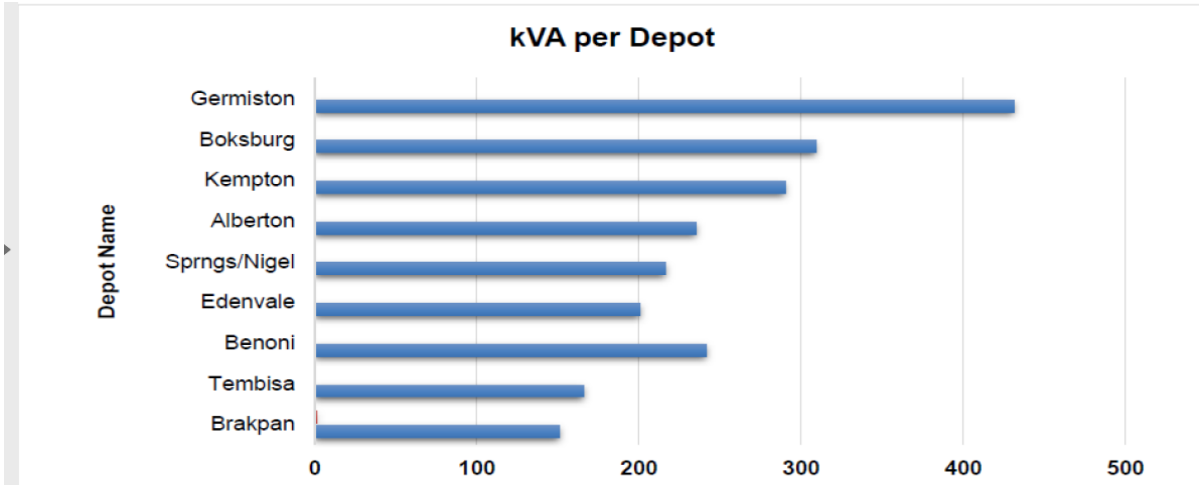

Figure 5.3: Eskom's distribution points / sub-stations for CoE (Source: Thenga, 2019, p 82)

Grid-interactive DG (solar PV and wind power) results in customers purchasing less electricity during periods of abundant sunshine and wind hours. This contributes towards revenue losses due to forgone sales and thus impacts on profitability of municipal-supplied electricity, especially where the business model is pegged on volume-of-sales. However, time-of-use (ToU) charges can be used to shift loads to match with sustained periods of sunshine and wind hours when tariffs are at their lowest and thus avoid pressure on the grid during peak demand periods. Figure 5.4 shows that revenue from electricity sales has been on a downward trend for the financial years between 2008/9 and 2017/8. This is in line with the trend for bulk purchases from Eskom shown in Figure 4.9. (Section 5.3.2).

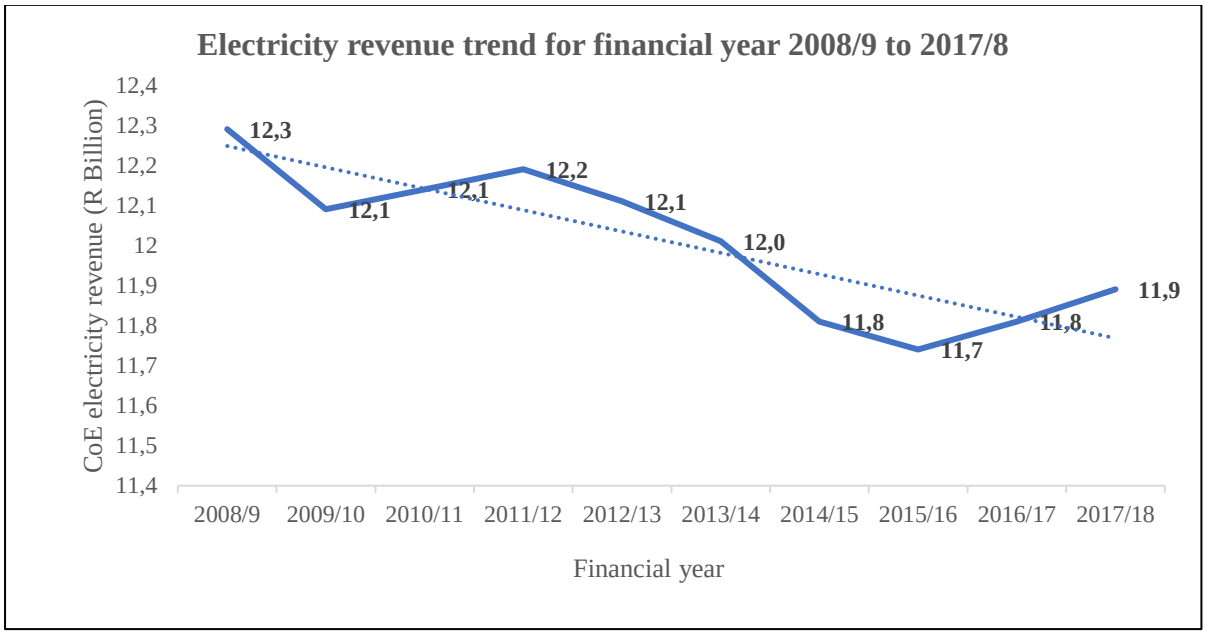

Figure 5.4: Electricity sales trend from 2008 - 18 (Source: adapted from Thenga, 2019, p 77)

An interview respondent from CoE indicated that there is a discussion on ways to mitigate challenges of lost sales and probable solutions include adopting a responsive business model such as decoupling of sales-volumes and adoption of dynamic tariff structures. CoE (2018b) recommended inclusion of a fixed monthly charge for grid-connected DG units depending on the tariff category as a way to recover lost revenue due to SSEG. SSEG is still out of reach for many residential customers who contribute the most to revenue and also feel the impact of high tariffs. However, as confirmed by registrations on CoE installation database, the installations are increasing, thus signifying the potential loss of highly profitable sales as shown in Figures 5.5 and 5.6.

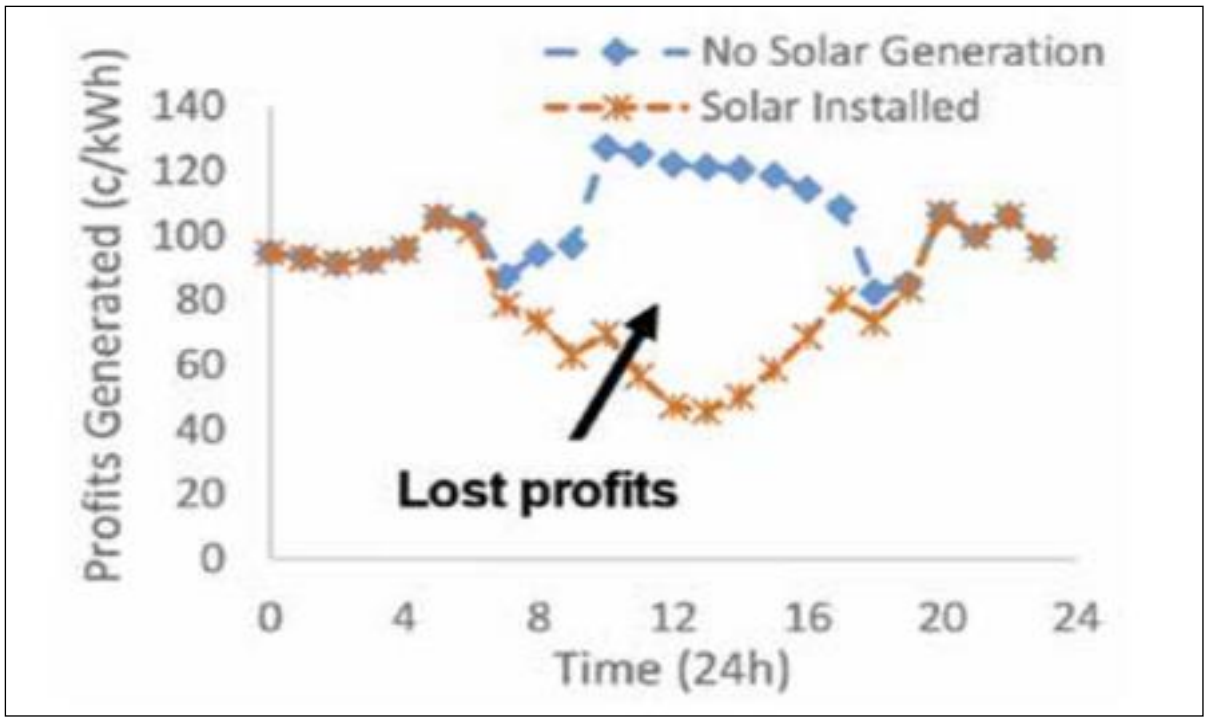

Figure 5.5: Municipal profitability with and without SSEG for high demand winter season (Source; Kotzen et al., 2019, p. 4)

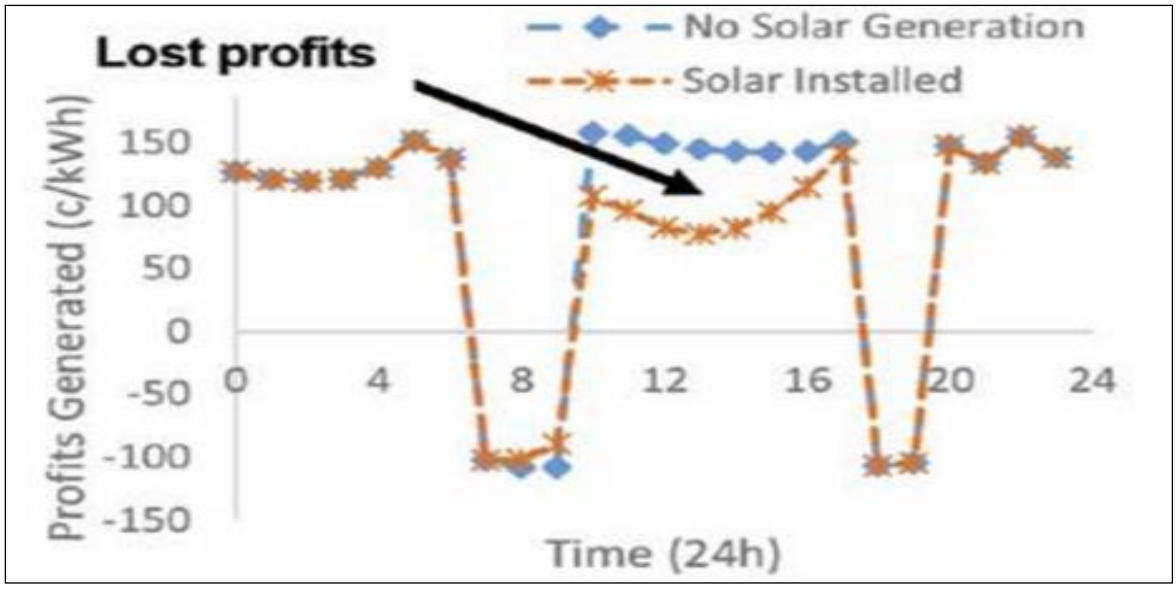

Figure 5.6: Municipal profitability with and without SSEG for high demand summer season (Source: Kotzen et al., 2019, p 4)

Figures 5.5 and 5.6 show the average change in gross profits when SSEG (solar PV) is installed in the residential sector in large quantities. This impact is best demonstrated in quantitative terms based on a household customer who installs 10kW peak power system rooftop solar PV and uses an average of 12 287kWh of electricity per year. This can be expressed as 12 287kWh per year of lost sales which is equivalent to R15 604 annual gross revenue for the municipality.

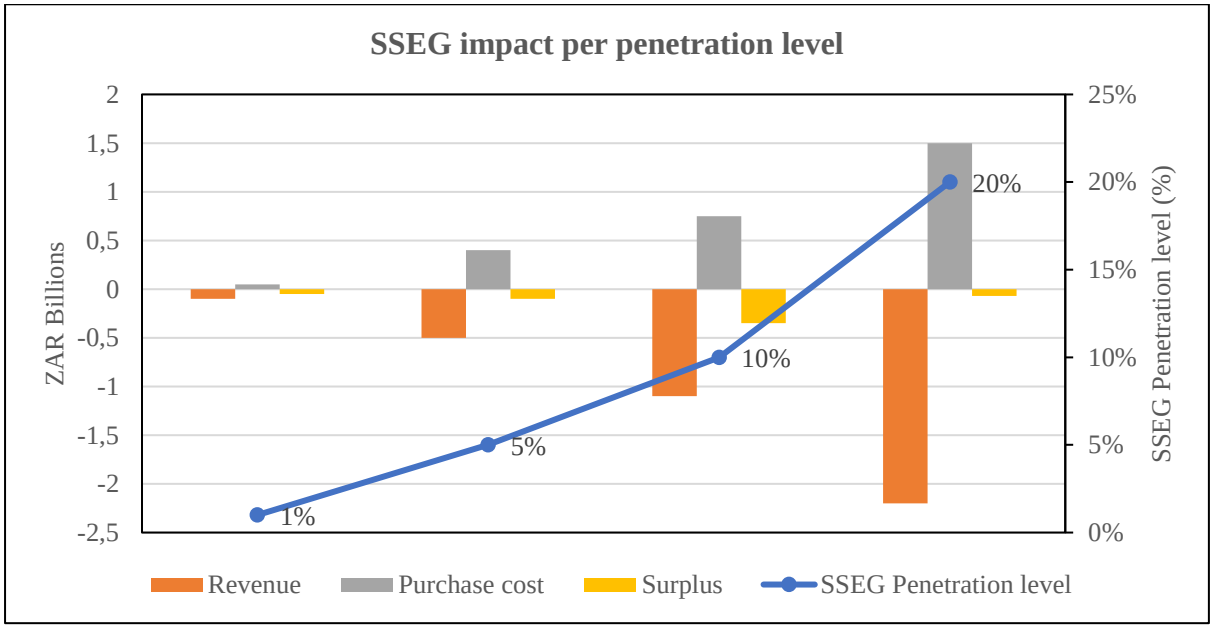

Figure 5.7: Impact of solar PV penetration in CoE (Source: adapted from CoE cost of purchases study, 2018, p 41)

Figure 5.7 shows the impact of solar PV penetration at different levels from 1% to 20% on cost of bulk purchases, revenue and surplus. The figures indicate a linear relationship between solar PV penetration level and revenue lost. For example, a doubling of the penetration level of solar PV leads to a doubling of revenue lost due to reduced sales. The impact of solar PV (at various penetration levels) was found to result in a loss of R0.39 for every kWh based on electricity generated for CoE's own use. It was also established that losses (both technical and non-technical) are responsible for a difference in the changes in revenue cost of purchases. Revenue due to lost sales falls at a faster rate than the cost of purchases leading to a reduction in the surplus. Based on average losses of 12% and SSEG penetration of 10%, revenue falls by 10% whilst the cost of purchases falls by approximately 9%. The impact on customers is dependent on the consumption patterns for each customer group and the applicable tariff structure as shown in Appendix 9.11 (CoE, 2018b).

Compensating for the loss of revenues and depletion of surplus requires CoE to use advanced analytical tools which can generate insights towards the development of an adaptive business model. In a static world, reduction in revenue from lost sales would be recovered simply by increasing the energy tariffs. However, this has the effect of further pushing customers away and increasing rooftop installations thereby accelerating the cycle of revenue decline which could potentially drag CoE towards a death spiral. This resonates with findings by Korsten et al. (2014) (based on the case study of Stellenbosch) where South Africa's electricity utilities have their business models based on consumption level (volumetric sales) which means that revenue generated is directly proportional to sales.

Figure 5.7 shows the impact of a 1% SSEG generation per kWh and the resultant reduction in revenue surplus. Tariff categories that are more kWh-based affect the surplus the greatest, compared to tariffs that include other fixed charges in the structure. Appendix 9.11 recommends the inclusion of a fixed charge per month to offset the negative impact of DG adoption on revenue due to lost sales (CoE, 2018b). Despite tariff increases of between 1.9% and 2.2% during the 2017/18 financial year, electricity income decreased by 0.8% due to lost sales as a result of increased penetration of SSEG (CoE, 2019, p 22).

As a measure to mitigate potential revenue loss, CoE has been charging grid connected SSEG fixed charges as compensation for availing its grid-infrastructure. This was confirmed by CoE officials who highlighted that the measure had been implemented to counter declining electricity sales. These charges are applicable to customers who choose to remain on the grid

network but there is an option to completely avoid them by remaining independent from the grid. In the extreme, some prosumers consider such charges to be punitive and are opting for unregistered connections. CoE officials confirmed that unregistered SSEG connections present CoE with safety challenges as well as escalation in downtimes due to non-compliance with laid down standards and regulations for grid connections.

The current grid infrastructure network requires expansion to improve capacity to accommodate new connections for CoE to achieve the milestones set out in the Integrated Development Plan 2018/2019. Load composition is forecasted to increase in the short-term and more than 50% is expected to be apportioned to residential, education and community facilities.

As alluded by Korsten et al. (2014), lack of grid capacity can inhibit levels of distributed energy resources exported into the grid (see section **Error! Reference source not found.**). Primary focus for electrical grid upgrade has been on large scale residential developments taking place. Amongst these residential settings are the informal settlements and dwellings that also need to be electrified and upgraded. The required infrastructure upgrades to accommodate the forecasted growth in load was further confirmed by an official from CoE, who also suggested that Eskom's grid network must also be upgraded to provide such capacity. SSEG policy which encourages self-generation has the potential to turn residential areas into significant islands of renewable energy generation as confirmed by CoE respondent.

5.3.2 Promotion of DG on CoE distribution network

Deployment of grid-connected DG systems can be scaled up through public policies and regulatory mechanisms, including well-designed financial incentive schemes (Zinaman et al., 2017:2). Financial incentives are mechanisms widely adopted by developed and developing countries to reward prosumers feeding surplus generation to the grid. These compensation mechanisms impact DG deployment because they strongly influence value proposition of a DG investment for individual customers. As shown in Table 5.6, a compensation mechanism can comprise of three core components which are: metering and billing arrangements, sell rate design and retail tariff structure a DG owner pays from grid and avoided cost if they self-generate and consume.

Table 5.2: An example of payments and refunds of residential SSEG (Source: City of Cape Town, 2017, p 16)

Typical monthly account if consuming 500kWh and generating 100kWh excess in a particular month					
	Units	Amount	Applicable tariff (excl)	Rand excl VAT	Rand incl VAT
Service charge	days	30	R11.43	R342.90	390.91
Purchase for consumption	kWh	500	95.76c	R478.80	545.83
Credit for generation**	kWh	100	49.72c	-R49.72	-49.72
Total payment					887.02

Table 5.2 shows residential SSEG comprising of daily service charge, electricity consumption charge per kWh consumed and rate per kWh at which the municipal distributor would purchase residential excess generation when billed monthly in a manner similar to services such as water and rates.

Currently there are 34 municipalities in South Africa who have an approved registration process designed for grid connection of small-scale embedded PV installations with seven of them incorporating NERSA approved feed-in tariffs. This demonstrates that several municipalities are in fact allowing export of energy into their distribution grids and compensating customers accordingly while CoE continues lagging.

Table 5.3 shows the export tariffs for some of the municipalities compensating prosumers (commercial and residential) for surplus generation fed into the grid. Various municipalities are beginning to incorporate SSEG in their policy formulations in response to revenue losses and for mitigation of unintended consequences of unregulated proliferation of installations. This has seen the development of installation guidelines and standards as well as export tariffs for SSEG, designed to suit each municipality's objectives as shown in Table 5.3. Majority of municipalities adopted retail price related tariff structures while Nelson Mandela Bay Municipality adopted net-metering (decided to allow meters to roll backwards) approach as its objectives were not revenue based but desire to improve security of supplies. CoE did not have SSEG tariffs in place as it was still waiting for approval from (NERSA) then and this position was confirmed by one of CoE respondents. Implementing such tariff structures requires the integration of diverse users and equipment connected to the grid to achieve system efficiencies (see Section 2.4).

Table 5.3: Current compensation schemes used in municipalities in 2018 (Source: Pandarum et al., 2018, p 3)

Municipality	Feed-in tariff
City of Cape Town	70.08c/kWh for every kWh exported
Theewaterskloof	48c/kWh for every kWh exported
EThekwini	68c/kWh for every kWh exported
City of Tshwane	10c/kWh for every kWh exported
City Power	36.14c/kWh - 42.79c/kWh for every kWh exported
Nelson Mandela Bay	Net-metering (compensated at import tariff)
Overstrand	65.25c/kWh for every kWh exported

5.3.3 Impact of CoE's maintenance plans on distribution efficiency

CoE compiles annual plans for capital expenditure aimed at refurbishing and upgrading or replacing the ageing network in order to stabilize its distribution network. The municipality continuously analyse the performance of its grid-network to pinpoint possible weak points before the occurrence of faults. Recent capital interventions included the replacement of about 40km of underground cables and switchgears in the regions of Kempton Park, Boksburg, and Germiston (CoE, 2019).

The execution of network maintenance and management, together with asset refurbishment strategy ensure compliance with the distribution network code as enforced by NERSA (CoE, 2019; NERSA, 2020). For example, during 2018/19 financial year, CoE spent R943 million on electricity infrastructure repairs and maintenance out of R2.3 billion allocated for all repairs and support for municipal assets in general (which was 41% of the total spent on repairs and maintenance). However, about 65% of the R943 million was spent on unscheduled maintenance and replacements primarily due to vandalism. Such enormous expenditure on unscheduled maintenance could have been channelled towards funding the much-needed infrastructure upgrades to prepare the grid for 21st-century power supply solutions.

Responses from CoE respondent also highlighted that there are installations of AMR (smart metering) systems in various locations targeting specific customer groups. The respondent elaborated that AMRs could detect tampering events, power outages, connect and disconnect the power supply for unpaid bills, facilitate load shifting and also monitor voltage spikes at each premises. AMRs are also reported to assist in scheduling and sizing transformers based on more accurate and granular data and thus improve operational efficiencies.

Such improvements are critical in addressing non-technical losses within the distribution network. By using AMR, CoE realizes 97% accuracy on its meter readings and this has contributed towards a reduction in losses coupled with nearly 50% increase of entire revenue from electricity transactions. Through the introduction of AMR and other digital technology systems, the City can handle various claims and queries on its billing systems more effectively (CoE, 2018, p 33).

One of CoE respondents highlighted that the municipality runs an annual operational maintenance expenditure (OPEX) budget that distributes dedicated funds towards maintenance and strengthening of infrastructure but has been unable to cope due to escalation in the rate of network deterioration. Another respondent confirmed this and also highlighted that the maintenance OPEX budget was inadequate, which has resulted in escalation of maintenance backlogs, especially in instances where the equipment is reaching the end of economic life. In addition, financial resources for the growing need of grid extensions and reinforcement are diminishing, which in turn compromises the ability of CoE to grow its customer-base and sustain reliable quality of electricity services for its existing customers in general.

CoE respondent indicated that a dedicated security operation was initiated to secure electricity infrastructure based on collaborations with the South African Police Service and Ekurhuleni Metro Police Departments. The operation mainly targets illegal connections and detection of meter tampering with a focus on identification and investigation of meters with no or low readings over a given time. As a result of such operations, CoE is spending more than R35 million annually for security and current statistics indicate a reduction from approximately 1,000 to 600 (of 40% - 60%) in theft incidents annually (CoE, 2018, p 72).

There has also been an overall decrease in the level of network interference and a reduction in the value of stolen material. Between 2014 and 2016, CoE operations resulted in 600 apprehensions with 90% conviction rate for equipment-theft or fraud. Additionally, the municipality has installed more than 200 pepper-gas systems in various substations, 70 anti-theft alarms and 12 cameras (CoE, 2016). CoE is also working on installing early warning systems on hotspots and these are mainly in the informal settlements where CoE has resorted to using pre-payment meters (CoE, 2019).

The enforcement of preventive measures is sometimes ineffective as staff from CoE are frequently threatened by residents who violently stop disconnections of illegal connections,

even though such officials are not stopped when working on other installations or restoration assignments. Such operations are therefore costly as they are mainly manual and also put the lives of security and technical personnel at risk when deployed to some of the communities.

In addition, even though the illegal connections have frequently resulted in fires and electrocutions in the past, residents show minimal regard for their own safety or that of their communities. This could be attributed to the ongoing slowdown of the national economy that has resulted to escalating unemployment which in turn drives the illegal connections and tampering incidents in order to access electricity without having to pay the bill (CoE, 2019).

A CoE respondent noted that there had been installation of smart meters which are smart-grid ready and compatible. The respondent indicated that over 300,000 single and 44,000 three-phase AMR meters around Kempton Park with Advanced Metering Infrastructure (AMI) had been installed as part of an ongoing exercise to replace aging meters. The operation has achieved a rate of about 70-100 installations per day. In addition to conducting this exercise, CoE respondent elaborated that the activity takes a lot of resources and cannot be viewed merely as a case of switching technologies. The technical obstacles constraining smart meter installations have led to the establishment of an Infrastructure Control Centre (ICT) which will be responsible for an integrated approach towards an overall smart city plan for CoE, with the smart grid as one of the components.

In line with NRS 049-1:2011 regulation (Electricity Regulation Act 4 of 2006) that specifically looked at the credit metering segment, CoE has started enforcement to ensure that all DG installations are compliant. However, this entails an imposition of expensive smart meters for the DG-customers at their expense which thus translates into a significant constraint. A SEA respondent further alluded that most of the constraints are not really on metering technology but CoE's willingness to develop a responsive strategy and get a commitment from political heads to resource a systematic roll-out/implementation plan.

The United State Trade Development Agency (USTDA) (2013) study looked at the various activities that sought to strategically place CoE on its transition towards smart grid and net metering, beginning with awareness campaigns followed by infrastructure upgrades. The study recommended that CoE should implement a smart-grid pilot project as a way of testing the concept before rollout on a full scale. However, as presented in Table 5.4, very few of the recommended activities have been initiated. Interview responses also concur that even though

AMR installations are continuing, the pace of grid infrastructure modernisation has been extremely slow. In particular, a CoE respondent who has been championing renewable energy strategies within the municipality observed that the few activities under implementation are also happening in a piecemeal approach. Table 5.4 forms part of the checklist of activities and processes recommended for transitioning towards a smart city as well as an assessment of CoE's preparedness to roll-out a smart grid system.

Table 5.4: Initiatives towards smart grid development (Source, CoE, 2014, p 19)

No	Description	Status Level	Readiness
1	**Dynamic pricing** (Real Time Pricing, Critical Peak Pricing & Time of Use)	Low	Low
2	**Real Time data sharing** (Total SCADA shared points)	Moderate	Moderate
3	**Distributed resource interconnection policies** (Standard grid-interactive distributed generation & Interconnection policies)	Moderate (NRS- NRS 049-1:2011)	Moderate
4	**Policy/Regulatory Progress** Smart grid investments recovery through rates, FIT and Renewable Portfolio standards (RPS) etc.	Low to Promising	Low to Promising
5	**Load participation based on grid conditions** (Load served by interruptible tariffs, direct load control and consumer load control tariffs)	Low	low
6	**Grid-interactive distributed generation** (Renewable/Non-renewable) Quantity of DG installed	Low	Low
7	**Electric vehicles** (Quantity of on-road light and heavy duty vehicles)	None	None
8	**Grid-response on non-generating demand side equipment** (Total load served by smart grid responsive equipment's)	None	None
9	**Cybersecurity** (Compliance with the NCPF)	Low	Low
10	**Open architecture /standards** (Interoperability maturity level)	Promising	Low
11	**Investors/Venture capital** (Annual capital invested to modernize electrical grid)	Promising	low

Given the activities and the slow rate of implementation of initiatives as listed in Table 5.4, CoE set up a unit to facilitate an integrated approach to promote the development of guiding principles for a smart city vision and aerotropolis with the smart grid as one of its components.

Based on their own experiences, a respondent from SANEDI expressed views that a smart grid framework provides a robust and resilient implementation plan where functional components

can leverage previously installed components without requiring a significant overhaul of the grid network. The smart grid roadmap is therefore optimally aligned with requirements for CoE's application for tariffs-approval or adjustments by NERSA (CoE, 2018b).

5.4 Results of smart grid development on DG in South Africa

Electricity access in South Africa is constrained and requires modernisation of infrastructure to meet the growing demand as well as integrating emerging sustainable energy options (Baker et al., 2015). As a step towards addressing these challenges, in 2013, SANEDI drafted the Smart Grid Vision 2030 as part of the South African Grid Initiative which was later revised in 2017 (SANEDI, 2018 p 2). The vision defines the long-term national roadmap for smart grid development in the country which is necessary to align the interests of all stakeholders in the country as well as to foster the relevant skills and technology development. The role of SANEDI would be to lead other energy sector players in the research and development of smart grids in South Africa (SANEDI, 2018, p 2).

The development of the Smart Grid Vision 2030 was necessitated by the changing electricity landscape driven by the need to embrace lower-carbon generation options and ensure efficiency in energy management. This has necessitated the need to invest in a sophisticated and intelligent network in order to renew and expand the aging electricity infrastructure across the grid. Prevailing challenges thus present an opportunity to incorporate automation into the network in order to transform the way electricity is generated and used. The vision lays out the implementation framework and metrics used to evaluate performance on progress. The objectives of the Smart Grid Vision 2030 are aligned to the country's medium-term target of producing 30% of the energy requirements from renewable energy sources (SANEDI, 2018, p 3).

Eskom has also been implementing capacity planning to facilitate the integration of renewable energy resources which are expected to play a crucial role in the energy mix (Eskom, 2019, page 87), but it has been accused by stakeholders of being the major impediment towards transformation of the energy sector (Ting and Byrne, 2020, p 1). The utility has been fighting IPPs in order to maintain its dominant role over the electricity sector (see Section **Error! Reference source not found.**). On its part, Eskom has lamented the lack of government support in form of incentives and subsidies to promote generation of electricity from renewable resources. It is relying on IPPs for renewables, but the use of take-or-pay contracts obligates

Eskom to pay for what would have been generated by the IPPs regardless of demand by consumers (Eskom 2019, p 88).

The integration of small-scale generators will accelerate with increased adoption of feed-in tariffs but will also lead to erosion of revenue for utilities as customers are likely to relegate the grid to serve as a back-up facility. Eskom (2019, p 89) argues that resolving challenges associated with integration of renewables will require a greater use of smart grid technology to manage the potential negative effects on revenue losses, safety, power quality and reliability. This will also facilitate improvement on the response time of the grid as well as enhance interaction with customers. The strategic focus is thus on achieving modernisation of the distribution grid by incorporating advances in information systems, asset optimisation and distribution network support technologies (Eskom, 2019, p 89).

Even though municipalities have developed their own registration processes to allow connection of DG units to their distribution grid infrastructure, NERSA as the regulatory body is also initiating formal national registration framework for SSEG (Pandarum, 2018). The fundamental factors sustaining the growth of small-scale PVs are expected to remain over the medium term (a period of between 5 to 10 years) primarily as a result of rising wholesale and retail electricity tariffs. In this regard, Sewchurran and Davidson (2016, p 2) highlighted that electricity prices had risen by an average of 14.5% annually from 2008 to 2016. Their study also expected that by end of 2020, electricity generated from solar PV would cost less than half of the R1.69/kWh Eskom electricity was expected to reach. According to Mordor Intelligence (2022, p 2) indicates that solar PV costs has further dropped by 24% from an average of ZAR1.14 in 2020 to an average of ZAR 0.87 per kWh in 2021, and this has had a positive impact on solar PV installations in South Africa.

5.4.1 The envisaged CoE smart grid roadmap

As per CoE respondent, the bottleneck in execution of the smart grid roadmap lies in political priorities which are tilted in favour of short-term interventions such as electrification of informal settlements at the expense of the long-term solutions that would address increasing incidences of energy insecurity. In that context, recommendations from the feasibility report on smart grids were not considered a priority for implementation and no budget allocation was provided even though the USTDA study aimed at helping CoE adopt an intelligent grid network for effective revenue collection processes and acquisition of advanced data for planning purposes.

Figure 5.9 presents the smart-grid roadmap recommended by (USTDA, 2013, p 125).

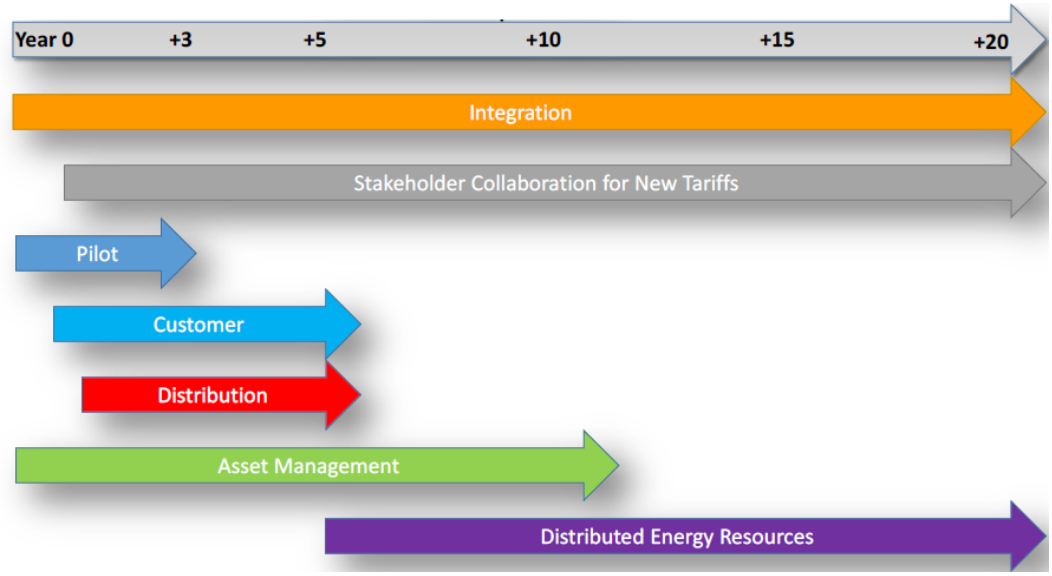

Figure 5.8: Smart grid adoption roadmap for CoE (Source: USTDA 2013, p 125)

Figure 5.8 shows the components that could have been achieved by now (eight years since the recommendations were made) to enable the transition to a smart grid. The backlog of activities includes the pilot project, engaging with various customers and upgrading of the electrical distribution lines. As highlighted by one of CoE respondents, so far, only AMR meter installations (which are smart ready) had been implemented for selected commercial customers. The inadequate implementation is possibly due to lack of political prioritisation and failure to comprehend widespread benefits of such technological innovations by the municipal decision-makers responsible for driving the strategic thrust of CoE.

This lack of prioritisation was confirmed by a SANEDI respondent who explained that ten municipalities (including CoE) were invited to participate in a smart grid pilot programme for South Africa. The programme was aimed at developing a convincing business case to roll out such smart grids for municipalities. However, most of the selected municipalities (including CoE) did not even attend the planned four workshop sessions per year. SANEDI respondent confirmed that nine municipalities that finally participated in the pilot project reported significant energy savings and improved revenue performance.

5.4.2 Relevance of Internet of Things (IoT) and blockchain for DG promotion

The first solar PV blockchain based initiative was launched in small town of Quartierstrom, Switzerland to increase the benefits of peer-to-peer energy sharing paradigm. The fundamental

objective is the potential value in energy sharing and the coordination framework encompasses value identification, bill estimation and performance (Worner et al., 2019, p 2). The Quartierstrom case study is based on Internet of Things (IoT) and blockchain technologies as explained in Section 2.7. It showcases new business model within distribution systems that facilitates trading of electricity and control of user consumption patterns thus providing greater economic benefits to prosumers.

Figure 5.9 shows that participants in Quartierstrom invested in solar PV and were provided access to the distribution network by the local electricity distributor (Water and Electricity Works Walenstadt - WEWW). This allowed participants to either purchase power from rooftop solar PV at wholesale market price when they had insufficient supply from their self-generation plants or sell to other consumers in the retail market when they had surplus generation. In this peer-to-peer sharing paradigm, prosumers could exchange and trade energy with each other directly in an energy sharing region at lower prices compared to electricity imported from large generators. This blockchain-based mini grid project was supported by the Swiss Federal Office of Energy (SFOE) with the aim of testing the potential of blockchain technologies and consumer behaviour towards the adoption DG.



Figure 5.9: Participants in IoT and blockchain enabled electricity sharing paradigm in Quartierstrom, Switzerland (Source: Worner et al., 2019, p 2)

5.5 Sub-findings on significance of prioritising smart grids in promoting DG

This section consolidates the key sub-findings on relevance of smart grids towards promotion and adoption of DG. The sub-findings mainly relate to distribution challenges faced by CoE in relation to grid-interactive DG and consolidated in terms of three key relevance categories which are distribution challenges, promotion of DG and the main overlaps across the two categories.

5.5.1 Key distribution challenges in CoE

Data extracted from Eskom show that a traditional distribution grid is unable to facilitate seamless integration of DG without investments for upgrading to a smart grid (see Section 5.3). Eskom (2019) noted that the growing demand of DG is increasing the complexity of managing the grid and is further complicated by rising electricity tariffs. The two factors in turn affect grid power quality, reliability and security. Responsive plans therefore revolve around planning for grid capacity upgrade to accommodate diverse generating technologies.

From the national grid to the local distribution network, CoE conventional grid infrastructure shows constrain in handling the growing demand for electricity supply which thus necessitates grid modernisation. As demonstrated in Figure 5.1 (see Section 5.3.2), CoE bulk purchases from Eskom and corresponding sales to customers reveal ongoing/perpetual revenue shortfall relative to bulk-purchase costs due to a combination of both technical and non-technical losses. The ongoing losses also demonstrate that under current practices, CoE is facing declining revenue trend despite its opportunity to pass on Eskom tariff-increases to its customers. Smart grid could play a vital role towards reducing technical and non-technical losses as well as improved revenue collection. Digitisation of distribution systems could enhance greater connectivity of DG and other devices connected to the grid.

In spite of the high levels of non-technical losses affecting the operational viability of CoE's distribution operations, it has not yet tackled this challenge directly, especially in terms of quantifying the impacts of the key contributing factors (such as vandalism, tampering, doubtful debts and illegal connections) on revenues. Such impact assessment of each factor would then guide the formulation of appropriate responsive strategies (which could include enhancement of security or reconfiguration of the business model). In addition, incorporating advanced information/communications systems into the distribution network could automate the process of monitoring grid performance on a real-time basis.

Secondary data also showed escalating costs of infrastructure-maintenance due to aging (see Section 5.3.1). In particular, annual operational cost budgets for electricity distribution from 2016 to 2019 increased gradually by 2.4% and 1.7% for 2017/18 and 2018/19 respectively (CoE, 2018b, p 14). Modernisation of the grid could therefore facilitate improved operational efficiencies as well as minimise operational/maintenance expenditure. Improved grid efficiencies would in turn support the acceleration of DG integration and thus alleviate the challenge of constrained electricity supply from centralised generation under Eskom.

CoE official indicated that the city support net billing rather than net metering as prosumers should only offset retail electricity bill. Benefits from net billing are related to the increased system flexibility by intensifying prosumers to self-consume and inject electricity into the grid when prices are high as well as withdraw electricity from the grid when prices are low. Net metering is therefore seen as a threat to revenue generation. In that context, under a net metering policy, prosumers are incentivized to produce electricity at a level that may not be optimal for the electricity system overall, sometimes being overcompensated for the renewable electricity fed into the grid, thus leading to the vicious circle of overgeneration (Trela and Dubel, 2021, p 4).

So far, minimal infrastructure upgrades such as enhancement for grid security have slowed down the rate of illegal connections, tampering and vandalism of the infrastructure. This has in turn contributed to a decline in incidences of unplanned power outages. CoE officials confirmed that over 300,000 single and 44,000 three-phase AMR meters with advanced metering infrastructure had been installed resulting in improved operational efficiencies. The meters are able to detect meter tampering events, illegal connections and can be used to remotely disconnect power supply on unpaid accounts. As a result of these interventions, CoE has achieved 97% accuracy on meter readings and 50% increase in revenue from electricity transactions (CoE, 2018b, p 33) (see data and analyses in Section 5.3.4) whilst downtime on network availability stood at 0.58% (CoE, 2019, p 79) (see section 5.3.1).

However, by themselves, these measures have failed to effectively stamp out the problem and ongoing reliance on manual surveillance and security-force is proving to be unsustainable in the long run given the extensive reach of the distribution network. It therefore remains difficult to identify all incidents of electricity theft (through illegal connections, meter tampering or bypasses) or rampant vandalism which is mainly due to theft of copper cables. Reliable levels

of security can be achieved by incorporation of intelligent grid components that can sense and remotely report such tampering as it happens with minimal time-delay.

Whereas USTDA (2013) provided strategic roadmap for smart grid, smart meters and net metering (see Section 5.4 and Figure 5.8), progress has been extremely slow and severely impacted by various factors such as financial deficit, inadequate political prioritisation and skills gap as confirmed by CoE respondent as well as CoE (2018b, p 18). The objective of the recommendation for smart grid pilot project was to allow for evaluation of the effectiveness of smart meters for different classes of customers within the distribution network. Through the interviews, a CoE respondent confirmed that infrastructure upgrade is already taking place but at an extremely slow rate and specifically prioritises the installation of AMR and smart metering technologies for the more reliable high-end customers.

One of CoE's principal concerns over grid integration of DG installations relates to the possibility of an increasing number of customers using the grid as a storage alternative in order to net-off their consumption during peak periods when tariffs are high (see analyses in Section 5.3.3 and Figure 5.7). While such customers can consume electricity in small scale (especially on an IBT tariff), with increasing DG installations, this can translate into huge decline in the volume of electricity sold by CoE thus signifying potential loss of highly profitable sales, which would in turn undermine one of CoE's most critical revenue streams. With the ability of smart grid system to dynamically integrate DG/SSEG, it would facilitate dynamic/real-time pricing tools to guide a more revenue-sensitive tariff-setting process which could include options such as ToU pricing, possibly with fixed connection charge as a part of the tariff structure.

5.5.2 Key overlaps on smart-grids in relation to distribution challenges versus promotion of DG for CoE

One of the key sub-findings from the study demonstrates that the adoption of DG within CoE is likely to continue even in the absence of a smart grid for its distribution network. However, the potential for smart-grid to maximize DG value for both prosumers and CoE has also been demonstrated. In essence, CoE grid-supply stands to benefit from increased DG as well from peak load management, especially as a balancing mechanism to deal with the uncertainty, variability/intermittency of renewable resource generation relative to centralized conventional/fossil-fuel resource generation.

The expected increase in DG will impact on the distribution networks under Eskom and municipalities which will in turn undermine quality of supply, security and overall reliability. The best available options to ensure flexibility and improve resilience while accommodating more DG would be the adoption of intelligent grid infrastructure through smart grid upgrades. Smart grids would also provide real-time information to the system operator with regard to unregistered connections, grid-tampering actions, vandalism, and theft that are likely to compromise the integrity of the overall network.

The use of high-accuracy supply-versus-demand forecasting techniques within a smart-grid network would also allow CoE to schedule RE that can be accepted as part of its normal generation scheduling. The distribution capacity would also be enhanced through Dynamic Line Rating (DLR) which alleviates grid issues when receiving feed-in power from RE. DLR technologies have capabilities for measuring thermal and physical line tension (or sag) to optimize line flows. The upgrade to a smart grid would therefore allow CoE, as the distribution-grid operator, full visibility of its distribution network, which would in turn facilitate real-time information on DG feed-in to the network.

Smart grids facilitate the integration of diverse DG technologies with varying reaction patterns to factors such as weather changes and varying loads. Smart grid upgrades could even enable CoE to trade energy from generating technologies in other regions at lower tariffs, thereby creating an additional revenue stream for the utility. Such opportunities can be enhanced through IoT and blockchain technologies as discussed (see Section 5.5.1), which would in turn facilitate scalability as well as automated balancing between supply versus dynamic loads due to diverse consumer-devices and appliances.

This presents immense opportunities to tackle intermittence as one of the key technical impediments towards the adoption of grid-integrated DG. Energy trading based on IoT and blockchain would thus open opportunities for innovative business models under a distribution system with greater efficiencies and potential for additional economic benefits to prosumers. Upon smart-grid upgrade, CoE's distribution grid would also gain capacity to balance demand-side with supply-side dynamics more effectively thus providing consumers and prosumers with greater information and options to manage their own energy consumption, which would in turn enhance operational efficiency of the overall distribution network.

CoE has been charging grid connected SSEG customers fixed charges as compensation for availing its grid-infrastructure, but some prosumers consider such charges to be punitive thus nudging some of them towards unregistered connections (see data and analyses in Section 5.3.2). As one of CoE respondent confirmed, they view commercial SSEG connections with less concerns compared to residential connections primarily because most commercial prosumers are already formally registered and are therefore paying the fixed charges. This indicates a highly reactive and passive approach where preservation of CoE's status quo business model remains the primary concern with minimal interest in tapping into DG opportunities at optimal scale for both customer and CoE benefits. Based on data and analyses presented in Section 5.6.3, there is increasing pressure for the deployment of smart-grid systems that can facilitate dynamic pricing models such as time-of-use, critical peak pricing and real-time pricing in order to further incentivise consumers to install grid-interactive SSEG

5.5.3 Key findings on the relevance of smart-grids to promote DG

The establishment of a compensation framework for surplus generation exported into the grid is another important aspect towards increased adoption of DG. Secondary data (see Section 5.3.2) shows that CoE does not currently have a compensation framework for power exported into the grid while on the other hand, it charges a fixed amount to connected customers for availing its grid infrastructure. CoE is concerned that the establishment of a compensation framework may encourage customers to use the grid as storage facility, thus affecting sales during peak periods.

However, this can be mitigated by use of dynamic tariffs which allow customers to purchase electricity at lower tariffs during off-peak periods (peak generation periods for DGs) and sell it back to customers at high tariffs during peak periods (off-peak generation periods for DGs). CoE could start by implementing the ToU tariff scheme based on dividing the day into several time blocks and each block gets allocated a fixed tariff aimed at encouraging consumers to voluntarily adjust their energy consumption patterns. Using case studies from sixteen countries (such as Germany, Australia and France), Bhagwat and Hadush (2020, p 2) observed that the ToU scheme was widely used because of its administrative simplicity whilst complex tariff schemes (such as critical peak and real time pricing) are implemented in mature markets with advanced ICT infrastructure (see Section 5.6.).

Smart grid case studies in India (see next chapter, Section 6.7) experienced inefficient use of DG resource at customer level which was addressed by installing remotely readable energy

meter (interactive customer gateway) such as modern power electronics, advanced AMR application of two-way communication databases between distribution systems operators - DSO, and energy players as a new way of customer participation.

Pandarum (2018) noted that the establishment of market-based compensation incentives such as feed-in-tariffs, cash rebates and tax credits, would facilitate increased adoption of DG. The compensation element defines the exact tariff-level a DG system owner can expect for electricity exported to the grid (see Table 5.3 under Section 5.3.3). These compensation schemes apply to system-generated metered grid-feed-in by customer depending on the metering and billing arrangement adopted by the municipality. Compensation mechanisms impact DG deployment because they strongly influence the value proposition of a DG investment for individual customers.

Secondary data from CoE (see Section 5.3) shows that there has been an increase in the number of informal settlements being electrified as well as the number of renewable energy projects being implemented by the municipality. This requires an improvement in grid integration of renewable energy sources for optimization towards balancing demand and supply. NERSA is in the process of developing the regulatory framework for SSEG to allow equal and non-discriminatory treatment of all players at a national level (see Section 5.3.1). Pending promulgation of the NERSA regulatory framework, CoE has developed its own SSEG policy to manage the transition because of increasing number of customers who are also generating their own electricity (CoE, 2019), thus escalating the need for ensuring safety of such connections for the grid and customers as well.

Secondary data presented and analysed in Section 5.4 show the importance of establishing a long-term strategy for implementation of smart grids. In South Africa, SANEDI is responsible for developing the long-term strategy on smart grid implementation based on Smart Grid Vision 2030, which would in turn level the playing field for participants on infrastructure access and operation. Primary data also show that, in partnership with SANEDI, DoE implemented a pilot Smart Grid Programme in 10 municipalities through funding from the European Commission.

The participating municipalities benefited in key areas such as operational efficiency, seamless interconnectivity of DG, enhanced revenue management, active asset management, and in particular, linkage to a platform for policy and regulatory input under SANEDI. This

highlights a need for a strategic shift on how CoE interacts with other stakeholders towards keeping pace with incorporating smart grid technology.

6 ENHANCING REGULATORY AND POLICY FRAMEWORK TO FACILITATE ADOPTION OF GRID INTERACTIVE DG

6.1 Introduction

This chapter presents data abstracted from secondary sources to address sub-question 3 on the infrastructure policy and regulatory frameworks that can be implemented to facilitate scale-up of grid-interactive DG (connection of prosumers) as well as mitigate concerns over revenue erosion in CoE. Analyses of secondary data collected provided insights on the diverse international policies and frameworks critical in electricity infrastructure modernisation.

Smart grid and net metering technologies offer new options for integrating DG and enforcing energy efficiency measures in the distribution network. The effectiveness of deploying these systems is also being underpinned by evolution of innovative policies, regulations, and business models that have played a critical role in climate change mitigation interventions. Secondary data from case study reviews demonstrate unique, attractive policies and regulatory reforms required to achieve sustainable growth of DG. The multiple policy scenarios and insights drawn from case studies around the world indicate that smart grid and net metering systems offer solutions to various challenges related to DG, including offering enhanced grid-flexibility to accommodate variable generation by prosumers.

Given the crucial role of smart grid and net metering technologies for the adoption of SSEG, there is growing need for a significant enhancement of current policy and regulatory frameworks for the electricity distribution sub-sector. In substantiation of this relationship, this chapter presents data and analyses on how improved regulatory and policy frameworks can expedite implementation of smart grid systems for enhancing scale-up of grid-interactive DG. The sub-findings emerged from a distillation of the constraining factors hindering the adoption of smart grid and net metering technologies globally based on secondary data abstracted from a sample of the studies reviewed in Chapter 2, as well as primary data from interview responses from industry experts.

Data and analyses presentation in this chapter is structured into six major sections, where four sections cover smart grid development in Germany, Mexico, Brazil, and India case studies mainly focusing on policy and regulatory transitions towards the integration of DG within the distribution network. The fifth and sixth section presents the case studies of Mauritius and Namibia respectively, mainly focusing on net metering policies to support the rollout of DG

based on PV technologies. Policy and regulatory data relative to each case study are captured and analysed in order to assess the significance of smart grid and net metering technologies in promoting DG. The data analysis and findings concerning various policies are presented in Table 6.1. Data are abstracted from six countries, with four of them demonstrating fully developed policy frameworks for smart grid and RE integration (Germany, Mexico, Brazil and India) and two regional countries (Mauritius and Namibia) which present similar prevailing historical conditions as South Africa with regard to utility transformation. The sub-findings are articulated in terms of supportive policy frameworks and smart grid development plans which were comparatively referenced to the South African utility market environment as discussed in Chapter 4.

6.2 Data overview

As summarised in Table 6.1, secondary data were abstracted from studies on other countries that have successfully implemented policies and regulatory frameworks to integrate the various elements of DG based on renewable energy resources. Smart grid technology is becoming increasingly important in achieving a high-level penetration of DG across various electricity markets. The findings from data and analyses on the various policy and regulatory instruments are combined with responses from interview participants to generate sub-findings on how CoE could improve on its electricity infrastructure policies in order to facilitate faster adoption of smart grid and net metering systems. The data and analyses thus provide a unique perspective on the intersection of innovative technologies versus evolution of policies and regulations in a manner that would be relevant for decision-makers in CoE's electricity market.

Table 6.1: Data overview for sub-question three

Case Studies	**Data abstracted**	**Challenges and experiences**	**Policy and Regulations adopted and implemented**	**Data Sources**
Smart grid development and DG Adoption in Germany	Renewable energy resources-based DG (Energiewende)	Lack of policy to promote renewable energy development and integration with grid	Germany's Renewable Energy Sources Act	Voss et al. (2017) Anaya and Pollitt (2014)
Mexico Smart grid case study	Electricity law and Energy transition law 2015	Lack of electricity market structure Inadequate policies	Smart Grid Implementation Plan PRODESEN act	Binz et al., 2019
Brazil Smart grid interventions on distribution networks: Case of Eletrobras Distribution Rehabilitation	AMI procurement improvements	Low quality electricity services Illegal connections, fraudulent activities and theft	New smart meters and AMI with telemetering capabilities	World bank, 2018
Indian scenario: Puducherry smart grid case study	Aggregate Technical and Commercial losses interventions	Inadequacies in grid infrastructure Cybersecurity Power storage concerns Data Management issues Communication issues Power quality and stability concerns Power theft and illegal connections Lack of meticulous regulations and policies	National Smart Grid Mission (NSGM) Nehru National Solar Mission Generation based incentive scheme (GBI) Viability gap funding Bundling scheme	(Kappagantu and Daniel, 2018)

Mauritius net metering	Small-Scale Distributed Generation and Net Metering	Fossil fuel dependency Lack of upscaling for renewable energy The limited hosting capacity of the grid Limited available land Environmental targets	Grid code for Medium Scale Distributed Generation (MSDG) The Green Energy SSDG Scheme for Cooperatives Net metering for Medium Scale Distributed Generation Scheme (MSDG) Feed-in Tariff for Small Scale Distributed Generation Grid code for SSDG	Bellin (2017) Ministry of Energy and Public Utilities (2019)
Namibian net metering	Net metering Schemes	Power quality concerns impact on utility revenue collection Curtailed growth of distributed generation	Customer generators at non-discriminatory rates Retail rate/monthly charges to be reflected in retail tariff schedules Solar Revolving fund (SRF) Renewable energy fund through a carbon tax on fossil fuel Power Purchase Agreements	Curran and Clarke, 2012 Bellin (2017)

6.3 Smart grid development and DG adoption in Germany

Fundamental changes in the German energy sector started in the mid-1990s as part of EU's transformation towards the establishment of competitive market environment in trade, supply and energy. The key principle of the liberalisation process was opening of the electricity grid infrastructure to allow access by diverse market participants under non-discriminatory conditions as a way of facilitating generation regardless of scale (Voss et al., 2017). The second phase was influenced by the desire to create efficient energy markets through promulgation of policies and regulations that fostered liberalisation of renewable energy resources to achieve decarbonisation and decentralisation objectives of Germany's electricity market.

The major elements of the transition were aimed at phasing out nuclear energy, introduction of an EU emission trading system together with a reliable and functioning support scheme for renewable energy generators through the enactment of Erneuerbare-Energien-Gesetz (EEG, which is also known as the Renewable Energy Sources Act) which took effect in 2000 (Voss et al., 2017). The Federal Government's energy policies were built on decisions made under the Energy Concept of 2010 and the Transformations of the Energy System of 2011 (Energiewende) which focused on the long-term strategy of developing renewable energy and migration towards net-zero by 2050 (Anaya and Pollitt, 2014).

6.3.1 Policy and regulatory interventions in Germany

Germany's policy thrust is based on encouraging renewable energy development based on a 20-year feed-in-tariff scheme as financial incentive to attract investments from new market players such as small and medium-sized companies, cooperatives and consumers in general. Financial resources for feed-in-tariff obligations are raised through a surcharge levied on all end consumers in Germany under the EEG framework. This resulted in more money being collected than paid out for electricity exported to the grid, making the surcharge an important element of the country's funding of energy policy initiatives. However, the surcharge was viewed as an additional tax and resulted in a significant increase in cost of electricity for the end-users (Voss et al., 2017).

Priority of grid connection is given to generating facilities that produce electricity from renewable energy sources and from mine gas in accordance with EEG requirements. Grid operators are required to connect the generating plant to the technically and economically most appropriate grid connection point while the renewable energy generator is liable for the costs of connection including any installation of metering devices for recording the quantity of

electricity transmitted and received under a deep/hybrid connection approach (specific grid connection charges). Network operators are responsible for modification and reinforcement of their networks to accommodate new renewable energy connections while also bearing all related and economically reasonable costs (Anaya and Pollitt, 2014).

The grid operators are also required to take technical control over the installations connected directly or indirectly to their grid system as a way to facilitate reduction of generation output from generators when required (such as in the event of grid overload) or call up additional generation as and when required. Installations with a capacity of over 100 kW are required to install control and communication equipment whilst solar PV generators with a capacity between 30 kW and 100 kW may decide between installing the control and communication equipment that allows the reduction of generation output remotely or be limited to 70% export-to-grid relative to their respective maximum grid-feed capacity.

These policy and regulatory developments have translated into a seamless deployment of smart grid components across the transmission and distribution grid. The regulatory framework also provides for compensation of up to 95% of lost income to a generator including additional expenses (net of any savings) attributable to grid bottleneck. In addition, the framework also entitles DGs to a compensation of 100% in the event that lost income in a year exceeds 1% of total income that would have been due to the generator for the year (Anaya and Pollitt, 2014).

6.3.2 Impact of policy and regulatory interventions in Germany

The EEG policy resulted in significant growth of generating capacity from renewable energy resources at the distribution level coupled with a steep decline in the cost of RETs which ultimately disrupted the electricity market. Under the previous centralised generation regime, electricity was mainly generated from around 150 big power plants. In contrast, after market liberalisation the number of generating units increased to around two million across the country.

In 2008, renewable energy accounted for 16.8% of gross energy production in Germany and this figure rose to 29% in 2016 with significant growth being registered in onshore wind and solar PV. This growth was attributable to the liberalisation of the sector through the promulgation of the EEG (Voss et al. 2017). Renewable power generation capacity increased significantly from 12GW in 2000 to 36GW by the end of 2007. By end of 2017, it had risen to 112 GW with about 97% of the renewable energy resources being connected to the grid. More

than 50% of DG units were owned by customers (private owners, industrial companies and farmers) whilst the four largest utilities controlled only 5%. The systematic integration of more electricity from renewable energy sources to the grid resulted in a competitive wholesale market as well as attractive feed-in-tariff incentive for generators. The decline in grid connection cost was partially offset by the surcharge levied on end-users as contribution towards building a war chest to cover the resultant revenue-shortfalls for grid operators (Anaya and Pollitt, 2014; Schifer and Trüby, 2018).

However, the high number of generating units poses a major challenge for distribution grid operators due to the high variability of renewable energy generators. The legislation therefore required existing central generating plants to be technically capable of handling rapid load swings to avoid outages and other destabilizing effects associated with importation of power from renewable energy generators (Voss et al., 2017).

The EEG and the feed-in-tariff system have had many positive effects in Germany resulting in deployment of renewable energy plants at an unprecedented pace and have contributed towards a significant decrease in the cost of renewable energy installations, especially for DG. However, one of the side-effects is the increase in electricity costs to the lower income groups as end-users/consumers carry the burden associated with the surcharge levied to raise funds for the feed-in tariff tax. The costs covered by the EEG surcharge amounted to €25 billion annually as at end of 2016 and were expected to increase beginning of 2020 as offshore wind farms with high tariffs were expected to enter the system. As a result, small household consumers end-up subsidizing large industrial customers who are often exempted from paying the surcharge, and at the same time compensate the PV installations of more affluent property owners that have the space to install PV plants on their properties. Such a redistribution of wealth from ordinary electricity consumers to industrial companies or more affluent homeowners is unusual, especially in the context of developing countries, where the tariff structures are designed in a way that affluent consumers (companies and citizens) subsidise the cost for socially disadvantaged consumers that cannot afford to pay the full cost (Voss et al., 2017).

6.4 Smart grid development and energy sector reforms: Mexican case study

Mexico's power reform was initiated in 1992 and resulted in more Independent Power Producers (IPPs) entering the electricity market (Binz et al., 2019). The country's growing ambitions in clean energy generation guided regulatory and policy modifications that resulted in a change in the electricity market structure mainly by allowing in new players who used new

technologies to generate increasing levels of renewable energy thus contributing to improved power quality and broadening of client choices.

The era of power sector reform in Mexico mainly responded to the increasing grid modernization to accommodate the new generating technologies. In order to meet these ambitious clean energy goals, Mexico prioritised transformation towards a more responsive, competitive and efficient electricity market. For example, the country's grid infrastructure under National Electric System (Sistema Eléctrico Nacional or SEN) was enhanced by implementation of smart grid (from generation to the customer's premises) for maximum benefits to all users which in turn incentivised responsive investments. This was achieved by instituting holistic planning based on cost-effective strategy to ensure success in the country's energy transformation journey. The strategy also entailed interactions with global industry experts which provided platforms to learn and acquire high-level technical skills as well as experience to attain smart grid development goals within reasonable timeframes and costs.

Binz et al., (2019) highlights the core pieces of legislative transformations that catapulted the formation of "Smart Grid Implementation Program" to meet clean energy goals while also focusing on improved efficiencies, system reliability and security. The report illustrates that the smart grid implementation program was guided by eight key energy goals which include incorporation of new ICT technologies, system optimisation, DG integration, smart equipment and appliance integration, interoperability standards, open grid access and removing barriers for smart grid development.

6.4.1 Policy and regulatory transformation in Mexico

Mexico's 1992 policy and regulatory framework transformation was followed by the implementation of the Electrical Industry Law (EIL) in August 2014 and Energy Transition Laws (LTE) in December 2015. These two legislative changes became the bedrock of subsequent transformations towards the inclusion of energy power pool guided by the Federal Secretariats of Energy (SENER) legislations of 2017 (Binz et al., 2019). The transformation of the electricity sector focused on grid modernization by the state-owned utility companies namely the Commission Federal de Electricidad (CFE), the Independent Systems Operators (ISO), and the Centro Nacional de Control Energia (CENACE) through unbundling of their functions. The unbundling allowed reviews of the state policy such as the *Smart Grid Implementation Plan* which fell under the Ministry of Energy (MoE) and Secretaria de Energia (SENER) with the support of a policy review panel that included all other layers in the utility

market. Mexico's transformation involved various arms of the state to promulgate the required policy measures aimed at promoting the development of clean energies (Binz et al., 2019).

The core drivers for smart grid deployment in Mexico were compared with drivers in EU, Asia, Africa, the Middle East and other parts of Latin America as presented in Figure 6.1. The comparison demonstrates that the drive for smart grid deployment is linked to similar factors regardless of the geography or country concerned. The key common factors include a desire to improve efficiencies across the value chain (generation, transmission and distribution).

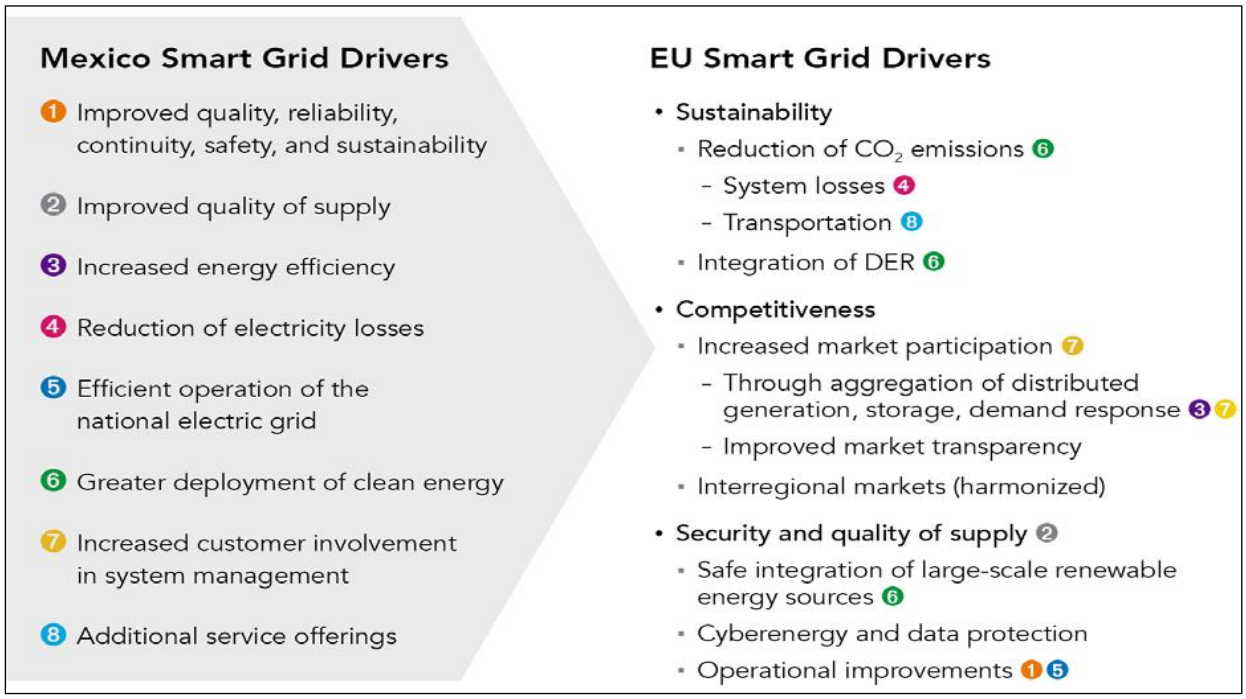

Figure 6.1: Key drivers of smart grid deployment in Mexico versus the EU (Source: Binz et al., 2019, p 10)

6.4.2 Resultant transformation

The major regulatory and policy transformation for the electricity market ushered in significant changes such as:

- Creation of wholesale/bulk power market
- Establishment of CENACE (an Independent Systems Operators)
- Creation of incentive systems for clean energies (certificates of clean energy); another revenue through electronic records to verify the origin of energy by DG

- Unbundling of vertically integrated state-owned utilities (CFE) into six independent competing entities and creating separate business divisions for CFE (transmission, distribution, and commercialization-open energy market)
- Smart grid program endorsements
- Assignment of new policy and regulatory responsibilities to SENER and CRE

Binz et al., (2019) illustrates the policy interventions and transformation process based on the pre-reform electricity market model in Mexico versus the post-reform structure as presented in Figure 6.2 and Figure 6.3 respectively.

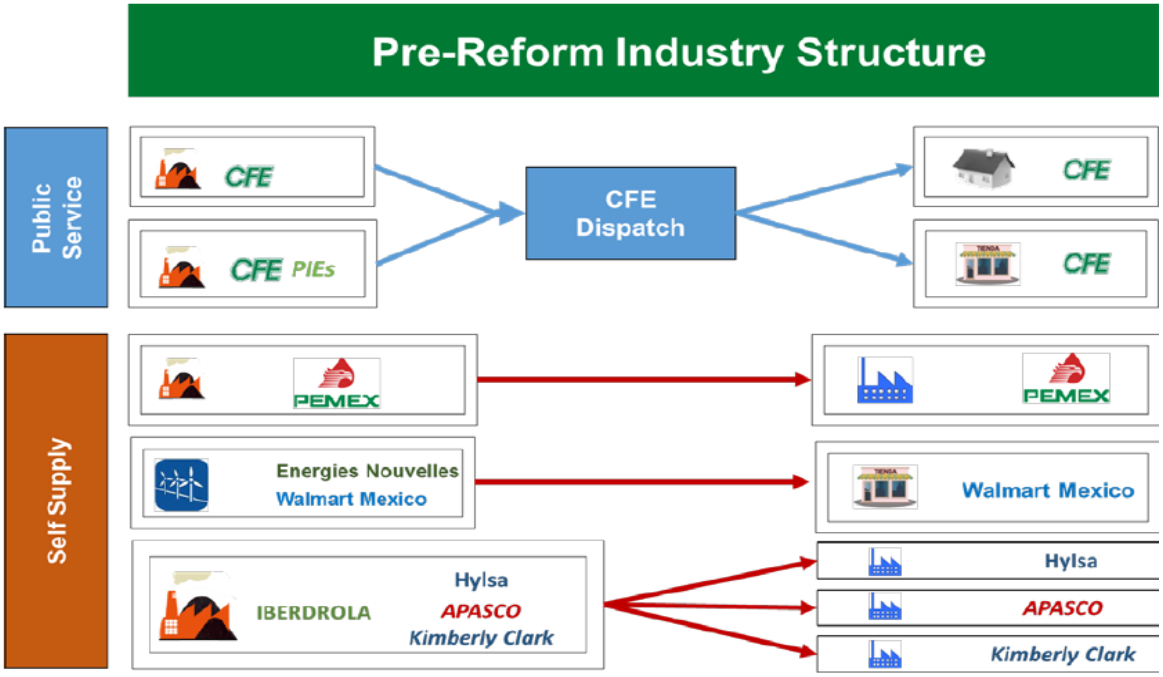

Figure 6.2: Pre-reform power sector (Source: Binz et al., 2019, p 18)

The pre-reform structure was based on the sell-and-buy functions solely under CFE. Under this structure, business and residential consumers had no other option for electricity supply beside CFE. In order to serve dedicated consumers, private generators had to initially sell their electricity to CFE which would then deliver it to residential and low-income clients on a wheeling basis. Whereas large commercial and manufacturing clients were allowed supply options via self-supply regimes, such activities were isolated and never incorporated into the public grid functions, thus denying such consumers a responsive market structure to reduce their generation costs. This uncoordinated structure was addressed through the formation of new structure as shown in Figure 6.3.

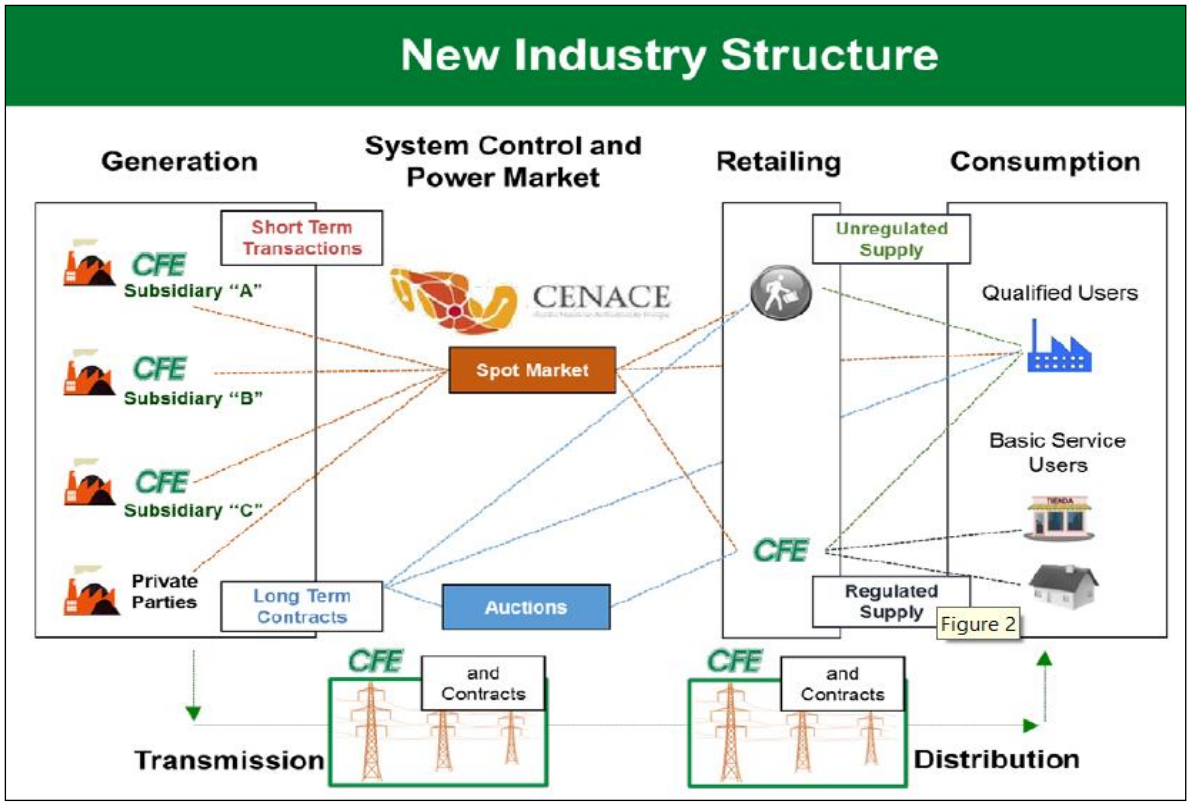

Figure 6.3: New post-reform power sector (Source: Binz et al., 2019, p 19)

In the new structure, CFE was unbundled into several competing entities responsible for generation, transmission and distribution. This allowed private generators to be treated similarly as CFE-generator affiliates which enhanced competition by allowing all generators to participate in the spot markets managed by CENACE. Mexico electricity sector was then liberalised and opened the wholesale utility market.

6.4.3 Impact of policy and regulatory framework in Mexico

Binz et al., (2019) reports that the most important piece of legislation in the transformation was the promulgation of LTE in December 2013 which mandated the Ministry of Energy to provide regular reports on smart grid technologies in Mexico with support from CENACE, CRE, transmission companies, distributors and suppliers published reports before 2015. These reports contained details that could help on future goals and forecasting in line with the following attributes:

- Benefits, costs and the technologies available for implementation of SG
- Identifying potential obstacles as well as their impacts on SG deployment

- Setting out requirements for investment for SG by assessing cost/benefit analyses of pursuing alternative scenarios

Binz et al., (2019) also note that, guided by SENER, CFE, CENACE and CRE, LTE greatly facilitated informed decision of SG architectures, priorities, and investment timing and estimation of benefits. In that context, LTE established clean energy short-term goals of 25% by 2021 and the long-term goals of 35% by 2024. The long-term goal was guided by UNFCC commitment during the 2015 Paris Summit.

Given the role of LTE in transforming the Mexican power sector, the PRODESEN Act (Programme for Development of the National Electric Systems) was promulgated in May 2015, with a set target for an installed electricity generation capacity of 130GW by 2031 (Binz et al., 2019). From the allocated capacity, 34% is reserved for fossil fuel, while 66% is allocated for clean energy technologies (including 11.4GW from solar energy). In addition, PRODESEN Act provided for regulations on clean energy certificates and the initial target was set at 5% by 2018. PRODESEN also addressed the smart grid program by reinforcing the upgrade of national distribution and global transmission networks in sustaining secure and reliable grid infrastructure capable of keeping up with the increasing demand. The SG program ensures the incorporation of modern technologies, the promotion of clean energies and DG.

6.5 Smart grid interventions on distribution networks in Brazil: Rehabilitation of Eletrobras distribution network

Brazil is ranked as the fifth most populated country in the world and has experienced economic stability over the last 10 years. Consistent with economic stability and industrial growth, Brazil's energy consumption rose to 578.9TWh in 2016 compared to 385TWh in 2012 (World Bank, 2018). Increasing energy consumption, poor distribution network and inefficient operation-management systems forced the implementation of electricity sector reform where five generation and six distribution companies were absorbed into Brazil's federally owned energy company known as Eletrobras. This provided the required favourable conditions for World Bank to grant them a loan towards electricity-sector development in their lagging regions. Through its International Bank for Reconstructions and Developments (IBRD), World Bank provided US$495 million to finance the rehabilitation of six electricity distribution networks in Brazil. The networks are Amazonas, Acre, Roraima, Rondônia, Piauí, and Alagoas (World Bank, 2018).

The project improved financial and operational performance of the six distribution companies mainly by reducing electricity losses, increasing bill collection rates and improved quality of services. These enhancements in the distribution systems were mainly achieved through the installations of smart metering infrastructure which enabled the companies to run viable business models. The benefits included lower electricity generation costs and resource savings due to reduction in electricity losses (technical and non-technical) as well as interconnectivity of various DG technologies (World Bank, 2018). Table 6.2 shows a summary of financial benefits across the six Distribution Companies (DiCos).

Table 6.2: Summary of Electrobas rehabilitation financial results (Source: World Bank, 2018, p 19)

Summary results for the projects financial analysis		
US$ in (000s)		
Discount rate		10%
Present Value of Cost (PVC)	$	-1,141,405
Present Value of Benefits (PVB)	$	2,519,788
Net Present Value (NPV)	$	1,378,383
Financial Rate of Return (FRR)		40.70%
Payback Period (Years)		3.61

The project yielded a financial rate of return (FRR) of 40.7% and a net present value (NPV) of US$ 1.38 billion (at 10% discount rate). The related payback period for the aggregate of US$ 709 million in loans from IBRD (US$ 495 million) and Eletrobras (US$ 214.3 million) to the Discos is 3.6 years. This translated into ten-year of benefits for Electrobas over a 15-year loan-term, with 5-year grace period and 10 years of amortization.

6.5.1 Key insights from Electrobas rehabilitation project

The Electrobas rehabilitation of the distribution network under the six companies improved power system reliability in areas covered by the distribution companies (World Bank, 2018, page 20). This has led to reductions in frequencies and duration periods of outages as well as virtual elimination of widespread blackouts. The use of improved real-time load forecasting techniques enabled more accurate predictions on when new capital investments were needed and reduced the sourcing of power from inefficient generating units to meet peak loads. Before the rehabilitation, the reliability and stability of the power system were adversely affected during peak demand periods, sometimes leading to unplanned outages or load shedding to

stabilize the grid. The rehabilitation reduced the frequency of outages and improvements in voltage levels. This was reflected in a 50% reduction in supervisory compensations (Agency fees to mediate, regulate and monitor the efficient functioning of the power sector) paid to consumers between 2016 and 2017.

Capability for grid self-healing provided a quick analysis of defects to protect the system from harmful effects as well as minimize the impact and duration of outages for Eletrobras. This was achieved using Automatic Circuit Reclosers (ACR), which shut when they sensed trouble and reopened when the threat had been cleared to restore the system. The number of routines repeat fraud offenders decreased from 42 to 6 in the original year of execution in Rondônia. There was also an improvement on cases recorded on safety-concerns with fewer cases of fires and electrocutions caused by illegal connections.

Advanced video security systems were also embedded in the smart grid so that the distribution operators could monitor the substations from remote locations to deter vandalism and theft. Despite an extreme recession in Brazil at the end of the project, the three companies sustained their enhanced performances while the other three evaded deteriorations. The scheme accomplished more than 725GWh of recovered power that was previously being lost as non-technical losses. The decline in losses also resulted in lower tariffs, ability to fully account for electricity sales as all unregistered consumers were identified and registered. The insights from the Brazilian electricity sector reform provides a learning platform for CoE's transition to a modernised distribution grid.

6.6 Smart grid and renewable energy integration in India

Kappagantu and Daniel (2018) reports on understanding of consumer interests and concerns in relation to solar PV integration into smart grids in India. The study was undertaken as follow-up to the national deployment of SG projects by the Indian Government (IG) based on the country's vision and roadmap on energy transformation. The findings highlight insights on smart grid development plan as well cost-benefit analyses and decision-making tools to inform SG deployment. However, the findings noted that smart grid implementation was facing severe challenges associated with resistance to adoption of developing technologies, socio-economic matters, inadequate guidelines and limited public awareness. The study was primarily intended to identify and elaborate on measures to overcome the obstacles linked to utilization issues and low client acceptance.

The study highlighted that India's grid network then was not sufficiently prepared to handle increasing demands of 21st century energy requirements and could face constraints that would affect issues such as quality, quantities, efficiencies, reliability, ecology, and economies. The acknowledgement of this critical shortfall provoked Indian Government's paradigm shift from centralized power generation towards DG. Indian Government has one of the most massive synchronous networks which is estimated at around 300GW of connected capacities and anticipated to reach 900GW by 2032.

The Indian Government adopted *Smart Grid Visions and Roadmaps, National Smart Grid Missions* (NSGMs) and *Nehru National Solar Missions* (NNSM) in January 2010 to accelerate the enhancement of grid performance and reliability. NSGMs has its own dedicated resources, authorities and efficient monetary autonomy to plan and control the SG policy and program implementation throughout India. This was complemented by NNSM as a national policy initiative to promote solar power and its integration to the national grid, with a target of 100GW by 2022. The target primarily consists of 40GW rooftop solar and 60GW of medium to large-scale grid-linked solar electricity installations (Kappagantu and Daniel, 2018).

The case study report focused on identifying challenges and barriers facing SG implementation and identified key issues that required to be addressed. The issues included:

- *Inadequate grid infrastructure*: the grid could not accommodate integration of DG which presented various challenges from design, erection, operation, and maintenance. In this context, the government took measures to overcome grid operation and connection problems through state transmission utilities, national regulators and distribution companies.
- *Cybersecurity*: there were threats from hackers and malware software which posed various vulnerabilities such as unauthorised information access. Cybersecurity issues were mitigated through smart grid which comes with a multilayer structure with security protocols built in to avert various ICT threats.
- *Power storage concerns* from RE due to intermittency and variability: This challenge was mitigated through installation of key demand storage devices to deliver power back into the grid network.
- *Social and economic frontier concerns* that needed to be addressed in order to play an essential role in technology access and attract investors through various stakeholder participation. This social and economic frontier aspects were

resolved by providing a platform for adopting new tariffs for DG that require real-time use (ToU) and Critical Peak Time pricing (CPT).

- *Data management issues* required to be addressed due to increasing installations and expanded network that comes with enormous quantum of meters, sensors and controllers. This was enhanced by capabilities in smart grid to analyse the breakdowns, alarms, forecasting demand, generation and pricing.
- *Stability concerns:* related to increasing integration of RE-based DG into the grid on a large scale causes bi-directional power issues such as angular stability due to lower systems inertia and voltage stability due to lower sharing support. Smart grid adoption was able to resolve these concerns through levelling out demand curves and peak reductions.

The case study on Indian smart grid solar PV incorporation provided insights on the importance of addressing stakeholder awareness and attitude towards promoting small-scale DG penetration. This was based on a survey of 25 respondents representing stakeholder groups in the state of Puducherry. The study concluded that smart grid technologies were of critical significance towards addressing key challenges associated with grid integrations of renewable generation, data management, grid-stabilisation and mitigation of cybersecurity threats, policy interventions and implementation models.

The bundling scheme was one of the proactive policy interventions in India and it was targeted at projects involved in selling renewable energy and thermal power generation in bundles so that final consumers could access uninterrupted power supply. The government first introduced the bundling through Nehru National Solar Mission (NNSM) where NTPC Vidyut Vyapar Nigam Limited (Indian largest utility company) would purchase solar power from developers who would then integrate it with the more affordable coal-based power (Kappagantu and Daniel, 2018). The report also highlights that prominent and strategically placed stimulus initiatives such as generation-based incentive (GBI) scheme, provide for 80% depreciation allowance for renewable power installations.

With this policy in place, the government attracted GBI-based projects and fed power into the grid from RES subject to an optimum allowance of 6.2million Indian Rupee per MW connected. This policy focus towards transitioning to decarbonised electricity attracted considerable financial resources into the development of integrated renewable energy projects. In this context, Indian Government identified “the viability gap funding scheme” which focuses

on the upgrade of the electricity grid and securing funding for long term grid development projects. The scheme is available through subsidies to attract public-private-partnerships (PPP) with up to 20% of project capital costs. The scheme therefore provided another viable option for the government to provide gap-funding or grants to support economically justified projects *(ibid.).*

6.7 Net metering policies in promotion of DG in Mauritius

In 2014, net metering policies implemented in Mauritius were aimed at encouraging the broad adoption of grid-interactive DG as one of the strategies of increasing energy generated from renewable resources in the country's energy mix. The envisaged transition is mainly driven by the need to ensure energy security as the country is heavily dependent on imported coal and oil (Bellin, 2017; IEA 2019). Mauritius' targeted to generate 35% of its electricity from renewable energy sources by 2025, up from 20% in 2018. In addition, it connected about 25,000 household rooftop solar PV of 1kW significantly contributing towards achieving the envisaged national target on renewable energy deployment. In that regard, various fiscal and infrastructural policy instruments (such as feed-in-tariffs, tax-relief and smart grid development) attracted investments into the electricity sector to support the development of renewable energy (Ministry of Energy and Public Utility - MEPU, (2019).

The Mauritius Central Electricity Board (CEB) launched its Small-Scale Distributed Generation Net-Metering Scheme (SSDG-NM) in August 2015 to encourage customers (mainly households) to invest in renewable energy installations. Under the SSDG-NM policy, customers generating electricity are required to export surplus power to the grid and receive compensation in the form of kWh credits which can be used when a customer's energy requirements are higher than the energy generated by their PV systems. Prosumers can therefore use the grid as their virtual energy storage at no additional cost (IEA, 2018). The SSDG-NM initiative was rolled out in three phases with a target cumulative capacity of 9MW. The first phase of the SSDG-NM targeted a minimum capacity of 2 MW of PV systems not surpassing 5 kW capacity each. As confirmed by Central Electricity Board (CEB), this supportive policy instrument incentivised investments in small-scale PV installations which exported surplus into the grid (Bellini, 2017; MEPU, 2019).

One of the key driving factors was reimbursements of installation costs for SSDG-Net Metering which was completely deductible from income tax returns. As additional incentives, customers who intended to connect their PV systems to the grid had access to low-interest loans from

local banks and the equipment were zero rated for value-added tax for subsequent phases (IEA, 2018). While allowing applications to the SSDG-NM scheme by customers, special allocation was made to allow the categories of *Integrated Resort Scheme* and *Real Estate Scheme* for mass installations of solar PV (Bellini, 2017).

IRENA (2019) revealed that by introducing this scheme through phases 1 to 3, Mauritius managed to install a total of 15MW of solar PV. Critical to renewable energy development ambitions, the government further established the Medium Scale Distributed Generation Net-Metering (MSDG-NM) scheme in May 2016. This was instituted to incentivise commercial customers in developing renewable energy generation with a target cumulative capacity of 10MW of Medium-Scale Distributed Production (MSDP) subject to grid impact assessments. The major purpose of the programme was to provide opportunities to medium-size generators to contribute towards the renewable energy objectives by integrating their systems to the grid. To this level, it was viewed as economically and technically viable for all potential prosumers to participate (MEPU, 2019)

The strategy on *Green Energy SSDG Scheme* for Cooperatives was also established through the business ministry in collaboration with the Energy and Public Services Ministry (EPSM) and CEB. It was intended to assist cooperative institutions and cooperative alliances to explore the opportunities to use solar photovoltaic technologies for power generation as part of the MSDG pilot project. Within this scheme, a maximum capacity of 100kW capacity PV was allowed for integration into the CEB grid for each cooperative society. To ensure sustainability of the programme, the cooperative society/federation was entitled to a once-off grant of Rs10, 000 per kWp PV installed up to a maximum of 5 kWp. Other related costs/expenses for the project were borne by the cooperative society.

6.7.1 Impact of policy and regulatory interventions

Bellin (2017) noted that the supportive policy and regulatory framework introduced by the government through its Central Electricity Board (CEB) were in line with the government's aspirations to increase renewable energy share to 35% of the national energy mix by 2025. The Mauritius Renewable Energy Agency (MARENA) adopted various infrastructure policy instruments to build capacity and benefited from regional and international exchange programs with peers. This enabled the agency to gain an understanding of the emerging innovative technologies that were key in managing grid penetration of renewable energy. The various policy instruments included *Grid Code for Medium Scale Distributed Generation* (MSDG**)**

(Ministry of Energy and Public Utility, 2019) which was applicable to system installations of 200 kW to 2 MW. This policy catered for connections to the CEB distribution network based on PV, wind power, hydroelectric and biomass-based renewable energy technologies. MARENA is also exploring the possibility of using floating solar PV on water bodies that are not used for supplying potable water to reduce pressure on land and avoid constraints imposed on limited roof space (Ministry of Energy and Public Utility, 2019, page 4).

Through a combination of fiscal/regulatory instruments and infrastructure upgrading, installed generating capacity for solar energy rose from 18 MW in 2014 to 95 MW in 2018. Net metering installations contributed around 20MW from the SSDG and MSDG schemes over the same period. The contribution of solar energy is expected to increase to about 160 MW by end of 2020 (which will be 8% to the electricity mix from less than 1% in 2014). Notable reforms in Mauritius' energy sector included the amendment of the CEB Act in 2016 through the Finance (Miscellaneous Provisions) Act to simplify and accelerate the licensing process for installations of less than 2 MW, an annual allowance of 50% on capital expenditure incurred on renewable energy technology equipment and a tax exemption on interest income earned on debentures or bonds issued to finance renewable energy projects. In support of RE connectivity, the government developed *Grid Code for Small Scale Distributed Generation* (SSDG) which was adopted to ensure compliance of installations in line with the requirements of the Grid Code, feed-in tariff scheme and other related issues regarding SSDG and deployment of renewable energy systems (MEPU, 2019, p 10).

6.8 Net metering in Namibia

Namibia's White paper of 1998 and Electricity Act of 2007 outline the challenges facing RE technology adoption into the main grid. In 2010, the Namibian Energy Regulatory Framework proposed market interventions such as RETS (REFIT, quotas, tax credits or grants). In 2016, Namibia's Electricity Control Board (ECB) embarked on an exercise to provide new rates applicable to PV systems installed under the net-metering scheme aimed at accommodating installations of up to 500kW. The purpose of the scheme was to spur the development of commercial and residential PV across the country (IRENA, 2017).

The ECB was the custodian of the net metering scheme which specified that rates would not be paid in monetary terms but had to be used for intended avoided cost. Under the scheme, power consumed by solar PV owners would be credited at the equivalent of the avoided energy cost of Namibian Power (NamPower - the national electricity utility). IEA (2019) highlights

net metering article 7 of ECB regulation which states that a customer/prosumer did not need to obtain a distribution license under the net-metering scheme. The ECB was required to provide the customer-generators electricity services at non-discriminatory rates (concerning rate structure and retail rate components) and monthly charges as per the retail tariff schedule shown in Table 6.3.

The net metering mechanism thus authorised the injection of surplus power into the local grid until 15% of the maximum demand of the main feeder line serving a specific group of customers is reached. Even though the scheme placed a cap on energy exported to the grid by prosumers, it also aimed at ensuring grid stability. In 2016, Namibia's net metering rules were promulgated into law mandating distribution companies to offer opportunity to customers with less than 500kW capacity to supply surplus power to the grid on the basis of tariffs shown in Table 6.3.

Table 6.3: Approved net metering tariffs under Namibia's distributors (Source: Bellin, 2017, p 15)

Schedule of Approved Tariffs 2016/2017 (Avoided Cost for Net Metering)							
	High Season			Low Season			All Seasons
	Peak	Standard	Off Peak	Peak	Standard	Off Peak	Non-ToU
	N$/kWh			N$/kWh			N$/kWh
Aranos TC	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Cenored (Pty) Ltd	2.29	1.37	0.92	1.39	1.11	0.69	1.13
City of Windhoek	2.26	1.35	0.91	1.37	1.09	0.68	1.13
Erongo Red (Pty) Ltd	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Gobabis Municipality	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Karasburg Municipality	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Keetmanshoop Municipality	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Klein Aub	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Luderitz TC	2.29	1.37	0.92	1.39	1.11	0.69	1.12
Mariental Municipality	2.29	1.37	0.92	1.11	1.11	0.69	1.12
Nampower Distribution	1.11	1.11	1.11	1.39	1.11	1.11	1.11
Nored (Pty) Ltd	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Okahandja TC	2.29	1.37	0.92	1.39	1.11	0.69	1.13
Oshakati Premier electric (Pty) Ltd	2.29	1.37	0.92	1.39	1.11	0.69	1.12
Rehoboth TC	2.29	1.37	0.92	1.39	1.11	0.69	1.12
Regional and Village Councils	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Roshkor	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Farmers Schemes	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Witvlei VC	2.29	1.37	0.92	1.39	1.11	0.69	1.13

Another policy mechanism introduced by the Ministry of Mines and Energy (MME) is the Solar Revolving Fund (SRF) aimed at providing credit facilities to facilitate demand for renewable energy technologies, particularly for people living in off-grid regions as well as municipal customers. The fund is a component of the Off-Grid Energization Master Plan for

Namibia (OGEMP), whose primary goal is to enable communities located far-off from the national grid to access relevant generation technologies for their electricity services.

6.9 Sub-findings and conclusion

The sub-findings on sub-question 3 relate to the key attributes and outcomes of the policy and regulatory interventions towards smart grids and net metering in relation to the adoption of DG for the respective case study countries. Each country's policy and regulatory interventions are correlated with relevant DG-outcomes. The sub-findings are consolidated into the key themes highlighted in Table 6.2.

The case studies reveal diverse reasons for grid infrastructure upgrades towards smart grid while also highlighting that it is not necessarily motivated by the desire to accelerate the adoption of DG. In particular, the case studies show that the overall policy goal was to integrate RE into the energy mix through deploying RE as a vital part of accelerating transformation towards net zero-emission.

Even though some case study countries provided supportive fiscal policies to accelerate DG, most of them prioritised smart grid and net metering policies in order to manage grid stability and security while also requiring respective utilities and distributors to buy from DG. In light of the successful policy interventions, broad RE targets were imposed on the utilities and distributors with climate change mitigation commitments in mind.

This section consolidates sub-findings based on a comparative evaluation of DG-impacts/outcomes versus smart grid and net metering policies and period of interventions, key challenges/constraints targeted by specific policy and consolidation of key policies and regulatory interventions across case studies. One of the overall findings is that systematic/responsive policies and interventions are critical in the transformation towards smart grid and net metering across the case study countries.

Table 6.4: Summary of sub-findings on smart grid and net metering policies towards promotion of DG

Case study and respective intervention period	**Key challenges/constraints targeted**	**Overall Policy and regulatory interventions**	**Specific smart grid and net metering element /scope of interventions relative to DG**	**Specific DG adoption outcomes and key insights on enhancing DG adoption/ Scaling up**	**Consolidation of key sub-findings across all case studies**
Smart grid and DG adoption in Germany (2000 – 2017)	• Local and regional air pollution caused by fossil-fuelled power generation • Limited access to the grid by DG operators • Lack of financial incentives to adopt DG for operators • Variability of distributed generation	• The Renewable Energy Act of 2000 • Energy Concepts of 2010	• Promote equal grid access for DG • Implementation of a 20-year feed-in tariff backed by surcharge on retail consumption. • Communication protocols for grid operators • Compensation framework for lost DG production not fed into the grid	• Increase in DG production capacity (from 12GW in 2000 to 112GW in 2017) • increased number of private DG operators • Increasing cost of electricity due the surcharges for supporting DG • Establishment of a competitive trading market for RE • Compensation for lost DG production • From 6% to 36% in DG adoption by 2017	• Policy evolution relative to DG outcomes • Key challenges targeted by policy and regulatory interventions • Specific policy and regulatory interventions relative to DG • Overall perspective on policy and regulatory

Case study and respective intervention period	Key challenges/constraints targeted	Overall Policy and regulatory interventions	Specific smart grid and net metering element /scope of interventions relative to DG	Specific DG adoption outcomes and key insights on enhancing DG adoption/ Scaling up	Consolidation of key sub-findings across all case studies
Smart grid development and energy sector reforms in Mexico (1992 -2021)	• Inadequate grid access by 1.42% of population • Heavy reliance on fossil-fuels for electricity generation • Distribution inefficiencies such as technical and non-technical losses • Lack of customer participation	• Electricity Industry Law (2014) • Energy transition laws (2015) • PRODESEN Act of 2017	• Modernisation of grid infrastructure to accommodate DG • Grid extension to remotely located population and use of SG to integrate DG • Diversify the wholesale market • SG as enabler to achieve 35% of clean energy generation by 2024	• Opening of market for IPPs • 11.4 GW allocated capacity for solar-based technologies • Deployment of AMI to reduce losses and engage customers • Clean energy sources energy-mix target of 25% • New models for clean energy generation such as RE auctions • New models for cleaner generation deployments (i.e., RE Auctions) • Creation of whole/ bulk power market • Certificates for cleaner energy	interventions versus DG outcomes.
Smart grid and RE integration in India (2005-2013)	• Lack of grid capacity to accommodate DG • Technical risks (cybersecurity, ICT issues such as	• Smart Grid Vision and Roadmap • National Smart Grid Mission	• Promotion of renewable energy generation capacity from 65GW to 100GW by 2022	• Introduction of Generation Based Incentive (80% depreciation allowance for RE developers)	

Case study and respective intervention period	Key challenges/constraints targeted	Overall Policy and regulatory interventions	Specific smart grid and net metering element /scope of interventions relative to DG	Specific DG adoption outcomes and key insights on enhancing DG adoption/ Scaling up	Consolidation of key sub-findings across all case studies
	coordination, grid stability concerns) • Inefficient use of RE /storage issues (customer using grid as storage) • Metering and billing inaccuracies	• Nehru National Solar Mission •	• Bundling of solar generated electricity for sale to the grid	• 20% subsidies to promote public-private partnerships (PPP) for RE development • Integration of RE technologies to the grid? • Grid stability and reliability •	
Rehabilitation of Eletrobras (Brazil) Distribution Network (2008 – 2010)	• Non-technical distribution losses • The high level of uncertainty brought by intermittent sources • The prospect for Demand-Side Management (DSM) strategies and storage technologies	• Funding for infrastructural development • National Electrical Energy Conservation Program • Mandatory rollout of smart meters policy	• Increased DG adoption • Regulations for new business models (allow participation of DG) • Improved R&D through smart grid pilot projects •	• RE tariff schemes focusing on household consumers • Quality standards for ICT to incorporate RES • Achieved 162.8GW of which 83% is from RES in 2018 • Time of Use (TOU) tariffs for electricity to reduce the peak demand	

Case study and respective intervention period	Key challenges/constraints targeted	Overall Policy and regulatory interventions	Specific smart grid and net metering element /scope of interventions relative to DG	Specific DG adoption outcomes and key insights on enhancing DG adoption/ Scaling up	Consolidation of key sub-findings across all case studies
	• Lack of access/tariffs to grid/tariffs due to natural monopoly • Inadequate billing systems	• National development policy for smart grid industry			
Net metering systems in Mauritius (2014-2019)	• Energy security and reducing reliance on imported fossil-fuels	• Small-Scale Distributed Generation-Net Metering (2014 - 2018) • Medium-Scale Distributed Generation –Net Metering (2014-2018) • Green Energy Small –Scale Distributed	• Integration of DG into grid • Encourage investment in RE by domestic/household, cooperatives and industry • Target 40% RE contribution in the electricity mix by 2030 (Global target is 30-36% by 2030)	• 21.7% RE contribution to the energy mix in 2018 (as compared to 5.5% and 8.1% in 2014 and 2016 respectively) • Net-metering credit in kWh • Tax rebates on purchase of DG equipment • Equal grid access • Increases in generating capacity from 18MW in 2014 to 95MW in 2018 • Simplified licensing process • Development of grid codes	

Case study and respective intervention period	Key challenges/constraints targeted	Overall Policy and regulatory interventions	Specific smart grid and net metering element /scope of interventions relative to DG	Specific DG adoption outcomes and key insights on enhancing DG adoption/ Scaling up	Consolidation of key sub-findings across all case studies
		Generation (2014-2018)		• 25,000 households connected	
Net metering in Namibia (2016-2019)	• Net metering scheme (2016-2019) • Solar revolving fund (SRF) (2016-2019)	• No licencing requirements for DG operators • Non-discriminatory net-metering rates • Credit facilities for DG investments	• Increase in share of RE in energy mix from 244MW to 431MW • Lack of financial resources to acquire DG units	• Developed grid codes for Small Scale Distributed Generation • Cap on RE fed to ensure grid stability (15% maximum demand) • Off-grid solar investments	

6.9.1 Period of policy evolution relative to DG outcomes

Table 6.5 is summary on the various policy initiatives undertaken in each country and the amount of time it has taken for the policies to evolve and achieve the set DG outcomes. The key finding under this theme is the transformation to a smart grid is mainly an evolutionary rather than a once-off process built from scratch. For example, it has taken Germany more than 20 years to finally embrace smart grid primarily because of evolutionary policies such as EEG for market unbundling to facilitate participation levels from a mere 150 to around 2 million RE generators.

Table 6.5: Summary of policy evolutions relative to DG outcomes

Country	Policies adopted and dates of implementation
Germany	• Germany introduced feed-in-tariff for RES in 1991, which was later succeeded by the Renewable Energy Act (EEG) of 2000. • In 2003, Germany responded to the EU directive that required all EU countries to achieve legal binding on unbundling of accounts, operations, and information necessary for electricity transmission and distribution grid operators and to make them independent from each other. The response to the directive led Germany to introduce the smart grid and smart market with differentiated regulatory frameworks. • In 2012, Germany Academy of Sciences and Engineering, in collaboration with BNetZA and Alcatech, introduced a new smart grid model for Germany called the future grid (FEG). By 2016, Germany registered significant growth in onshore wind farms and solar PV farms which was attributable to EEG Act on liberalisation of the electricity market.
Mexico	• Power sector reforms which saw the introduction of IPPs into the electricity sector started in 1992. By 2013, Mexico responded to the growing adoption of DG by enacting the Electricity Industry Act, which became law in 2015. • Another key legislation was the introduction of articles 37 and 38 in the Ley de Transicion Energetica (LTE) law in 2017 to take care of Mexico's goal on clean energy by 2024. SENER also issued the PRODESEN Act for the period 2015 to 2032 to facilitate smart grid development plans and the expansion of DG generation.
India	• In September 2013, a national smart grid and renewable energy generation integration plan was launched, with national rollout up to 2027.

Country	Policies adopted and dates of implementation
	• The national smart grid initiative became a reality in 2015 under the Ministry of Power (MOP), and after that, guidelines for implementation of integrated pilot technologies in major urban areas were issued. The entire smart grid rollout was projected to start in 2017 and expected to be completed in major urban centres by 2022. It envisioned a transformation of the power sector into a secure, adaptive, sustainable, and digitally-enabled ecosystem that provide reliable and quality energy while also facilitating active participation of all RE generators. The plan also included major fiscal policy initiatives such as the generation-based incentives (GBI) scheme which allows for up to 80% depreciation for independent power producers (IPP).
Brazil	• In 2010, all-electric utilities began studying and preparing themselves for transitioning to a smart grid. In 2011, the country initiated an R&D on intelligent grid project to guide the national plan for migration of its distribution networks in stages towards full adoption throughout the country by 2030. In 2013, Brazil's largest utility, AES Eletropaulo, launched its smart grid systems by installing 60,000 smart meters. • In 2010, World Bank provided financing towards rehabilitation of Brazil's six electricity distribution networks. Smart meters were deployed by the end of 2014 and expected to achieve over 75% of penetration by 2030.
Mauritius	• In 2015, the government set a target of 35% of renewable energy towards its energy mix which also primarily aimed at diversifying from imported fossil fuels – mainly coal and oil. • This approach allowed Mauritius to introduce responsive fiscal and infrastructure policy instruments to support smart grid development. Policy instruments included net-metering roll-out schemes targeted at diverse investment groups, including co-operatives and property developers. Mauritius also introduced grant funding towards small-scale solar generation aimed at incentivising expedited adoption of residential solar PV.
Namibia	• Namibia Electrical Control Board (NECB) introduced special rates under the net metering scheme (SSDG) in 2016 to accommodate commercial and residential solar PV. The purpose was to incentivise the export of at least 15% surplus from RE into the grid without the need for feed-in-tariffs because the cost of installation would be subsidised through a solar-revolving fund (SRF). This policy was targeted for municipal customers as well as those living in off-grid regions. The implementation of the net metering rules has resulted in high consumer-level Small-Scale Distributed Generation (SSDG) and the modification of the single buyer model (MSBM) (phase 1 and 2) to facilitate the liberalisation of the electricity market.

6.9.2 Comparative dynamics of smart grid and net metering development

Depending on country characteristics and economic situation, smart grid and net metering vary in development. This is influenced by the business model and regulatory approach adopted at each stage towards liberalisation of the energy market. Similarly, the technology aspects have been similar by firstly focussing on key aspects of supportive policies aimed at encouraging DG. In these multi policy scenario case studies, there was focus on Research and Development (R & D) to guide national planning and capacitate distribution networks towards full adoption throughout the country. The case studies also showed that the level of economic development can mitigate key challenges arising from lack of grid access and funding which normally constrain scaling up of DG adoption.

Given these motivations, countries reviewed put up measures to achieve a fair share of RES into energy mix. The policy instruments that were adopted included net metering schemes, grant funding, carbon credits and various incentives for residential solar PV. These policy shifts were mainly targeted at removing barriers to level the playing-field such that small-scale generators could compete with existing centralised utilities. Guided by clear vision and mission, policies and roadmaps spearheaded the smart grid development over the extended evolutionary periods. In contrast, the electricity sector relies on the state-supported and monopoly-shielded utilities to guide the adoption of smart grids and net metering systems.

6.9.3 Specific policy and regulatory interventions relative to DG

One of the characteristics of the historical electricity sector is that it usually entails a highly regulated market whose operations are shrouded by complex regulations and policies. This has helped to sustain monopolistic market structures where centralised generators are also the power transmitters, and in some countries, the distributors as well, thus distorting the playing-field. Specific policy and regulatory interventions therefore need to be implemented towards liberalisation and opening up of the sector to facilitate the penetration of DG into a country's energy mix. Table 6.6 provides a summary of the key policy and regulatory initiatives adopted to scale up DG.

Table 6.6: Summary of policy and regulatory interventions adopted for DG

Country	Specific policy & regulatory intervention relative to DG
Germany	The Renewable Energy Act of 2000 focused on long-term strategy to achieve net-zero emission by 2050. This in turn created opportunities for maturation of various RE technologies (wind, solar farms and biogas) from 1980 to the 1990s. The diverse RE technologies were key factors for smart grid roll-out projects since 2015 under the country's utility NetzBW Gmbh and smart metering company (Landis+Gyr) with significant financial support from the German Federal Ministry of Economics.
India	The government introduced the Generation Based Incentive (GBI), which provided a depreciation allowance of 80% for infrastructure investments into RE development. The GBI was further supported by a 20% subsidy on Public-Private Partnership for RE development projects and thus became a key catalyst towards a national RE-generation capacity of 100GW by 2022 (see Section 6.7.1). The two policies were meant to shorten the payback period for investments towards acquiring DG installations.
Mauritius	Mauritius offered a cocktail of incentives such as the deductibility of DG installation costs from income tax returns, access to low-interest loans from local banks and exemption from value-added tax on DG equipment.
Namibia	Namibia revoked the licencing requirement for DG operators because their unit sizes were deemed to be insignificant in relation to negatively impacting on grid performance. With approved feed-in-tariffs (as shown in Figure 6.3) provided favourable conditions for DG adoptions. However, the Namibian markets are still in the early developmental stages and require a lot of government commitment (political will) before both countries can achieve fully liberalised electricity markets.

6.9.4 Overall perspective on policy/regulatory interventions versus DG outcome

From the case studies reviewed, supportive government policies and regulatory interventions constitutes a key factor in facilitating DG adoption. The policies were further supported by opening access to the grid in a non-discriminatory manner to signify evolving electricity market and the end of the centralised generation legacy operated on a monopolistic market model. While opening the grid to all players has ensured a competitive wholesale market, it also requires competent regulators to enforce the regulatory provisions in order to foster trust amongst industry players.

The policy reforms for each country were dependent on the country's respective objectives and stage in the market liberalisation process. The primary aim amongst countries adopting DG was to promote the adoption of RE-generation at diverse scales. The German market has been transforming for the last 20 years and serves as a demonstration of systematic benchmarking across the evolutionary pathway towards ultimate liberalisation of its electricity market. Currently, it enjoys a highly advanced electricity market with numerous players, is heavily regulated to ensure that the established players (with financial resources) do not manipulate the market and force the small players out of business. Germany's example shows that undertaking grid modernisation interventions such as smart grids require commitment from the government in collaboration with the private sector in order to ensure the required long-term capital investment.

The other case study markets are still at varying stages of their market liberalisation pathway towards smart grids and increased levels of DG adoption, which thus requires consistent government intervention to tilt the playing-field in favour of emerging players. Germany's outcomes show that compensation policies for energy from DG operators require supporting regulatory mechanisms to give certainty towards planning and investment for DG. For example, the evidence in Germany indicates that the use of 20-year feed-in tariffs enabled a sharp increase in the number of DG operators from a mere 150 to two million and a generation capacity of 112 GW by the end of 2017.

7 OVERALL FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter consolidates the sub-findings on the three sub-questions addressed in Chapters 4 to 6 in order to answer the main research question, which sought to establish the significance of smart grid and net-metering systems in promoting DG in CoE. The sub-findings on the first sub-question were consolidated according to the following key parameters:

- Internal CoE constraints
- National-level electricity sector constraints
- Prosumer-side constraints

The sub-findings on the second sub-question were consolidated according to the following key relevance categories:

- Addressing distribution challenges
- Facilitating promotion of SSEG
- Significant overlaps across the two categories.

The sub-findings on the third sub-question were consolidated according to the following key themes:

- Period of policy evolution and implementation
- Key challenges/constraints targeted
- Specific policy and regulatory interventions versus smart grid and net metering scope of interventions relative to DG
- Synthesis of perspectives on policy/regulatory interventions versus DG-outcomes

As summarised in Table 7.1, the overall findings were consolidated based on the overall implications of the sub-findings towards the adoption of DG for CoE. The chapter finally concludes with the presentation of the findings on the overall research question as well as recommendations for further research.

Table 7.1: Summary of sub-findings and implications on overall research question

Research sub-question	**Sub-findings on theme / parameter 1**	**Sub-findings on theme / parameter 2**	**Sub-findings on theme / parameter 3**	**Key implications of sub-findings relative to overall research question**
Sub-question 1: What are the key constraining factors inhibiting the adoption of DG within CoE?	**Internal CoE constraints** • Fragmented municipal policy framework • Aging grid infrastructure • Lack of local technical expertise	**National-level constraints** • Lack of coordinated national policy/ regulatory framework for electricity market • Lack of financial resources for infrastructure upgrades	**Prosumer-side constraints** • Operational inefficiencies on installed CoE DG plants • Absence of feed-in tariffs for prosumers within CoE	Policy dilemma and aging grid/network infrastructure is hampering the scaling up of SSEG. Investment towards a modern grid would unlock the current grid supply constraints within CoE by safely and stably accommodating grid-integrated DG
Sub-question 2: What is the significance of smart grids towards addressing CoE's distribution challenges while also facilitating the promotion of DG?	**Addressing distribution challenges** • Reduction of non-technical losses • Security of grid infrastructure • Reduction in infrastructural maintenance costs	**Facilitating promotion of distributed generation** • Implementing a compensation framework for prosumers • Optimising power demand and supply • Enhance operational efficiencies	**Significant overlaps between the two** • Dealing with variability and intermittency of DG • Maintaining quality of power supply • Scheduling of power production and dispatch	• Reliance on conventional grid infrastructure leads to high losses of around 12% per annum on electricity bulk purchases. A smart grid is vital in reducing distribution losses and managing the high variability and intermittency of RES which most DG installers are likely to adopt.

Research sub-question	Sub-findings on theme / parameter 1	Sub-findings on theme / parameter 2	Sub-findings on theme / parameter 3	Key implications of sub-findings relative to overall research question
Sub-question 3: How can the regulatory and policy framework be enhanced to expedite implementation of smart grid systems for facilitating scale-up of grid-interactive DG?	**Period of policy evaluation and implementation**	**Key challenges / constraints targeted**	**Specific policy and regulatory interventions**	Harmonisation of policies and regulatory interventions is critical to promote DG. Promoting access to the grid and implementing supportive fiscal policies to reduce DG costs has been critical in accelerating DG
	Germany (2000 – 2020)	• Limited access to the grid by DG operators in Germany • Reduction of nuclear use in the energy mix	• Prioritisation of grid connection to RE-based DG operators • Implementation of 20-year feed-in tariffs	
	Mexico (1992 – 2032)	• Limited grid access • Aging grid infrastructure operated by state-owned utility (monopoly) • Heavy reliance on fossil-fuels in electricity generation	• Restructuring of power sector to attract IPPs • Grid modernisation and allocation of 25% generating capacity to RE sources	
	India (2013-2027)	• Lack of grid capacity to accommodate DG • Technical risks of integrating DG • Metering and billing inaccuracies	• Introduction of fiscal incentives for RE investments • Creation of an aggregator (bundles) for solar generated electricity	
	Brazil (2010 – 2030)	• High incidences of distribution losses	• Installation of smart meters • Increased DG adoption	

Research sub-question	Sub-findings on theme / parameter 1	Sub-findings on theme / parameter 2	Sub-findings on theme / parameter 3	Key implications of sub-findings relative to overall research question
	Rehabilitation of Eletrobras Distribution Network	• Electricity theft • Lack of access/tariffs to grid/tariffs due to natural monopoly • Inadequate billing systems	• Regulations for new business models (allow participation of DG) • Improved R&D through smart grid pilot projects •	
	Namibia (2016 – 2019) Implementation of net metering systems	• Absence of incentives for grind-interactive DG • Power shortage • Increasing demand for SSEG	• No licensing requirements for DGs • Non-discriminatory net-metering rates	
			• Credit facilities for acquisition of DG units	
	Mauritius (2014 -2019) Implementation of net-metering systems	• Enhance energy security by increasing RE generation by residential and commercial customers • Reduce reliance on imported coal/gas for power generation	• Implementation of net-metering system to incentivise prosumers • Fiscal incentives targeted to reduce the cost of solar PV equipment • Development of grid codes to guide grid access and connections	

Research sub-question	Sub-findings on theme / parameter 1	Sub-findings on theme / parameter 2	Sub-findings on theme / parameter 3	Key implications of sub-findings relative to overall research question
Main Research Question: What is the significance of smart grid and net-metering technologies towards the promotion of grid-interactive DG for municipal utilities in South Africa?	Extreme challenges in grid supply, infrastructure constraints and operational inefficiencies are driving CoE's distribution network towards a point of dysfunctionality and possible collapse. This calls for an urgent and radical upgrade of the infrastructure towards smart grid and net-metering, especially when revenue erosion concerns are factored into the equation. There has been slow adoption of DG in CoE (and South Africa in general) compared to countries such as Germany where smart grid and related technologies have been under implementation for almost two decades. Brazil also offers insights into the capabilities of smart grids in addressing distribution losses similar to those currently experienced by CoE while also facilitating integration of DG. The harmonisation of policies and regulations is a key complementary intervention in smart grid development strategy, where accommodating DG would be a key driver of the policy reform. This has been effective towards facilitating feed-in tariff expectations as well as the balancing of loads within the distribution network in a cost-efficient way. **OVERALL FINDING**: Even though smart grid upgrade can be motivated on the basis of mitigating the prevailing distribution grid dysfunctionalities under municipalities in South Africa without having to factor in DG, it is also clear that grid supply based on centralised generation has entered a new phase where its cost-effectiveness and security of supply have been challenged primarily due to inability to keep up with demand (with perpetual load-shedding as a key outcome) as well as tariff escalation beyond inflation rates which has rendered DG economically competitive and increasingly attractive for prosumers and other investors. This puts the business model of distribution network operators (primarily municipalities in South Africa) at risk due to perpetually declining volume of sales which contributes to erosion of revenue over time. This would in turn mean inadequate budgets for maintaining the grid to ensure operational integrity through mitigating the key contributing drivers to ongoing dysfunctionalities. Increased adoption of DG towards mitigation of these constraints, as well as for the enhanced exploitation of RE resources, necessitates the upgrading of the distribution grid to ensure improved real-time load management (especially given RE-intermittency), grid security/safety and transparent administration of a fair feed-in-tariff scheme by the distribution network operator.			

7.2 Aging grid infrastructure and related electricity losses call for expedited smart grid upgrade in CoE

Extreme challenges in grid supply, infrastructure constraints and operational inefficiencies are driving CoE's distribution network towards a point of dysfunctionality and possible collapse. This in turn calls for an urgent and radical upgrade of the infrastructure towards smart grid and net-metering, especially when revenue erosion concerns are factored into the equation. Policy gaps and aging grid/network infrastructure in CoE is also hampering the scaling up of SSEG. Investment towards a modern grid would unlock the current grid supply constraints by safely and stably accommodating grid-integrated DG. Appraisal of international experiences revealed that a policy and regulatory framework on RE and infrastructure development addresses critical inhibitory factors contributing to operational inefficiencies and lack of progress on implementation of DG in CoE, with the delays on LREIPP as one of the clear examples. These policy initiatives must be documented in the IDP and be given the required political prioritisation for implementation as demonstrated in countries such as Mexico and Mauritius.

Given that current grid supply constraints are likely to persist over the medium term due to falling generation capacity by Eskom, this will continue impacting negatively on municipal revenues where electricity sales are already in perpetual decline. Growth of DG can be an alternative solution to plug the current generation shortfall from centralised Eskom and large-scale IPP plants. In Germany, prosumers became a key component in electricity generation due to incentivising through attractive policies which opened the grid and offered attractive 20-year feed-in tariffs. This was also enabled by implementation of a smart grid that provided distribution operators the means to manage a complex grid with diverse generators.

The policy framework, coupled with smart-grid upgrades, opened the pathway towards a liberalised market and by end of 2017, residential and commercial prosumers in Germany controlled more than 50% of the market and contributed to generation capacity of 112GW. Mauritius and Namibia also demonstrate a systematic policy approach towards net-metering technologies combined with other fiscal incentives to reduce the cost of RE-technologies in order to encourage distributed RE generation.

CoE is also experiencing operational inefficiencies as a result of an aging grid infrastructure and inadequate capacity, especially with regard to technical expertise. In addition, having concluded that non-technical losses constituted a large portion of the challenges threatening financial viability of CoE's electricity business, the USTDA (2013) feasibility report recommended a smart grid pilot project as a way to test its efficacy in reducing ongoing losses. Even though the recommendation was not implemented, a similar programme initiated by SANEDI in collaboration with other municipalities (but CoE declined to participate) concluded that operational efficiencies could be achieved through implementation of a smart grid. This is further substantiated in the Brazilian case where installation of smart meters improved operational efficiencies and security of the grid for six distribution utilities in the country.

7.3 Expediting adoption of DG through smart grid technologies and responsive policies

A smart grid is vital in reducing distribution losses and managing the high variability and intermittency of RES which most DG installers are likely to adopt. In Brazil, the implementation of smart meters jointly financed by the Government of Brazil and the World Bank resulted in distribution utilities improving their operational efficiencies and strengthening

their financial positions. The case also shows that smart grid implementation can be phased in and targeted at issues/factors contributing the most to operational inefficiencies. CoE can adopt a similar phased approach through accelerated installation of AMRs that have been identified to contribute positively towards enhanced revenue collection, detection of tampering and also entail capabilities to disconnect/connect supplies remotely. This approach can significantly reduce financial burden associated with infrastructure upgrades.

Even though there has been slow adoption of DG in CoE and South Africa in general compared to countries such as Germany where smart grid and related technologies have been under implementation/operation for almost two decades, the current growth of DG within CoE is likely to continue even in the absence of a smart grid for its distribution network. However, the municipal utility is unlikely to leverage the benefits of this growth due to capacity constraints on its distribution grid which makes it difficult for integrating grid-interactive DG in a safe and stable manner.

Countries such as Germany, India and Mexico prepared for massive injection of grid-interactive DG by investing in smart grids to manage the complexities associated with DG. Given the high number of illegal connections in CoE, deployment of a smart grid can self-report on a real-time basis all activities within the distribution network. It would also equip CoE with insights on dealing with the intermittency of renewable energy resources in order to maintain a balance between demand and supply. Other opportunities offered by a smart grid include ability to shift the load (peak shaving and valley filling), maintaining quality of power supply, security and overall reliability of the grid infrastructure as well as services. Increased adoption of DG can also minimize overall system losses based on the fact that loads would be closer to the generating units.

The appraisal of CoE in comparison with international experiences in Germany, India, Brazil and Mexico reveals that an aging grid is unreliable and unable to maintain a balance between supply and demand associated with DG. In conventional grid systems, a high load and intermittent supply from DG forces the distribution network to trip, and an operator would not know whether it was simply due to a circuit breaker tripping, an overheated/sagging cable or mere line-interference due to nearby obstructions. It might then take hours to confirm security and safety of distribution lines based on manual inspections. By contrast, the smart grid approach detects imminent overcapacity and takes immediate corrective actions depending on the grid conditions and pre-set artificial intelligence (algorithms) which facilitate automated balancing process.

The application of net metering by distribution level operators is not clear from a South African perspective due to the absence of related policies/regulations from the respective national government department (DoE) and regulators (NERSA). This has meant that municipal distributors are taking differentiated approaches and responses based on their isolated assessment of DG-risks versus opportunities.

Given ongoing electricity market dynamics and especially the increasing adoption of DG, CoE needs to urgently adopt a net metering scheme and incorporate it into local MSDF and IDPs to facilitate systematic roll-out. Mauritius and Namibia are regional examples that provide insights on the importance of net-metering schemes targeted at small-scale generators and

yielded an increase in contribution of RE to their energy mix by 35% and 15% respectively. The same critical lesson is provided from Germany and Mexico, where reforms eliminated the single buyer business model and thus liberalised their respective electricity markets.

7.4 Importance of policy harmonisation in smart grids development and DG adoption

The harmonisation of policies and regulations is a key complementary intervention in smart grid development strategy, where accommodating DG would be a key driver of the policy reform. This has been effective towards facilitating feed-in tariff expectations as well as the balancing of loads within the distribution network in a cost-efficient way. The study has established that developed countries are also at an advanced level of implementing smart grids and reflects that the state of electricity infrastructure is also linked to socio-economic development. Developed countries have been advocates of liberalized markets and their regulatory reforms are targeted at breaking their monopolistic utilities in favour of attracting other actors in the market.

From international reviews, Germany's lead in smart grid development can be attributed to a series of policy and regulatory transformations implemented over a period of close to two decades. On the other hand, developing countries like Brazil and India are in the initial stages (which include rolling out smart meters, developing compensation frameworks and AMI installations) which serve as the preparatory measures towards upgrading to a fully integrated intelligent grid network. The study also reveals that integration of DG has been one of the drivers for smart grid adoption thus facilitating the development of responsive policies, smart grid roadmaps and focused pilot projects.

Governments and public utilities at the forefront of developing smart grids are mainly motivated by the need to eliminate distribution losses and promote RE-based DG. While it is evident that regulatory and policy frameworks in developed countries have prioritized both large scale infrastructure development and RE generation, the study does not find a similar pattern in CoE or in South Africa generally. Instead, the few interventions now evident have been executed in a piecemeal approach. Germany utilities were pioneers in embracing the significance of DG in the energy mix of the country's overall generation as demonstrated by its implementation of a 20-year feed-in tariff scheme. This has brought certainty in planning for DG equipment while related smart grid investments by the government ensured ease of connection to the grid. The different stages, drivers, and regulatory policies relative to the smart grid have significantly influenced the new business model. The harmonization of the regulations and policies in the energy market has been a key element in encouraging adoption of DG by ensuring that diverse stakeholder-interests are aligned.

Policy instruments promulgated in the case study countries have led to the liberalisation of energy markets by removing conventional electricity market barriers which in turn allowed small-scale generators (households and commercial property owners) to break into a sector previously preserved for big players with significant capital muscle. Market unbundling in Germany and Mexico created competitive wholesale and retail markets. Further to liberalization, fiscal incentives have also been offered to support the development of the RE market by reducing the cost of DG units. Such policy initiatives are now under implementation in India, Mexico, Mauritius, Namibia and Germany. The establishment of net-metering

systems for small-scale DG operators in Namibia and Mauritius resulted in the liberalization of the wholesale market and overall disruption of the single buyer model.

With increased number of players in the market, governments have also been forced to create competent regulator entities to foster trust amongst industry players and ensure that markets continue to operate fairly. The role of regulators has been to interpret and enforce the regulatory provisions adopted by government in order to support its policy objectives. The findings also confirm that it takes a relatively long period for markets to mature. It took close to 20 years for the German market to reach maturity. Mature markets with several players are able to self-regulate to a greater extent, while nascent markets rely more heavily on government interventions to give policy directives on adopting DG as well as overseeing the compensation frameworks. After reforms, the large operators in Germany lost a significant portion of their market share due to their failure to innovate in order survive the growing disruption due to increasing adoption of DG.

Although the policy reforms in Germany were initiated at national level, the two major components that transformed the electricity industry were certainty of the compensation framework and guaranteed access to the grid which were implemented by distribution operators. This demonstrates that, as an electricity distributor, CoE can also benefit from implementing similar policies to incentivise prosumers to connect to the grid. Fiscal incentives such as the ones implemented in Mauritius are also critical in facilitating the acquisition of generating equipment and this demonstrates the multilevel interdependence between national and local governments.

7.5 Overall findings and conclusion

The objective of the study was to investigate the relevance of smart grid and net metering systems towards the promotion of DG adoption in CoE. From the summary of key sub-findings in Table 7.1, the study found that even though smart grid upgrade can be motivated on the basis of mitigating the prevailing distribution grid dysfunctionalities under municipalities in South Africa without having to factor in DG, it is also clear that grid supply based on centralised generation has entered a new phase where its cost-effectiveness and security of supply have been challenged primarily due inability to keep up with demand (with perpetual load-shedding as a key outcome) as well as tariff escalation beyond inflation rates.

This has in turn rendered DG to be economically competitive and increasingly attractive for prosumers and other investors, especially due to the ongoing cost reduction of related technologies such as PV systems. This puts the business model of distribution network operators (primarily municipalities in South Africa) at risk due to perpetually declining volume of sales which contributes to erosion of revenue over time. This would in turn mean inadequate budgets for maintaining the grid to ensure operational integrity through mitigating the key contributing drivers to ongoing dysfunctionalities. Increased adoption of DG towards mitigation of these constraints, as well as for the enhanced exploitation of RE resources, necessitates the upgrading of the distribution grid to ensure improved real-time load management (especially given RE intermittency), grid security/safety and transparent administration of fair feed-in-tariff schemes by the distribution network operator.

The current deployment of smart grids is also dependent on regulatory and policy transformations that encourage liberalization of electricity markets across the globe. The German experience is one of the good practice models that CoE can adapt towards developing and implementing its own comprehensive smart grid and tariff scheme. Germany's experience has proved that the power of centralised generation monopolies such as Eskom can be reduced with increased prosumer participation in the electricity markets. With the right policy frameworks, CoE can follow similar pathways and unshackle itself from Eskom's monopoly while also enhancing reliability and overall quality of services to its customers coupled with improved revenue prospects from its distribution operations.

7.6 Recommendations and suggestion for further research

International experiences indicate widespread small-scale smart grid pilot projects entail partnership with private sector while also facilitating enhanced grid capabilities to overcome obstacles related to operational optimisation and customer retention. Incorporation of small-scale generators in the pilot projects was also facilitated through RE integration, data management, grid-stabilisation and cybersecurity threats. A smart grid demonstration project could be an important gateway for the CoE towards management of increasing adoption of DG and elimination of inefficiencies (technical and non-technical losses). There is need to undertake further research on the amount of electricity that can be feasibly harnessed from current DG units and their overall contribution towards addressing prevailing demand-supply gap for CoE and other municipal distributor areas.

The study has presented different approaches in smart grid developmental stages which has critical influence in defining market needs and value proposition for distribution utility business. These approaches focussed on rooting out fraudulent activities, improving efficiencies and aiming at RE integration to the grid. Due to delimitation of scope, these approaches could not be specifically evaluated in this study. This calls for further enquiry to ascertain relevance of the interventions for South Africa's municipalities.

The study has focused on how smart grid implementation can influence the growth of DG under municipal utilities and finds that substantial financial investment as well as participation of several stakeholders would be critical factors in the process. CoE therefore needs collaboration and political mobilisation teams from economic developments, finance and other concerned departments to provide inputs towards successful transition. This would assist in guiding the formulation of appropriate responsive business model, political prioritisation and strategies to address critical constraining parameters across the value chain. The identification of the critical constraining factors and quantification of their impacts would facilitate the assessment of lost opportunities in terms of revenue enhancement and increased generation capacity under DG versus Eskom's constrained supply. Results can then be used to develop generation and consumption scenarios to inform alternative and sustainable business models in face of disruptive effects of increasing DG adoption.

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9 APPENDICES

9.1 **South African electricity generation capacity** (Source: Bello et al., 2015, p 2)

Energy Source	Existing Generation and 20-year Plan		
	Capacity (MW)	Energy (GWh)	Integrated Resource Plan (2011) MW
Coal Based	37,715	21,8212	6,250
Hydro-electric	661	1904	2,609
Pumped Storage	1,400	2,962	
Gas turbines	2,426	709	6,280
Nuclear	1,910	23,502	9,600
Renewable Energy	3.15	2	17,800
Total Capacity	44,115	237,291	
Foreign Imports		13,038	
Local IPP & Co-gen		4,107	

9.2 Integrated Resource Plan 2019 (Source: DME, 2021, p 42)

	Coal	Coal (Decommissioning)	Nuclear	Hydro	Storage	PV	Wind	CSP	Gas & Diesel	Other (Distributed Generation, CoGen, Biomass, Landfill)
Current Base	37 149		1 860	2 100	2 912	1 474	1 980	300	3 830	499
2019	2 155	-2373					244	300		Allocation to the extent of the short term capacity and energy gap.
2020	1 433	-557				114	300			
2021	1 433	-1403				300	818			
2022	711	-844			513	400 1000	1600			
2023	750	-555				1000	1600			500
2024			1860				1600		1000	500
2025						1000	1600			500
2026		-1219					1600			500
2027	750	-847					1 600		2000	500
2028		-475				1000	1 600			500
2029		-1694			1575	1000	1 600			500
2030		-1050		2 500		1 000	1 600			500
TOTAL INSTALLED CAPACITY by 2030 (MW)	33364		1860	4600	5000	8288	17742	600	6380	
% Total Installed Capacity (% of MW)	43		2.36	5.84	6.35	10.52	22.53	0.76	8.1	
% Annual Energy Contribution (% of MWh)	58.8		4.5	8.4	1.2*	6.3	17.8	0.6	1.3	

Installed Capacity
Committed / Already Contracted Capacity
Capacity Decommissioned
New Additional Capacity
Extension of Koeberg Plant Design Life
Includes Distributed Generation Capacity for own use

9.3 REIPPPP summary of expression in 2011 (Source: Bell et al., 2015, p 3)

Generation Technology	Independent Power Producers		
	Number of Projects	Interests (MW)	DoE REIPP (MW)
Wind	175	19,150	1,850
Solar Photovoltaic	374	14,466	1,450
CSP	25	2,409	200
Biomass	63	498	12.5
Biogas			12.5
Landfill			25
Small Hydro			75
Total	637	36,523	3,625

9.4 **REIPPPP awarded bids and response rates per each round** (Source: Montmasson-Clair and Ryan, 2014, p 4)

Awards (MW)	Initial Determination (2012-2016)	Second Determination (2017-2020)	Round 1 allocation	Round 2 Allocation	Round 3 Allocation
Wind	1850	1470	634	563	787
Solar PV	1450	1075	632	417	450
CSP	200	400	150	50	200
Small hydro	75	60	0	14.3	0
Landfill gas	25	47.5	0	0	18
Biomass	12.5	47.5	0	0	16.5
Total	3625	3100	1416	1044.3	1456
Bid responses received	N/A	N/A	53	79	93
Preferred Bidders	N/A	N/A	28	19	17
Success rate	N/A	N/A	53%	24%	18%

9.5 **Register of installed SSEG in CoE** (Source: CoE official, 2020)

NAME	ADDRESS	CAPACITY (kW)	DATE
Sunward Park Hospital	Kingfischer Av & Aquarius Bert Lacey Dr	350	Apr 10
Bell	27 Va der Stel, Rd, Albarante, Alberton	7	May 12
Bus Truck -Marketing	16 Wolverhampston	190	May 14
Alberton Mall	43 Clinton Rd, New Redruth	340	Jun 14
Danone Southern	99 Skew Rd, Andebolt, Boksburg	1500	Mar 15
Railway Truck Supply	23 Anvil Rd, Isando	350	Apr 15
Ebotse Golf Estate	63 Tawny Eagle, Rynfield 1514	4	Jun 15
Actom Pty Ltd	2 Magnet Rd, Knight, Germiston	993.7	Oct 15
Actom Pty Ltd	2 Magnet Rd, Knight, Germiston	382.2	Oct 15
Netcare N17 Hospital	7 Tonk Meter Drive, Pollak Park, Springs	435	Oct 15
Netcare Sunward park	Kingfischer Av & Aquarius, Boksburg	125	Jan 16
Medicross Pty Ltd	140 north rand Rd, Bardene, Boksburg	117	Feb 16
Emperors Palace	8 Jones St, Jurgens park, Kempton Park	1045	Feb 16
Redefine properties	Bentel Avenue, Boksburg	923	Mar 16
MICC Properties	1 Brickfield Rd, Germiston	200	Mar 16
Medcross Boksburg	140 North Rd, Bardeen Ext 1, Boksburg	117	May 16
Medicross Boksburg	41 Olivier St, Germiston	47.6	May 16
Medcross Boksburg	140 North Rd, Bardeen Ext 1, Boksburg	117	May 16
Peermont Global	8 Jones St, Jurgens park, Kempton Park	1546.8	May 16
Medcross Boksburg	41 Olivier St, Germiston	47.6	May 16
Casa Grande Industries	489 Pinnacle Rd, Tunney, Elandsfontein	275	Jun 16
Pioneer Foods Pty Ltd	7 Tile Crescent Clayville, Olifantsfontein	436	Jul 16
Choice Property	40 Thirteen Rd, Witpoort Estate AH	600	Jul 16
Distell	10 Marshall Rd, Springs	1400	Jul 16
Choice Property	40 Thirteen Rd, Witpoort estate AH	600	Jul 16
Peermont Global	8 Jones St, Jurgens park, Kempton Park	1546.8	Oct 16
Pioneer Foods Pty Ltd	1 Guthrie Rd, Germiston, Wadeville	450	Nov 16
PPG Pty Ltd	139 Tarry Rd, Alrode South, Alberton	139	Dec 16
Top Pronutro	Murray St, Wadeville Germiston	200	Dec 16
Tamk Quip	28 Barium St, Alrode	50	Jan 17
Wasa	6 Wolverhampton St, Apex, Benoni	250	Jan 17
Karaglen Shopping	48 Baker Road, Spartan, Kempton Park	50	Feb 17
Apple Mint	4 Tak Avenue, Chloorkop, Kempton park	140	Feb 17
EOH Business Park	Gillolys View. Osborne Lane, Berdfordview	220	Mar 17
Natchem CC	11 Bundo Rd, Sebenza, Edenvale	15	Apr 17
Dunrose Investments &	1 Francis Rd, Anderbolt, Boksburg	660	Jun 17
Cranbrook Flavour	16 spartan Kempton park	88	Jun 17
KSB Pumps & Valves	2 Activia Park, Germiston	90	Jun 17
Top Spar Group	117 Struwig St, Driefontein, Kempton Park	1400	Jun 17
Netcare Clinton	62 Clinton Rd, Alberton	221	Jun 17
Netcare Clinton	47 Clinton Rd, Alberton	70	Jul 17
Cranbrook Flavour	16 spartan Kempton Park	88	Jul 17

NAME	ADDRESS	CAPACITY (kW)	DATE
Frikkie Beukes	33 Euginea Rd, Edleen, Kempton park	7.2	Jul 17
Honing Craft	29 Dekema Rd, Wadeville	23	Aug 17
Speciality Metals	53 Main Rd, Eastleigh Rd, Edenvale	16	Aug 17
Farramere retail & trust	Kei & Klip Rd. Benoni	486	Oct 17
Whitaker	1 Scotts way, Bedfordview	12	Oct 17
Air Products SA Pty Ltd	4 Spencer St, Kempton park	175	Oct 17
Goring JWL	11 Fletching St, Kempton Park	10	Oct 17
Total SA	133 Monument Park, Kempton Park	25	Oct 17
Total SA	2 Reverrand Rd, Namane drive, Tembisa	2	Oct 17
Custom printing	14 Palmer St, Alrode, Alberton	20	Oct 17
Total Albermarle	Hartfield Rd, Germiston	51	Nov 17
Senderwood	2 Wordthworth Av, Senderwood Brakpan	64	Nov 17
Total Boksburg	35 Atlas, Rd, Anderbolt, Boksburg	39.24	Nov 17
Peermont Global	8 Jones St, Jurgens Park, Kempton Park	700	Nov 17
Langenhoven	45 Langenhaven St, Parkrand, Boksburg	4	Nov 17
Stay Bond EC Pty Ltd	22 Industry Rd, Clayville, Olifantsfontein,	198.4	Dec 17
Inhouse Trade Pty Ltd	9 Milne Rd, Spartan, Kempton Park	150	Dec 17
Auto & Truck Retread	5 Bezuidenhout Rd, Wadeville, Germiston	150	Dec 17
Atoll Mine Total	Main Reef Rd, Benoni	800	Dec 17
Cat Distribution Centre	Glen Marais, Kempton Park	150	Jan 18
Mpact Operations Pty	Dekema Road, Wadeville	900	Feb 18
CCBSA	Baksteen & Hammer Rd, Clayville Industrial	1000	Feb 18
YPH Properties	Moderfontein & Mastiff Roads	360	Feb 18
CCBSA Properties	3 Steenbrass Rd, Wadeville	750	Feb 18
Wilprp 31 Pty ltd	142 Michelson Rd, Boksburg	80	Feb 18
Elematic SA	Main Reef Rd, Modderfontein, Benoni	125	Apr 18
Eastpoint Mall	Rietfontein, north rand Road, Jansen Park.	995	Apr 18
Sapphire Cove	Putfontein & Cloverdene, Benoni	576	May 18
Evans	3 Adelpracht Place, Glen Erasmia, Kempton	4.6	May 18
Pretorius Stad Pty Ltd	46 dan Ellis Rd, Nigel	14	May 18
New Invest Pty ltd	195 North Rand Rd, Jansen Park, Boksburg	662.4	May 18
Skycity Mall	1709 Waterval Spruit, Alberton	700	Jun 18
EDS Properties	15 deodar St, Pomona, Kempton Park	110	Jun 18
Baldwin Properties	Sett St & Pretoria Rd, Boksburg	983	Jun 18
Jamella Trust	763 Meyersdal Nature estate	10	Jul 18
Ngwenya	44 Constance Rd, Berdfordview	5	Jul 18
Improvon Growth Fund	3 Merlin Rd, Lancaster Park, Parkhavern,	500	Jul 18
National Brands	71 Monteer Rd, Isando,	198	Jul 18
Serra services Pty Ltd	14 las Celles Rd, Meadowbrook, Germiston	25	Aug 18
Discuss House Pty Ltd	20 old Pretoria, Kempton Park	431	Aug 18
TOTAL INSTALLED		29,339	

9.6 Respondents' concerns/interest on SSEG (Source: Customer interviews 2020)

Respondent	Interview Question Guide	Response	Response	Response
Customer Generator 1 to 5	What household appliances do you regularly use?	Computer/TV/fridges/Radio 5	Kitchen/geyser/Water heater 5	Air conditioner/Fan 3
	What types of lighting bulbs are you using?	Incandescent 0	Fluorescent 2	CFL/LED 5
	How often do you review your monthly electricity bill?	Never 0	Once/few 5	Very often 5
	On monthly basis, how many times do you experience power cuts?	Almost daily 4	Almost weekly 5	Every 12 hours 3
	When does your solar PV benefit you most, is it during blackout or normal daily use?	During Blackout 2	During the day 3	At night 1

	Are you interested in energy savings/conservation measures such as smart grid?	Yes 5	No 0	Maybe 0
	If net metering policy can be adopted, would you be interested to connect your roof top Solar PV to the grid?	YES 5	NO 0	Maybe 0
	Who do you think would benefit most from SG adoption	Consumer 5	Municipality 3	Eskom 2

9.7 **Respondent awareness and attitude toward rooftop solar PV** (Source: Responses to customer interviews 2020)

Respondent	Description	Response	Response	Response
Customer Generator 1 to 5	Would you like to sell your excess electricity generated from your roof top PV to municipality/Eskom?	Yes 5	No 0	Maybe 0
	Did you register your solar PV power with the municipality?	Yes 4	No 0	In Progress 1
	Did you get funding for the solar power through any of the following - grants/loan/incentives/tariffs	Yes 0	No 5	In progress 0
	Do you wish municipality could provide subsidy for such installations?	Yes 5	No 0	Maybe 0
	Do you have or plan to have battery backup for your solar PV?	Yes 3	No 2	Maybe 0
	Will you be in interested in?	Net metering 5	Feed in tariff/Subsidy 5	Smart grid systems 5
	Do you believe coal generated electricity contributes to carbon emission and climate change?	Yes 5	No 0	Maybe 0

9.8 Interview Questions: Transcript of interview responses with CoE officials and industry experts

Sub-question	Transcripts of interview with CoE officials and industry experts
What are the constraining factors inhibiting the adoption of distributed generation within CoE?	• Briefly explain the status-quo of the current electricity grid distribution systems in the City and any challenges? **CoE-Official:** As you may be aware, the distribution systems emerge from the colonial era which faced serious challenges. The current distribution systems are experiencing power shortages due to increase in demand, electrical losses, aging grid network that requires extensive repairs and overhaul. ***1.*** *What is your comment on the penetration level of grid-interactive distributed generation?* **CoE-Official:** Installations have been happening at a steady rate. We have a database for those applying to connect to our grid network, however they are numerous installations that we are not aware of. We are only made aware that an installation occurred when a customer lodges a complaint in the event of a fault. In most of these cases, it is found

Sub-question	Transcripts of interview with CoE officials and industry experts
	that customers use wrong meters or are wrongly installed without following required installation standards such NRS-049 installations codes and it poses risk to our grid infrastructure. It has been noted also that customers use cheaper or unqualified installers to save on cost. In summary commercial customers are on the increase in installing solar PV to offset the cost of electricity and self-supply during power outage. **SEA-Official:** Something like 30 municipalities and all the large metros have developed export tariffs for grid connected solar PV. In general, the absence of tariffs along with the imposed costs of metering and sign-off render most residential installations economically unviable but commercial scale PV is currently a good investment under most current tariff conditions. Municipalities, in general, perceive distributed generation to be a threat to revenue but the discourse has changed to one of acceptance and are starting to prepare for the impacts as well as facilitating the technology within the legal and operational framework. The lack of municipal capacity is more of a barrier at small municipalities than willingness. **NERSA-Official:** The debate and discussion is ongoing to address the increasing demand for Distributed Energy Resources (DER). However, government policy is clear as set out in the IDP master plan on energy mix but regulations for integrating these DER are not yet finalized. ***2.*** *Is there is any perceived gap in policy and regulatory framework for wider deployment of grid-interactive distributed generations? Briefly explain?* **CoE-Official:** Yes, Installations are more widely adopted by the business sector and high earning individuals hence contributing to gap between the residential and business customers. However, the City has been on the drive to encourage distributed generation by installing rooftop solar PV (from 150KW- 1000MW) in accordance with NERSA

Sub-question	Transcripts of interview with CoE officials and industry experts
	SSEG regulation. It also plans to expand these installations in the next 3 to 5 years to set an example for wider communities and businesses at large. Currently, there are no available incentive policies such as feed-in-tariffs and any power purchase guarantee, however, the city guarantee interconnection as per NRS-049 regulation as we are still waiting from NERSA for SSEG regulations and tariff approvals. ***3.*** *Since you are witnessing growth in the adoption of distributed generation, how is this impacting municipal sales and revenue from electricity?* **CoE-Official:** Indeed, as a City we have to move quickly to counter declining electricity sales. As a City, [we] have thought of introducing fixed cost charges as long as customers remain on our grid network. For those who want to be off the municipal grid, they are welcome to do so provided they fill in applications to stop charges [accruing]. **Synthesised views of SEA/GIZ-SA/Other Experts:** The conversation is around utility business models and until a general approach is clearly established, including wheeling regulations and other supporting national policies, policy frameworks will vary greatly from one municipality to another depending on local capacity and ambition around related issues such as climate change mitigation goals. ***4.*** *In light of USTDA (2013) feasibility report on status of grid network and suggestion to implement smart grid systems, what is the status on the recommendations from the study?* **CoE-Official:** Nothing has happened since the report was issued and it has been business as usual. However, various reasons behind this can be established. One of the major issues is that smart grid is not priority for the City, and we take our mandate from our politicians who find it more reasonable to direct funds towards informal settlements electrification. To our knowledge no one yet has started to implement it in South Africa let alone our neighbouring

Sub-question	Transcripts of interview with CoE officials and industry experts
	municipalities. We have heard that City of Tshwane attempted to work on it but unfortunately it stalled all together. We would be encouraged by major developed countries such as Germany. ***5.*** *Several municipalities have introduced net metering policies to encourage distributed generation, are there any planned activities for CoE to follow suit?* **CoE-Official:** CoE is considering various tariff options and a study is underway to determine how the tariff will affect the revenue to get approval from NERSA for implementation. However, we are of the view stated by City Power, "that customer must not supply power to the City but [the] other way around". Therefore, we prefer net billing systems other than net metering. In addition, there is need to upgrade fleets of devices in the field to ensure an integrated system. To our knowledge, only Nelson Mandela Bay has a net metering approach to distributed generation. Like us, most municipalities opt for net billing rather (export is compensated at less than import costs).
What is the relevance of smart grids in promoting distributed generation and net metering for CoE?	***6.*** *Briefly explain the status-quo on the smart grid and net metering policy development?* **SANEDI-Official:** As mandated by DoE through the South African Smart Grid Initiative (SASGI), we have developed 2 strategies to address smart grid development which include: • immediate focus (improve network availability, security and accommodate renewable energy sources), • Medium to long term focus (self-healing, reliability, energy storage, reduce technical/non-technical losses, improve municipal revenue collections, facilitate customer participation). In terms of the status quo, we been implementing a smart grid pilot project involving various municipalities across the country to encourage them to adopt smart grid systems. The pilot project is mainly to improve efficiencies and

Sub-question	Transcripts of interview with CoE officials and industry experts
	active network management, AMI, asset management and enhancement of revenue generation in the participating municipalities. **GIZ-ZA-Official:** We have not started yet to engage municipalities in that direction of smart grid but soon we anticipate it. We are therefore arranging a department that will deal with that sector. However, there is a conversation around utility business models towards smart grid and distributed generation. Until a general approach is clearly established, including wheeling regulations and other supporting national policies, policy frameworks will vary greatly from place to place depending on local capacity and ambition around things like climate change targets ***7.*** *What has been your experience in these smart grid pilot projects? Briefly explain.* **SANEDI-Official:** As indicated about SG pilot projects, ten municipalities were invited to participate in the programme. One of them was the CoE, which unfortunately turned down the request. We anticipated that CoE will provide us best case study as it is regarded as one of the top performing metro areas in South Africa, and it was envisaged that through their participation, they would achieve a convincing business case to rollout smart grid. Municipalities were expected to attend four information sessions per annum and a majority never turn[ed] up. Municipalities are not even interested and make excuses; some are available at points when the discussion is about grants. Municipalities who took part, achieved a lot of efficiencies in terms of energy savings and improved revenue collections. However, am sorry I cannot diverge detailed results achieved as we signed confidentiality clauses. ***8.*** *How can the smart grid and net-metering systems contribute to municipalities in line with increasing adoption of distributed generation?*

Sub-question	Transcripts of interview with CoE officials and industry experts
	SALGA-Official: As a representative for municipalities on policy and regulation directives, we believe in smart grid systems as the modern and efficient way to incorporate distributed generation especially the roof top solar generators. It is also believed that we can harness more from smart grid as it improves grid network management systems. In South Africa, based on SANEDI reports, we are still at piloting and research stage until such time it is ready. We will advise our member municipalities to follow suit. As you may be aware, we are also still waiting for NERSA to finalize SSEG policy and will follow up on those regulations. The regulations might be the driver to encourage more installations of solar PV. **OUTA-Official:** As an advocacy/lobby group, we represent the voiceless and [prevent] abuse of public resources to benefit the masses. I have been at DoE/SANEDI before I came to OUTA and I understand bureaucracy in terms of policy implementation. I believe SANEDI is in the processes of conducting smart grid projects, please contact them and ask for the pilot project report as it will give you more information. We believe that DoE should start implementing smart grid and net metering systems if they want municipalities to be relevant. In addition, at OUTA, we have reservations on the delayed NERSA SSEG registrations which we believe is not fair and should be left to be handled by municipalities. **SEA-Official:** Large metros have many meters in the field. Cape Town has over 600,000 pre-payment meters. They need to install 70-100 per day just to keep up with meters reaching the end of their lives. So, it's not just a simple matter of switching technology. There are fleets of devices in the field in an integrated system. Only Nelson Mandela Bay has a net metering approach to distributed generation. Most municipalities opt for net billing rather [export is compensated at less than import costs]. There is not really a municipality constraint here as the metering technology

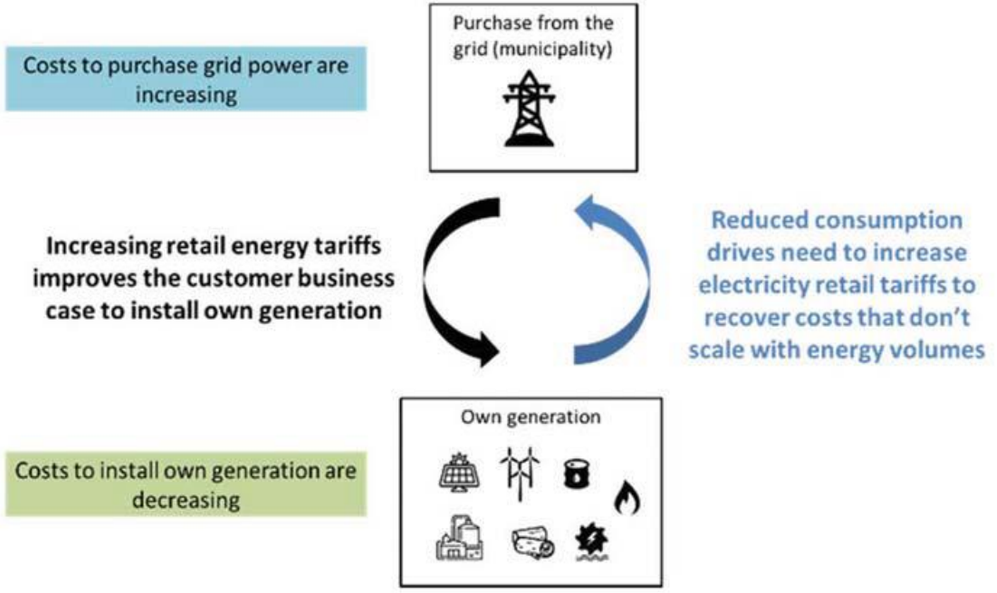
Sub-question	Transcripts of interview with CoE officials and industry experts
	is available and in common use. The imposition of expensive meters for the customers expense on residential customers is rather a constraint on adoption ***9.*** *With changing dynamics in the electricity utility market towards smart grid network, what has been your role to assist in driving the change?* **NERSA-Official:** I'm not at liberty to diverge much information in the space of smart grid systems. However, DoE/SANEDI is well placed to answer your question. At NERSA we regulate electricity tariffs to protect customers and we would embrace any innovative technologies that would enhance utility operational efficiencies **SALGA-Official:** In the current paradigm shift in the electricity market many decisions are made through [the] Ministry of Energy. However, the industry is moving forward in the absence of policies and rules. Evidence is that solar PV installations are on the increase and we hope so soon the Government will play a catch-up game. In the absence of [a] regulatory framework for smart grids, we anticipate that soon or later municipalities will start working on preparations. Some of them have already started installing smart meters which are an essential part for smart grid systems. We are actively conducting dissemination workshops and public participations in various municipalities on broad range of issues such as loss of revenue due to increasing demand for distributed generation. This is to mitigate many challenges by revising electricity business models in municipalities. **SANEDI-Official:** As an institute, our role is development and coordination of national utility and associated agencies to reduce barriers towards smart grid development. Whilst we have just finished conducting smart grid pilots, research studies and demonstration projects, it is still unclear on when they can be in force. Our concern is to make the benefits of a smart grid clear at this early stage and provide inputs to the development of the policy and

Sub-question	Transcripts of interview with CoE officials and industry experts
	regulatory framework. However, you see that the utility market size and the ubiquitous impact of the smart grid have attracted a large number of stakeholders with competing positions. We are in partnership with ISGAN to collaborate on power systems research and policy developments linking with various case studies. **SEA-Official:** From the onset, the approach is to start looking around utility business models to get general approach. Regulations around SSEG and wheeling regulations are drivers in supporting national policies and policy frameworks. I can understand why there would be a demand for solar PV generation services but not why there would be an intrinsic demand for smart grid itself except for niche and big customers. Generally, customers install DER presumably to get cheaper or perhaps more reliable energy services or in the case of some large developments because the utility is not in a position to expand the capacity of a connection. Some customers may feel they should produce green energy perhaps but much of this phenomenon may be driven by the marketing of solar contractors. If network grid electricity got very cheap because of cheap utility scale solar for instance, we might see distributed electricity penetration slow [down]. **FINANCIERS/DBSA-Officials:** On the conversation around utility business models, we used to have a policy and framework department to assist municipalities. These services were at no cost to municipalities which was later disbanded due to funding shortages. As a bank we work on profit motives wherever possible and treasury was supporting this initiative by assigning professionals actively involved in policy development. As stated, currently there is no clear path or intentions [on distributed generation]. Until a general approach is clearly established, people cannot wait for municipalities any longer that is why they continue in the absence of these regulation. However, DBSA does have various funding instruments accorded to municipalities. The DBSA supports and facilitates funding

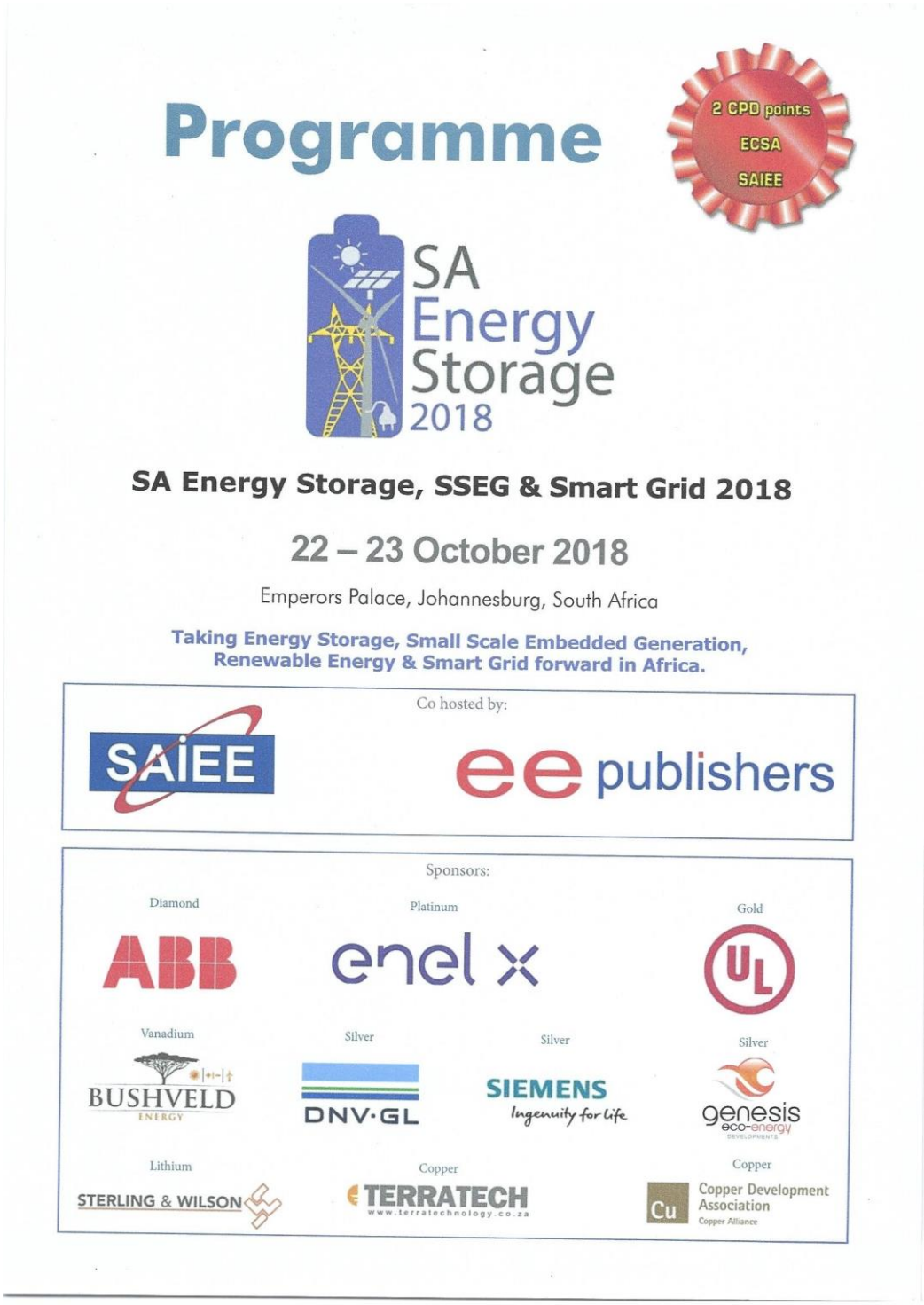
Sub-question	Transcripts of interview with CoE officials and industry experts
	for sustainable technology transitions through various instruments [such] as debt financing, mezzanine financing and limited no-recourse lending in collaboration with KfW Development Bank, the World Bank, National Treasury and various other financial powerhouses. The funding criteria follow various business models and structures. In some municipal funding, ring-fenced funds are used for special schemes such as feasibility studies, spatial planning frameworks, electrical distribution lines and efficiency challenges, such as reducing electrical losses. Grant funding is also possible from treasury side [and is] earmarked for infrastructure investment managed by DBSA. The grant funding can be in the form of interest rates subsidy, capital grant, and this type of funding is in excess of R100 billion in the form of CAPEX to municipalities. Funding from project surplus is set-aside to facilitate development and be 50% co-funding if the municipality projects are viable. Currently, no municipality came forward in terms of smart grid or electrical infrastructure upgrade
How can the regulatory and policy framework be enhanced to facilitate grid interactive distributed generation through implementation of a smart grid system and net metering systems?	***10.*** *What barriers are constraining CoE in the adoption of smart grid/net metering interventions?* **SANEDI-Official:** There is gap on the potential experiments to be tested under certain policy instruments which have been hampered by inadequate renewable energy regulations, monopolistic market structure and investments in the infrastructure upgrades. We should have rolled smart meters by now for all municipalities and that would have eventually reduced the influence of corrupt politicians. To fast-track policy implementations, we also share smart grid pilot projects with other municipalities to generate insights for rules and regulations. SEA-Official: Noted the following issues towards SG development • Energy and innovation policies have been identified to orchestrate complementary action • There is gap in pilot project funding of regulatory programs open to public

Sub-question	Transcripts of interview with CoE officials and industry experts
	• No intensity on research and innovation instruments (e.g. public funding of replication projects) • Absence of legislative measures (e.g. experimental clauses), coupled with innovation oriented regulatory bodies • Instruments of energy policy from DoE to allow regulatory bodies in facilitating smart grid pilot programs. • The lack of debate on the discourse and allocation of goals for regulatory bodies towards a balanced weight on long- and short-term societal benefits of energy systems • Government should establish the legislation as well as provide regulators with enough room for manoeuvre, which would allow them to become supportive actors within the innovation ecosystem, instead of being considered as hindrance. **CoE-Official:** We are financially incapacitated to rollout smart grid systems due certain regulations contained in MFMA Act. To that end, we are following development in the sector and actively looking for alternatives to adopt the smart grids. As a municipality we do not have much authority in policy discourse matters. For example, we have been protesting the heavy penalties imposed on us should the consumption exceed the limit allocated to municipality by Eskom. These limits are exceeded in most cases during power outages. We are still in the dark about policy directions. ***11.*** *What can be done to overcome barriers in the distributed generation policy and regulations and possible solutions?* **SEA/SALGA-Official:** In partnership with municipalities SALGA drafted energy efficiency and renewable energy strategy in 2013. The strategy provides clear guidance for the sustainable energy transition in South African municipalities. Some extracts of the “strategic priorities” of the strategy are as follows:

Sub-question	Transcripts of interview with CoE officials and industry experts
	• Good governance through the development of local, flexible and integrated energy plans and leadership that can engage in applicable national energy-related development planning • Efficient institutions able to manage energy consumption in their own facilities and operations and transform intelligent grid network • All households have access to affordable, safe and clean energy sources • Renewable energy options are a significant component of local energy supply where they are technically and economically feasible, contributing to low carbon development and local economic growth/sustainability • Sustainable electricity service delivery that can accommodate and promote access to electricity, efficiency and renewable energy development SEA/SALGA provided a summary of business model interplay between prosumer business case and utility tariffs to spur wide acceptance of DER

Sub-question	Transcripts of interview with CoE officials and industry experts
	

9.9 **South Africa Energy Storage/Smart Grid Conference Proceedings on 22nd and 23rd October, 2018: Emperors Palace, Johannesburg, South Africa.** (Source: SAIEE and EE-publishers, 2018)



SA Energy Storage 2018

Conference Programme: Day 1

MAIN CONFERENCE PROGRAMME: Emperors Palace, Assembly Room		
Day 1: Monday 22 October 2018		
07h30 to 08h15	Registration and refreshments	Exhibition
	Introduction	
08h15 to 08h30	Welcome: Chris Yelland, EE Publishers; Programme director: Bohlale Mathathe, Quantum Leap	
08h30 to 08h45	Opening address: Hon. Jeff Radebe, Minister of Energy	
	Morning Session 1	
08h45 to 09h15	Keynote address: Dr. Fereidoon Sioshansi, Menlo Energy Economics, USA: *"Electricity sector in transition: integration, service innovation and business disruption"*	
09h15 to 10h35	Paul Vermeulen, City Power: *"Energy storage application definitions and how these relate to SA policy, legislation and regulation"*	
	Mike Barker, Building Physics: *"Energy storage safety - hazard analysis, battery failures and installation guidelines"*	
	Dr Matthew Rowe, DNV-GL Energy, UK: *"Safer, smarter, greener - the role energy storage will play in sub-Saharan Africa"*	
	Dr Thomas Krausse, Blue Sky Energy, Austria: *"New generation saltwater electrical energy storage"*	
10h35 to 11h00	Morning tea in Exhibition Hall	
	Morning Session 2	
11h00 to 12h20	Dr Farshad Barzegar, University of Pretoria: *"Supercapacitor or battery?"*	
	Prince Moyo, Cigre SA: *"Battery energy storage systems"*	
	Cord-Henrich Dustmann, Zebra, Switzerland: *"Zebra battery flat plate design"*	
	Paul Tuson, Mott McDonald: *"Managing seasonal hydrology with energy storage in Asia"*	
12h20 to 13h30	Lunch in Exhibition Hall	
	Afternoon session 1	
13h30 to 14h00	Keynote address: Stuart Michie, ABB: *"Distributed energy resource management - the way forward"*	
14h00 to 15h00	Dean Marcus, Aztec SA: *"Thin plate lead carbon batteries – a viable alternative for large scale energy storage systems"*	
	Loïc Charmoille, Wärtsilä, France: *"Future-proofing energy storage investments"*	
	Sherwin Harris, GE: *"Lessons learned from advanced battery energy storage and microgrid projects"*	
15h00 to 15h30	Afternoon tea in Exhibition Hall	
	Afternoon session 2	
15h30 to 17h20	Dr Dmitri Bessarabov, HySA, North-West University: *"Renewable energy storage and microgrids for clean mining"*	
	Daniel Günther, Younicos/Aggreko, Germany: *"Cost-effective OPEX-models for energy storage as a game-changer for improving operation and resilience of electricity"*	
	Corentin Baschet, Clean Horizon, France: *"The role of energy storage in the energy transition"*	
	Ravin Singh, ABB: *"Increasing profit margins with microgrids"*	
	Maurice Johnson, UL, USA: *"New energy in battery infrastructure"*	
17h20 to 17h30	Wrap up: Mike Barker, Building Physics	
17h30 to 20h00	Cocktail party	

Keynotes General paper

SA Energy Storage 2018

Conference Programme: Day 2

MAIN CONFERENCE PROGRAMME: Emperors Palace, Assembly Room		
Day 2: Tuesday 23 October 2018		
07h30 to 08h20	**Registration and refreshments**	Exhibition
	Introduction	
08h20 to 08h30	**Welcome: Programme director: Bertha Diamini, ABB**	
08h30 to 09h00	**Opening address: Thava Govender, Eskom Group Executive: Generation/acting Group Executive: Risk and Sustainability**	
	Morning Session 1	
09h00 to 09h30	**Keynote address: Doug Staker, Enel-X, USA:** *"Using rate design to optimise the energy transition system"*	
09h30 to 10h30	**Gregory Ireland, University of Cape Town:** *"Combined system-wide value of demand flexibility in South Africa's energy system"*	
	Dr Linoh Magagula, NMISA: *"Smartgrid - as smart as the quality of its measurements"*	
	Randall September, ABB: *"Deploying battery energy storage systems on the SA grid"*	
10h30 to 11h00	**Morning tea in Exhibition Hall**	
	Morning Session 2	
11h00 to 12h30	**Beth Cilliers, Eskom:** *"The role of battery storage in the future electricity utility"*	
	Peter Oldacre, Bushveld Energy: *"Vanadium value chain innovation to reduce energy storage costs"*	
	Duncan Abel, Nedbank: *"Approaches to funding of energy storage and renewable energy for corporate clients"*	
	Prof. Daniel Chowdhury, Tshwane University of Technology: *"Hybrid energy storage system for transport"*	
12h30 to 13h30	**Lunch in Exhibition Hall**	
	Afternoon session 1	
13h30 to 14h00	**Keynote address: Madina Mukhanova, Fluence, The Netherlands:** *"The value of energy storage – enabling renewable energy"*	
14h00 to 16h00	**Dr Peter Klein, CSIR:** *"Overview of thermal energy storage technologies for sector coupling and waste heat recovery"*	
	Doreen Kanetey-Essel, Juwi: *"Grid parity analysis of a PV-BESS hybrid case study"*	
	Hiten Parmar, uYilo: *"Resilient smartgrid infrastructure for electric vehicles"*	
	Matimba Mathebula, Xahumba Engineering Consulting: *"Design, installation and maintenance of solar home systems in rural areas"*	
	Dr Pieter Pretorius, Terratech: *"Earthing and lightning protection of utility-scale PV plant - what's missing?"*	
	Aradhna Pandarum, Eskom: *"Trends and statistics of solar PV distributed generation in South Africa"*	
16h00 to 16h15	**Closing wrap-up: Prince Moyo, Cigre SA**	

WORKSHOPS AND SEMINAR	
Day 1: Monday 22 October 2018	
13h30 to 15h00	**SAESA meeting**
Day 2: Tuesday 23 October 2018	
07h30 to 16h45	**Small Scale Embedded Generation (SSEG) Seminar NCC Room**

☐ Keynotes ☐ General paper

SA Energy Storage 2018

SSEG Seminar Programme: Day 2

Small Scale Embedded Generation (SSEG) Seminar: Emperors Palace, NCC		
Day 2: Tuesday 23 October 2018		
07h30 to 08h20	**Registration and refreshments**	
	Introduction	
08h20 to 08h30	**Welcome: Roger Lilley, EE Publishers: Welcome and housekeeping**	
08h30 to 09h15	**Dr Hendri Geldenhuys, SAIEE president: Introduction**	
	Jacob Mbele, DoE: Keynote address: *The Draft IRP 2018 and the SSEG environment*	
	Joanne Dean, SAPVIA / SAESA: *Status and implementation of the SSEG legal and regulatory framework*	
	Morning Session 1: Regulation, standards, safety, certification and quality assurance	
09h15 to 10h30	**Dennis Seemela, NERSA:** *"SSEG Regulations - the regulatory framework - quo vadis?"*	
	Robbie van Heerden, CSIR: *"SANS 10142-1-2 standard for SSEG installations – status and progress"*	
	Dr Hendri Geldenhuys, Eskom: *"Safety of SSEG systems in public networks"*	
	Niveshen Govender, SAPVIA: *"Greencard quality and safely asurance for roof-top solar PV installations"*	Exhibition
10h30 to 11h00	**Morning tea break**	
	Morning Session 2: Technology, systems and components	
11h00 to 12h20	**Norman Jackson, SAESA:** *"Battery technologies in SSEG systems"*	
	William van Wyk, ABB: *"State-of-the-art inverter technologies in SSEG systems"*	
	Andre Anderson, Energyneering: *"Smart remote control, protection and monitoring of SSEG systems"*	
	Hano Oelofse, Dehn Africa: *"Lightning and surge protection of SSEG installations"*	
12h20 to 13h30	**Lunch break**	
	Afternoon session 1: The business case, business models, return on investment and financing	
13h30 to 15h00	**Davin Chown, SAPVIA:** *"The business case for small scale embedded generation in Africa"*	
	Vally Padayachee, AMEU: *"Impact of SSEG on municipal electricity distributors and emerging new business models"*	
	Shirley Salvoldi, Eskom: *"Tariff design to cater for the growing use of SSEG within distribution networks"*	
	Deerosh Maharaj, Standard Bank: *"Innovative financing of SSEG installations"*	
	Duncan Abel, Nedbank: *"Challenges and solutions in financing rooftop solar PV systems"*	
	Christopher Gross, GIZ: *"Challenges and opportunities for integrating SSEG in commercial and municipal distribution networks"*	
15h00 to 16h00	**Panel discussion**	
	Conclusion	
16h00 to 16h15	**Summary and thanks: Nivesh Govender, SAPVIA**	

☐ Keynotes ☐ Presentation

SA Energy Storage, SSEG & Smart Grid 2018

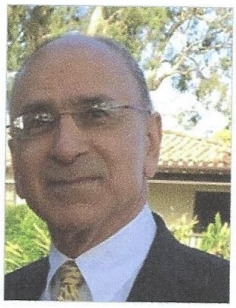
Keynote speakers

Jeff Radebe, Minister of Energy



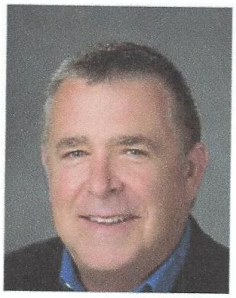
Jeffrey Thamsanqa "Jeff" Radebe is South Africa's Minister of Energy. He served as Minister in the Presidency from 2014 to 2018. Prior to that, he was Minister of Justice and Constitutional Development from 2009 to 2014. Radebe is South Africa's longest continuously serving cabinet member, having been part of every national administration since 1994. He holds an LLM in International Law from the Karl Marx University in Leipzig.

Dr. Fereidoon Sioshansi, Menlo Energy Economics



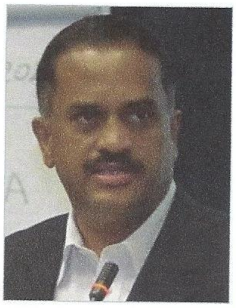
Dr. Sioshansi is President of Menlo Energy Economics, a consulting firm based in San Francisco advising clients on the implications of the rapid transformation of the electricity sector and emerging business models. He is the editor and publisher of *EEnergy Informer*, a monthly newsletter with international circulation. He has over 35 years of experience including working at Southern California Edison Company (SCE), the Electric Power Research Institute (EPRI), National Economic Research Associates (NERA), and Henwood Energy, now part of ABB. Since 2006 he has edited ten books, published by Academic Press, the latest being *"Innovation and disruption at the grid's edge: How distributed energy resources are disrupting the traditional utility business model"*, which was published in May 2017. His next book, *"Consumer, prosumer, prosumager: How service innovations will disrupt the utility business model"* will be published in early 2019. He has degrees in Engineering and Economics, including an MS and PhD in Economics from Purdue University.

Doug Staker, Enel-X



Doug Staker is an energy professional who has worked globally for 28 years. He is a pioneer in the world of smart grid technology and focuses on smart metering and intelligent energy storage. He is vice president of utility business development at Enernoc, a distributed energy management and storage company and a subsidiary of Enel. The company is a thought leader in the development of both delivery and supply rate structures which align the goals of utility load management with commercial power and energy savings. Enernoc led the growth of behind-the-meter energy storage in New York City and collaborated with local approval agencies in developing the permitting process for in-building installations.

Thava Govender, Eskom



Thava Govender is a member of the Eskom Executive Committee and serves on the Social, Ethics and Sustainability Committee of the Eskom Board of Directors. He is a director of Eskom Enterprises and a member of the board of the Rotek and Roshcon (an Eskom Enterprises subsidiary), and the chair of the council of Eskom's Academy of Learning. He is a board member of EPRI, the vice-president of the GO15's steering board for 2017 and president designate for 2018. He is also a member of the Coal Industry Advisory Board and a member of the executive committee of the Southern African Power Pool (SAPP), and the executive sponsor for the Eskom Expo for Young Scientists.

Madina Mukhanova, Fluence



Madina Mukhanova is the marketing manager for Fluence, a Siemens and AES company. She oversees the origination, development and coordination of energy storage sales and project proposals for clients across the Middle East and Africa. She is a founding member of Fluence, a leading global energy storage technology and services company with over 500 MW of operational or contracted energy storage in 16 countries. Prior to this, she worked in various positions within AES including as a quality specialist in the project management department. She holds a MEng degree in technical physics from the Siberian Federal University. In 2006 she was awarded a German academic exchange service scholarship for her MEng in energy and environmental management at Flensburg University.

Stuart Michie, ABB



Stuart Michie is a registered professional engineer and has Bachelors and Masters degrees in Electrical Engineering from the University of Cape Town. He has spent 22 years working in the area of automation in the power industry, starting in the operations of a medium sized electrical distribution utility and, since 2001, progressing through various engineering, sales and management positions in ABB South Africa. He is a member of ABB South Africa's country management team. As the digital lead, he is responsible for driving the digitalisation agenda of ABB in Southern Africa, which is seen as a key driver as the world moves into the Fourth Industrial Revolution.

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decentralized energy

INDUSTRIAL ELECTRIX

The key issues covered in the conference and linked to the sub-questions of the study

Sub-question 1 issues	Sub-question 2 issues	Sub-question 3 issues	Key insights from the conference
• Lack of coordinated national policy/ regulatory framework for electricity market • Lack of financial resources for infrastructure upgrades • Operational inefficiencies on installed CoE DG plants • Aging grid infrastructure	• Optimising power demand and supply • Scheduling of power production and dispatch • Reduction in infrastructural maintenance costs • Dealing with variability and intermittency of DG	• Limited access to the grid by DG operators in Germany • Aging grid infrastructure operated by state-owned utility (monopoly) • Restructuring of power sector to attract IPPs	• Integrated Resource Plan (IRP2018) to increase SSEG to 2300MW by 2030 • DoE to create smart grid policy input platform to address gaps in standards, applications and implementations • The new electric company to be your home-based technology shift towards Zero-Net Energy Buildings

During the conference deliberations, various speakers concluded on the following issues;

- Involvement for alternative regulatory bodies other NERSA to focus solely smart grid developments to be a supporting actor.

- The urgency in creation of municipal energy master plans (MEMPs) is a critical foundation to determine what type of energy to procure, when to procure and boundary conditions for procurement. Such municipal energy master plans form the business case for the municipal role in the sustainable energy transition, leveraging municipal competencies and integrating availability of spatially dependent local resources.
- Challenges in regulatory and license approvals for municipalities to procure energy from IPP and MF as well as MFMA constraints at national level approvals (National Treasury) to enter into long term contracts
- Multiple key stakeholders such SALGA, AMEU, COGTA, NERSA, DoE, Treasury, Department Public Works, Department Economic Development, Tourism & Environmental Affairs and others are working in silos.
- Budget constrains to develop polices, plans and strategies are uncertain. In addition, it is unclear on how to access funding from carbon tax, climate change funding organizations

9.10 **Licensing exemption and registration notices** (Source: DME, 2021)

GOVERNMENT NOTICES • GOEWERMENTSKENNISGEWINGS

DEPARTMENT OF MINERAL RESOURCES AND ENERGY

NO. 374 **23 April 2021**

ELECTRICITY REGULATION ACT, 2006

LICENSING EXEMPTION AND REGISTRATION NOTICE

I, Gwede Mantashe, the Minister of Mineral Resources and Energy, hereby;-

(a) under section 36(4) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) ("the Act"), and after consultation with the National Energy Regulator ("Regulator") and any person who may be affected, intend to amend Schedule 2 to the Act by substituting it with the Schedule ("the Schedule 2") set out in the Annexure hereto; and

(b) under section 9(1) of the Act, and in consultation with the Regulator, intend to increase the threshold for embedded generation from 1MW to 10MW and determine that a person who operates a generation facility contemplated in items 3.1, 3.2, 3.3, 3.4 or a person who performs the activities of a reseller as contemplated in item 3.7 of the Schedule, must register with the Regulator.

Interested persons and organisations are invited to submit, within 30 days, written comments on the proposed amendments to the Licensing Exemption and Registration Notice to the Director-General, Department of Mineral Resources and Energy, Private Bag X96, Pretoria 0001; Matimba House 192 Visagie Street, Pretoria; or email to Matthews Bantsijang. (Email Address: Matthews.Bantsijang@dmre.gov.za, telephone number: 012 406 4776). Comments received after the closing date may not be considered.

GWEDE MANTASHE, MP
Minister of Mineral Resources and Energy
31/03/2021

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9.11 Licensing exemption and registration notices (Source: DME, 2021)

GOVERNMENT NOTICES • GOEWERMENTSKENNISGEWINGS

DEPARTMENT OF MINERAL RESOURCES AND ENERGY

NO. 1000 **5 October 2021**

ELECTRICITY REGULATION ACT, 2006 (ACT No. 4 OF 2006)

AMENDMENT OF GOVERNMENT NOTICE NO. 737, PUBLISHED ON 12 AUGUST 2021, GOVERNMENT GAZETTE NO .44989: LICENSING EXEMPTION AND REGISTRATION NOTICE

I, Samson Gwede Mantashe, the Minister of Mineral Resources and Energy, hereby; -

(a) In terms of section 36(4) of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) ("the Act"), and after consultation with the National Energy Regulator ("Regulator") and interested and affected parties, hereby amend Schedule 2 to the Act by substituting it with the Schedule ("the Schedule 2") set out in the Annexure hereto; and

(b) under section 9(1) of the Act, and in consultation with the Regulator, hereby determine that a person who operates a generation facility contemplated in items 2, 3, and 4 or a person who performs the activities of a reseller as contemplated in item 3.5 of the Schedule, must register with the Regulator.

GWEDE MANTASHE, MP
Minister of Mineral Resources & Energy
19 August 2021

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and the Regulator has prescribed the manner in which the Distributor shall keep a register of each Facility.

3. The following activities are exempt from the requirement to apply for and hold a licence under the Act, but these activities must comply with the Code and must be registered with the Regulator:

Activities with a capacity of no more than 100MW, exempt from licensing and must be registered with the Regulator

3.1 The operation of a generation Facility with or without energy storage, with a capacity of no more than 100 MW with a Point of Connection on the transmission or distribution power system, in circumstances where –

3.1.1 the generation Facility is operated to supply electricity to one or more customers and there is no wheeling of that electricity;

3.1.2 the generation Facility is operated to supply electricity to one or more customers by wheeling; and the generator has entered into a connection agreement with the holder of the transmission or distribution licence in respect of the power system over which the electricity is to be wheeled;

3.1.3 the generation Facility has a connection point but does not export nor import any electricity onto or from the transmission or distribution power system.

Other activities exempt from licensing and require registration

3.2 The operation of a generation Facility with or without energy storage for demonstration purposes only, whether or not the Facility is connected to a transmission or distribution power system and where the Facility will be in operation for not more than 36 months.

3.3 The continued operation of an existing generation Facility with or without energy storage which, immediately prior to the date of commencement of this Schedule, was exempt from the requirement to apply for and hold a licence under the Act, must register with the Regulator within six months of commencement of this schedule subject to –

3.3.1 the generation Facility having complied with the Code and being connected to the transmission or distribution power system.

3.4 The operation of a distribution Facility up to the Point of Connection that connects the generation Facility contemplated in items of 3.1 and 3.3 above where there is conveyancing of electricity through the transmission or distribution power system.

3.5 The trading of electricity by a reseller in circumstances where –

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3.5.1 the price charged by the reseller to customers does not exceed the tariff that would have been charged to such customers for the electricity if it had been purchased from the holder of a distribution licence for the area in which the electricity is supplied to the customer; and

3.5.2 the reseller has entered into either a service delivery agreement in accordance with the Municipal Systems Act, (Act No 32 of 2000) (where the licensed distributor is a municipality) or a similar agreement with the distributor (where the licensed distributor is not a municipality) that regulates the relationship between the reseller and the holder of the distribution licence and the obligations of the reseller in respect of the quality of supply to customers; and the Regulator has ratified the general terms and conditions of such service delivery agreement.

Revocation and deregistration

4. The Regulator may vary, suspend or remove any registration on receipt of an application by a registrant or on application by a third party or upon violation of the regulatory requirements to comply with the Code.

5. The Regulator may revoke a registration under the following circumstances –

5.1 On application by a registrant or when the facility is no longer required or when the conditions of registration are not met.

6. A registrant must, in the circumstances contemplated in item 5.1 give the Regulator at least 6 months' notice in writing of his or her intention to cease activities, unless the Regulator determines otherwise.

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9.12 **Calculated fixed charge for SSEG** (Source: CoE, 2018b, p 50)

Description	Surplus Impact (ZAR)	Annual sum of connected SSEG customers	Monthly charge (ZAR pm/ customer)
Tar A Bus	(977,969)	3,947	248
Tar A Res (IBT)	-	-	-
Tar B Res	(11,313,503)	56,873	199
Tar B Resellers 400 V	(1,709,459)	1,635	1,045
Tar B Resellers >400 V	(155,749)	10	14,845
Tar B Resellers >400 V	(372,479)	24	15,216
Tar B Bus (Mixed)	(2,294,696)	12,592	182
Tar C 400V	(1,863,049)	766	2,433
Tar C 400 V Sub	(60,178)	10	6,269
Tar C <=11kV	(744,085)	108	6,897
Tar C <=11kV	(1,828,806)	252	7,265
Tar C <=11kV (off-peak)	(15,518)	6	2,771
Tar D 400 V Sub	(3,734)	0.3	10,891
Tar D <=11kv	(444,910)	8	54,985
Tar D <=11kv	(4,429,580)	73	60,827
Tar D >11kv	-	-	-
Tar D >11kv	(1,362,558)	7	189,244

Description	Surplus Impact (ZAR)	Annual sum of connected SSEG customers	Monthly charge (ZAR pm/ customer)
Tar D >11kv	-	-	-
Tar D >11kv	-	-	-
Tar D >11kv	-	-	-
Tar E 400V	(829,069)	337	2,457
Tar E 400 V Sub	(111,955)	25	4,473
Tar E <=11kV	(537,707)	63	8,557
Tar E <=11kV	(2,289,407)	251	9,108
Tar E >11kV	(8,999)	0.7	13,124
Tar F Lights	(1,211,242)	81,463	15
Tar F Traffic	(6,063)	823	7
Tar I CP 400V	-	-	
Tar I CP <=66kV	(57,380)	1.4	41,839
Tar J Consol	(203,523)	0.3	593,609
Tar J Denel	(32,044)	0.3	93,461
Tar J ergo	(47,051)	0.3	137,232
Tar J NCP	(305,857)	0.3	892,084
Tar J Nestle	(18,979)	0.3	55,356

9.13 Ethics clearance certificate

[redacted]

SCHOOL OF ARCHITECTURE AND PLANNING
HUMAN RESEARCH ETHICS COMMITTEE

SCHOOL OF ARCHITECTURE PLANNING

CLEARANCE CERTIFICATE
PROTOCOL NUMBER: SOAP056/07/2018

PROJECT TITLE:	Smart grid and Net-metering for Grid-interactive Distributed Generation for the City of Ekurhuleni
INVESTIGATOR/S:	Alfred Phiri (Student No: 409031)
SCHOOL:	Architecture and Planning
DEGREE PROGRAMME:	Masters in Sustainable Energy Efficient Cities (MSEEC)
DATE CONSIDERED:	29 June 2020
EXPIRY DATE:	29 June 2021
DECISION OF THE COMMITTEE:	Approved and extended

CHAIRPERSON B C Boshoff
(Dr Brian Boshoff)

DATE: Signed under lockdown: 29.6.20

cc: Supervisor/s: Daniel Irurah

DECLARATION OF INVESTIGATORS

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to endure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

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