Strategic National Smart Grid Vision

For the South African Electricity Supply Industry

Version 2.0

South African National Energy Development Institute

Strategic National Smart Grid Vision
For the South African Electricity Supply Industry

VERSION 2

This Strategic National Smart Grid Vision forms part of a set of working documents previously developed by the South African Smart Grid Initiative (SASGI) policy workgroup. It serves to create a national framework and to guide the national approach to Smart Grid implementation in South Africa. The Strategic National Smart Grid Vision was revised by the South African National Development Institute (SANEDI) in March 2023, in collaboration with various Electricity industry stakeholders through consultative workshops. This Strategic National Smart Grid Vision document targets the electrical distribution utilities, entities and associated stakeholders.

The South African National Energy Development Institute, an agency of, the Department of Mineral Resources and Energy.

Foreword

South Africa is at a cross road as we transition from a dominant coal-based energy system to low-carbon sustainable alternatives. We must keep in mind our challenges of stagnant GDP growth, rising unemployment, poverty and inequality, but most importantly, the lack of stable electricity to drive our economy as load shedding becomes the new norm. We must also never forget the interdependence of our water and energy systems, energy is required to extract, convey, and deliver water for various human uses while water is used in all phases of energy production, especially electricity generation.

There is no silver bullet to address all these critical challenges, however, with challenges comes opportunities, these windows of opportunities are not going to remain opened forever for South Africa or the African continent. The concept of a "smart grid" is not new, however, this concept has gained significant attention in recent years as a solution to many of the challenges facing electricity utilities globally. Smart grids are critical to driving the required change and impact of keeping this country, continent and its economy on its feet for generations to come. Our Integrated Resource Plan (IRP) would have to take into account the changing characteristics of the electricity grid, mainly due to introduction of renewable energy and energy storage systems.

What is a smart grid based on the South African context? As defined within the Strategic A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. This is basically a digitalised electrical grid that uses modern communication and information technologies to improve the efficiency, reliability, and sustainability of the electric power system. Increasing the intelligence of the electricity grid will enable for better response to situations such as when generation capacity constraints are experienced, to better leverage technology to compliment other energy resource availability, to support the growing demand, projected economic growth and climate change commitments and to dampen the impact of electricity price increases through efficiency and reduction of system losses.

A strategic national smart grid vision is an essential component of any plan to modernise the electric power system. It provides a roadmap for the development and implementation of a smart grid, outlining the key objectives, goals, and milestones that need to be achieved to realise the benefits of this technology. Successful smart grid implementation requires a comprehensive approach that involves all stakeholders in the electricity value chain, including utilities, regulators, technology providers, as well as customers. The strategic smart grid vision provides a framework for collaboration and cooperation among stakeholders, ensuring that everyone is aligned and working towards a common goal.

In this context, the strategic national smart grid vision outlines the purpose, scope, and key themes of the vision. It sets the tone for smart grid objectives and highlights its importance, emphasising the need for a collaborative, long-term approach to smart grid implementation within the electricity industry in South Africa.

Dr. Titus Zwanani Mathe
Chief Executive Officer
South African National Energy Development Institute

Table of Contents

List of Figures

List of Tables

Acronyms

AAM	Advanced Asset Management
ADAM	Approach to Distribution Asset Management
ADO	Advanced Distribution Operation
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
AO	Asset System Operation
ATO	Advanced Transmission Operation
BESS	Battery Energy Storage System
CE	Customer Enablement
CC	Climate Change
CPA	Central Purchasing Agency
CSM	Customer Side Systems
CV	Conventional Vehicles
DA	Day Ahead
DEA	Department of Environmental Affairs
DER	Distributed Energy Resources
Department	Department of Energy (also referred to as the ‘DOE’)
DMRE	Department of Mineral Resources and Energy
DMS	Distribution Management System / Distribution Automation
DPE	Department of Public Enterprises
DPW	Department of Public Works (also referred to as ‘NDPW’)
DR	Demand Response
DSM	Demand Side Management
DST	Department of Science and Technology
DTI	Department of Trade and Industry (also referred to as ‘the DTI’)
DOT	Department of Transport
DX	Distribution
EDI	Electricity Distribution Industry
EE	Energy Efficiency or Energy Efficient (as the context dictates)
EMS	Energy Management System
ERA	Electricity Regulation Act
EV	Electric Vehicles
Eskom	Eskom Holdings Limited

ESI	Electricity Supply Industry
FACTS	Flexible AC Transmission
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GX	Generation
Government	The South African Government
HAN	Home Area Network
HEM	Home Energy Management
HVDC	High-Capacity High Voltage
ICT	Information and Communications Technology Integration
IED	Intelligent Electronic Devices
IEP	Integrated Energy Plan
IPAP	2007/2008 Industrial Policy Action Plan
IPAP 2	2010/2011 to 2012/2013 Industrial Policy Action Plan
IPP	Independent Power Producer(s)
IRP2	Integrated Resource Plan 2010, published in 2011
Load Factor	Ratio of average energy demand (load) to the maximum demand (peak load) over a period of time
MDMS	Meter Data Management System
MO	Market Operator
National Energy Act	National Energy Act of 2008 (as amended)
NERSA	National Energy Regulator of South Africa
NETL	National Energy Technology Laboratory (USA)
OMS	Outage Management System
PEV	Plug-in Electric Vehicles
PHEV	Plug-in Hybrid Electric Vehicles
PQ	Power Quality
RE	Renewable Energy
SABS	South African Bureau of Standards
SALGA	South African Local Government Association
SANAS	South African National Accreditation System
SANEDI	South African National Energy Development Institute
SANS	South African National Standards
SARS	South African Revenue Services
SAS	Substation Automation System

SASGI	South African Smart Grid Initiative
SME	Small and Medium Enterprise
SO	System Operator
SSEG	Small Scale Embedded Generation
TA	Transmission Enhancement Applications
TMS	Transmission Management System
TSO	Transmission System Operator
TX	Transmission
UNIDO	United Nations Industrial Development Organization
V2G	Vehicle to Grid
WAMS	Wide Area Measurement System
WASA	Wide Area Situational Awareness

Executive Summary

Sustainable energy provision, inclusive of electricity, is globally regarded as key to the growth and sustainability of an economy. South Africa's electricity network has provided vital links between electricity producers and customers for many decades. Historically, these networks and infrastructure were developed to support the large, predominantly carbon-based generation sources that were congregated around the coal resources in the country.

South Africa is now facing increasing economic challenges combined with a changing electricity landscape. Adequate electricity availability is a fundamental requirement for supporting South Africa's economic growth and development objectives. To realise this, among others, the electricity supply industry (ESI) reform debate gained substantial momentum in South Africa. The national scale electricity loadshedding introduction during 2007 was perhaps the most visible proof that the ESI in South Africa was on an unsustainable trajectory. Since 2007, the frequency and duration of loadshedding escalated to an unprecedented level, reaching stage 6 of load shedding during 2022[1]. In the search for sustainable energy solutions, the ESI landscape changed dramatically while the introduction of renewable energy (RE) options and independent power producers (IPP's) permanently changed the business landscape.

Global and local developments serve as testimony that effective technology deployment can be leveraged as an enabler to enhance energy availability and sustainability. Without adopting relevant smart grid technology enablers, the ESI will not be able to capitalise on the emerging business opportunities, inclusive of renewable energy, and to address the climate related challenges. The 'South Africa's Net-Zero Transition' report states that, in a decarbonised world where trade partners act on their net-zero commitments, about 50% of South Africa's export value, one-million direct jobs and 15% of gross domestic product could be at risk if current high carbon emissions are maintained[2]. Furthermore, South Africa will require R1.5trn[3] during the period 2023 to 2027 to fund the just transition to a low carbon economy.

Furthermore, the national drive for lower-carbon generation options (including renewable energy and distributed generation), combined with greatly improved efficiency on the demand side, necessitates more sophisticated and intelligent network capabilities. Pressures to invest in the renewal and expansion of aging electricity infrastructure across the country are mounting if South Africa is to ensure an acceptable quality of life for all South Africans and economic activity and future growth can be supported.

The Smart Grid (SG) Vision aims to guide the transformation of the country's electricity system into a modern, integrated, and intelligent grid with a focus on three key areas: smart asset management, renewable energy integration, and improved revenue enhancement. Smart asset management is critical to ensuring the reliability and efficiency of the electricity grid. This technology enables utilities to better manage the grid, optimize energy efficiency, and reduce electricity waste. Renewable energy integration is another key focus area of the SG Vision. The integration of distributed energy resources, such as rooftop solar panels and battery storage, can help reduce reliance on centralised power sources and enable more customer choice and control over energy consumption. The SG Vision recognises the importance of policy and regulatory frameworks that enable the deployment of renewable energy technologies.

Improved revenue enhancement is also a focus area of the SG Vision. The integration of smart grid technologies can help utilities better understand and manage energy usage, which can lead to improved revenue collection. The SG Vision also includes the development of innovative pricing models and the integration of demand response programs that encourage customers to shift their energy usage to off-peak periods. The implementation of the SG Vision will require collaboration between government, utilities, industry, and other stakeholders to ensure a coordinated and effective transition to a modernised national electricity infrastructure. However, the benefits of this transition are significant and include increased energy efficiency, reduced carbon emissions, greater grid reliability, and improved access to energy for all South Africans.

The Smart Grid (SG) Vision, developed under the guidance of the South African National Energy Institute (SANEDI) in cooperation with the industry, forms part of a greater framework to guide the effective transition to a modernised national electricity infrastructure.

1 Introduction

1.1 Overview

South Africa's electricity supply industry stands at the threshold of critical transformation. This moment presents an opportunity for innovation to improve service delivery and to enhance the industry sustainability. However, it also requires important decisions to be made for the optimal deployment of available resources that will provide the best platform for the economic and technological needs of the country – now and into the foreseeable future. To provide the required context, the vision document reflects on the Electricity Supply Industry (ESI), however, the primary purpose of the Vision is to describe the aspirational future state of the Electricity Distribution Industry (EDI) in South Africa. The aim is to balance practical realism with a suitably ambitious and aspirational Vision so that the economy and society can reap optimum benefit from the significant infrastructure investments that will necessarily be made in the immediate future. The target audience of this document is therefore distribution utilities/entities and associated stakeholders.

1.2 Smart Grid Definition

The definition that the South African Smart Grid Initiative (SASGI) has adopted and incorporated into the Smart Grid framework documentation is by the European Technology Platform Smart Grid (ETPSG) which defines the Smart Grid as follows:

"A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies".

Based on ETPSG definition, Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- Better facilitate and manage the connection and operation of all sources of energy.
- Give consumers more choice so they can help to optimise energy use.
- Provide consumers with greater information and choice of supply.
- Significantly reduce the environmental impact of the whole electricity supply system.
- Deliver enhanced levels of reliability and security of supply.

1.3 Smart Grid Drivers

There are several drivers that are fuelling the adoption and development of smart grids such as renewable energy integration, energy efficiency, aging infrastructure, electric vehicles, consumer engagement and net-zero transformation. Overall, smart grids are seen as a key enabler of a more sustainable, reliable, and resilient energy system in the 21st century.

Table 1: Smart Grid Drivers

DRIVER	DESCRIPTION OF THE SOUTH AFRICAN CONTEXT AND RELEVANCE OF THE SMART GRID
Growing energy demand	Even with consumption slowing from the forecasts used to develop the IRP2, electricity demand for South Africa is anticipated to grow exponentially within the next two decades, requiring substantial investment in all related infrastructure. Continued economic growth, changing electricity needs, structural changes in economic activities, increased utilisation of information and communication, electrical and electronic equipment and continued electrification are contributing to growing energy consumption and adding to peak demand. Currently in South Africa, distribution losses amongst municipalities average 14%, almost double the target of 8%[1]. Optimal utilisation of the available resources i.e., efficient use of energy, minimisation of losses and integration of distributed generation capacity, amongst others, will form an integral part of a holistic, cost-effective solution. Increased grid intelligence will aid with addressing these challenges.
Capacity expansion and diversified mix	In response to the growing energy demand, South Africa has embarked on a massive generation capacity building programme that will see the electricity supply capacity double within the next decade. With the rise of renewable energy sources like solar and wind power, the grid needs to be able to handle variable and distributed generation. Smart grid technology can help manage this complexity. The renewable energy independent power producer procurement programme forms a significant component of the build programme; for the first time introduces significant RE into the South African energy mix and is a key component of the IRP 2. The introduction of RE, IPPs and distributed points of generation will significantly add to the complexity of the power network. The current grid and technology deployed are inadequate to respond effectively to these changing dynamics. This build programme is associated with high capital investment resulting in a corresponding escalation in energy prices. Unless mitigated through improved efficiency, rampant electricity price increases will in turn negatively impact economic activity and growth.

[1]EDI Holdings Ring-fencing Results 2008 to 2010

DRIVER	DESCRIPTION OF THE SOUTH AFRICAN CONTEXT AND RELEVANCE OF THE SMART GRID
Energy independence and security	South Africa is largely electricity independent with adequate coal supplies and an abundance of renewable energy resources, but the country remains subject to fuel (mainly oil) supply challenges and rising/ volatile fuel (coal, oil, gas) prices associated with decreasing availability and increasing demands globally. Optimal utilisation of available resources therefore becomes an ever-growing imperative.
Environment and climate change	South Africa's current energy supply capacity is predominantly centralised and fossil fuel-dependent. Increasing awareness of, and commitments to environmental and sustainability issues, both globally and locally, is changing practices in the power sector. In South Africa this shift is particularly evident in the intensified focus on renewable energy and energy efficiency. The changing dynamics of dispersed supply and variable resources such as wind and solar will place greater demands on the grid functionality and the traditional methods used for system planning and operations.
Economic growth	Power supply is a general purpose technology, which affects the economy directly and/or indirectly through multiple channels. Electricity and energy availability is critical to support the projected economic growth and necessary development in the country[2]. South Africa remains an energy intensive country where power consumption and GDP is directly related. As the economy grows, so the demands on the power system will therefore continue to increase. The risk of inadequate and unreliable supply to the economy was evident during the severe supply constraints in 2008, when the inability to supply the electricity needs of the country had an estimated impact of R 50 bn on GDP. Similarly, a 2004 study[3] by researchers at the Berkeley National Laboratory found that power interruptions cost the American economy $80 billion per year; other estimates are as high as $150 billion per year. This emphasises the importance of efficiency, reliability, quality and security of supply.
Policy and Regulation	Policy and regulation play a crucial role in driving the development and implementation of smart grids. These policies and regulations can incentivize investment in smart grid infrastructure, encourage the integration of renewable energy sources, and promote the adoption of smart grid technologies by consumers. Additionally, regulations can ensure that smart grids are reliable, secure, and

[2] A study of Sub-Saharan Africa published by the University of Southern Denmark in 2012, estimated the annual economic growth drag of a weak power infrastructure to be about 2 percentage points.

[3] Kristina Hamachi LaCommare and Joseph H. Eto, Understanding the Cost of Power Interruptions to U.S. Electricity Consumers, Ernest
Orlando Lawrence Berkeley National Laboratory, September 2004, e.g., Figure ES-1 among other discussions in the paper: http://certs.
lbl.gov/pdf/55718.pdf (September 2010).

DRIVER	DESCRIPTION OF THE SOUTH AFRICAN CONTEXT AND RELEVANCE OF THE SMART GRID
	resilient, while protecting consumer privacy and data security. By providing a supportive policy and regulatory environment, governments can help accelerate the deployment of smart grids, ultimately leading to a more efficient, reliable, and sustainable energy system.
Technology advancement	The smart grid constitutes an acceleration of, and a coordinated approach to the 'natural' trend of automation and technological advancement of electricity supply infrastructure. The various smart grid technologies have made rapid advancements during the preceding decade and combined with continued innovation, a range of new smart grid products and solutions are available. Smart grid technology will continue to mature and new technologies will enter the market. These technology advancements offer greater capability and choice, but it complicates the selection of appropriate, cost-effective solutions from an overwhelming offering (as experienced by the Eskom AMI pilot initiative[4]) At the same time, technology developments in other areas (e.g., data centres and electric vehicles) are increasing the demands on the required intelligence of the electricity network. With respect to technology development, South Africa has by default become an industry follower. This offers the benefits of leap frogging learning curves, but the national position should remain open to identify any opportunities for localisation, customisation or where South Africa can play a technology leader role in the smart grid arena.
Increased efficiency through grid operations	For optimum utilisation of available electricity resources, the grid will play an increasingly important role in improved efficiency in electricity consumption and grid operation. The network is expected to support and provide for: • Multiple integration points for intelligent grid hardware and software from transmission to consumption • Embedded sensor and monitoring capabilities • Deployment of advanced two-way communication networks • Growing supply of renewable and distributed power generation and storage • Intelligent support for multiple forms of intermittent renewable power sources (centralised/decentralised)
Advanced customer services	The requirements on customers to manage electricity consumption and adjust their usage patterns are growing, but concurrently, customers are expecting better information to inform their behaviour and to manage their costs. Advanced customer service is key to enhanced customer experience. At best, the current distribution industry in some areas does have view of a portion of the medium voltage networks/grid. However, there are no examples of low voltage grid intelligence which can be

[4] Challenges and lessons learnt documented for the Eskom AMI pilot initiative.

DRIVER	DESCRIPTION OF THE SOUTH AFRICAN CONTEXT AND RELEVANCE OF THE SMART GRID
	deployed from a system operations perspective or to enhance customer service/interface. To facilitate these improved or more sophisticated service levels, the grid would be expected to accommodate: • Robust, simple customer management platforms i.e., a system/technology platform that incorporates, among others, the ability to convert data into 'real time' customer and management information and provide a proactive service to customers, therefore providing for seamless customer support services. • Networked devices within the smart home i.e. the HAN devices that provides the intelligence as well as capability to manage appliances, geysers, alarms, and other equipment within the customer's home. • New efficient pricing models for electricity usage e.g., real time pricing that adjusts to reflect the current system conditions and energy mix • A more active role by all role players in efficient power usage e.g., demand response signals and customer responses • Empowered customer i.e. making adequate information available to the customer to enable an informed response about level and timing of energy usage • Establishing a technology platform for all South Africans to global standards by making modern technology and infrastructure readily and cost effectively available to all South Africans e.g., making internet and telecommunications access available to electricity customers
Infrastructure reliability and security	The current grid infrastructure is vulnerable to natural disaster (including those predicted as a result of climate change), vandalism, theft and attack (although not perceived as a major threat under current political conditions) with limited "self-healing" corrective capability. The additional information technology of the smart grid may enhance corrective capabilities but may also render it more vulnerable than the conventional grid to cyber-attacks, and as such may pose a very real threat to reliability. Improved intelligence and modernised systems/platforms should therefore aim to address: • Network/systems tolerant of cyber-attack, theft and natural disasters • Ability to anticipate and automatically respond to system disturbances
21st century power quality	South Africa is seeing increased market penetration levels of electronic equipment and sophisticated electric appliances that are more dependent on power that is free from sags, spikes, disturbances and interruptions. Improved power quality, possibly

DRIVER	DESCRIPTION OF THE SOUTH AFRICAN CONTEXT AND RELEVANCE OF THE SMART GRID
	with a more intelligent modernised grid, is therefore increasingly important.

1.4 Potential Benefits for Smart Grids

The transition to a smarter grid entails changes and enhancements to the complete grid value chain, from how the electricity utilities operate, to how the network is structured, to how the end user interacts with the grid infrastructure. It requires extensive alignment, cooperation, and integration. As a result, it offers, and should offer, significant benefits throughout the value chain from the utilities to the customers and, importantly, to society. The motivation for incorporating a smart grid solution into the planned infrastructure upgrades and expansions lies with the associated benefits to the respective stakeholders and the expectation that the benefits outweigh the costs. Estimated maintenance, refurbishment and strengthening backlog costs in the distribution network alone have been calculated at R68.1 bn (2014 values), growing at a rate of R6.2 bn per annum. This is a cost that must be incurred with or without a smart grid implementation. Incorporating greater intelligence into the grid might add to these costs[5], but should deliver benefits commensurate with, and more than the additional investment. An investment of this magnitude does however require the associated value proposition to be compelling to all stakeholders. The smart grid contributes value to stakeholders in four areas, see Figure 1. The expected benefits to all stakeholders are considered prior to the vision definition as this should guide and influence the envisaged goals/targets. Stakeholders can effectively be grouped into four categories of beneficiaries, namely: Power Generators, Electricity Utilities, Customers and Society. The values with respect to each of the illustrated areas are considered for each stakeholder category and the costs and benefits for each are briefly summarised.

[5]The magnitude of additional costs depends on the complexity and extent of intelligence that is incorporated hence providing accurate cost implications is difficult. An EPRI study, The Power Delivery System of the Future", completed in 2004 and updated in 2010 indicated a benefit-to-cost ratio for the implementation of a smart grid solution could be as high as five to one (5:1). Source: Eskom Integrated Report 2021.

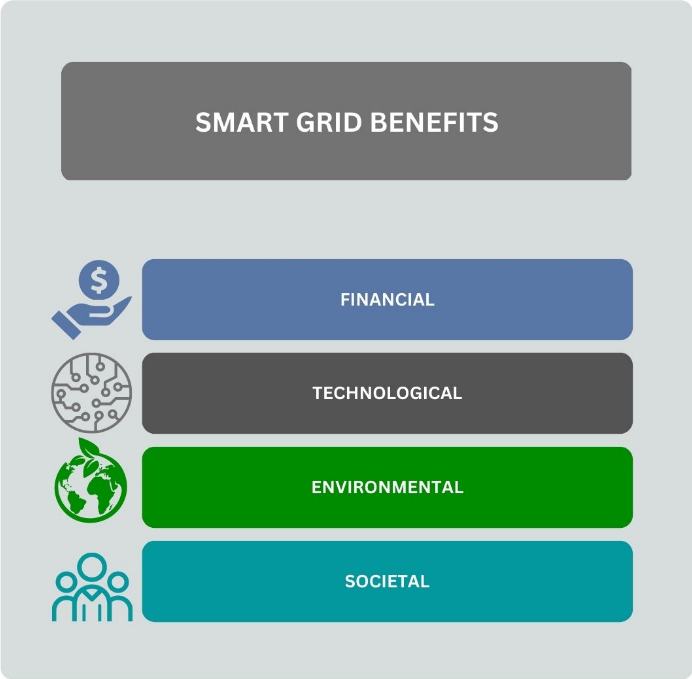

Figure 1: A smart grid value contribution

1.4.1 Potential Benefits for Power Generators

The current shortage of generation capacity and the low availability of the existing coal-fired power stations are regarded as a significant challenges confronting the ESI. Eskom is the main electricity generator in the country. However, several new independent power producers (IPPs) entered the market during the past couple of years. It is anticipated that the national RE IPP procurement programme will continue to rapidly increase the number of role players in the market. The latter is regarded as a key intervention in addressing the generation shortage currently experienced. The policy shift to RE IPP's is opening opportunities for a more diverse energy mix and hence a more diverse geographic distribution of generators. Numerous distributed generators of varying capacity and intermittent power supply from RE sources present new business opportunities as well as network integration and system operation challenges for the existing electricity network infrastructure. The global energy transition trend suggests that the transition to cleaner energy is slower than the desired expectations. Therefore, the energy transition must receive the deserved attention. In the case of South Africa, this must also be considered against the climate change challenges and escalating loadshedding frequency and duration. Figure 2 below reflects the global transition to alternative energy opportunities.

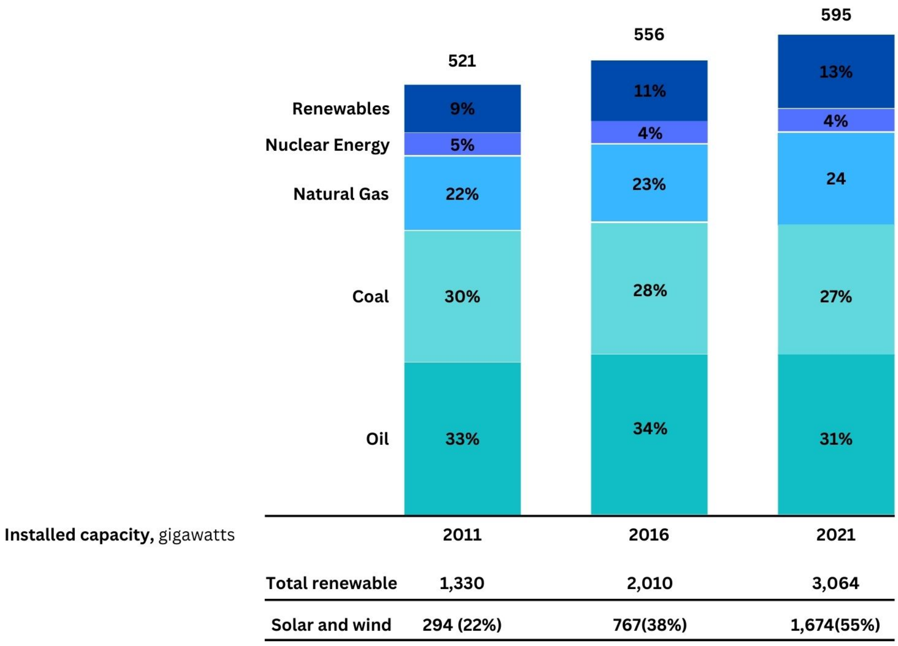

Figure 2: Global transition to alternative energy opportunities

The introduction of a smart grid will facilitate the changing generation landscape, requiring investment while offering critical capabilities, see Table 2.

Table 2: Power generator costs and benefits

POWER GENERATOR BENEFITS	UTILITY 'COSTS' OR CHALLENGES
The smart grid provides new market opportunities for Generators, as new forms of generation are demanded.	While new market opportunities exist and the value of base-load generation is expected to increase, the potential for stranded assets, particularly high operating cost peaking units, is real. Generating companies that focus on renewable energy production may find a profitable niche that the smart grid can facilitate.
Enables the integration of new, intermittent power sources and distributed generation contributing to diversity, capacity development and offering greater sustainability benefits.	But, as the smart grid becomes populated with smaller, more decentralized units and the peak load is flattened as customers respond to price signals in the new market, the opportunity for peaking units with higher operating cost to operate will diminish.

1.4.2 Potential benefits for Electric Utilities

In South Africa, Eskom (National Transmission and Distribution), 174 municipalities, 9 metros, 3 licensed energy traders and a small number of redistributors are responsible for delivering electricity to end-users. Eskom Distribution and municipalities dominate the electricity distribution industry (EDI) component of the ESI value chain from an asset/infrastructure ownership and number of customers served perspective. The EDI represents a critical component of the electricity supply value chain accountable for the safe and sustainable delivery of capacity and electricity to end-customers. This component of the industry is also accountable for managing the customer interface and revenue collection. With distributors accounting for 42% of the Eskom revenue[6], the current inability of the EDI to effectively manage revenue collection is posing a risk to the financial sustainability of the entire value chain; the latter being of vital importance since it underpins the ESI sustainability. The EDI is the most neglected component of the ESI value chain from a strategic direction, policy, and integrated investment perspective. All utilities (municipal, metro and Eskom) are subject to annual assessments and reporting commitments with respect to service delivery objectives and performance. At present, utilities are confronted with severe maintenance and investment backlogs, impacting negatively on service delivery. They will therefore have to take focused action to create sustainable and effective electricity distribution networks.

While the EDI, to date, was predominantly a business categorised by "one-directional energy flow" and limited customer choice, this changed substantially during the last couple of years. With among others, the introduction of renewable energy (RE) options, energy storage technologies, IPP's and attractive small scale embedded generation (SSEG) solutions, the EDI landscape changed significantly. Bi-directional energy flow and customers becoming prosumers are now a reality. Furthermore, it is essential that the EDI position itself to cater for the emerging customer needs, such as the growth in electric vehicles (EV) and other e-mobility developments. A new world of business opportunities emerged and are available to those who are ready, willing to review their infrastructure utilisation, and able to embrace the change. For many years, distribution utilities were confronted with an ever-increasing cost associated with the procurement of bulk capacity and energy. With the introduction of RE opportunities, these utilities can now change their bulk capacity and energy profile and thereby reduce their largest expense items. The potential of choice in getting energy supplied from alternative sources also provides for greater flexibility in respect of grid connection options and associated costs. Furthermore, customers (all categories) with access to photovoltaic installations can now

[6] Source: Eskom Integrated Report 2021

become prosumers, providing energy to the distribution grid/network. This approach presents a win-win situation for the grid/network owners and customers. It is acknowledged that the required technology deployment and prudent operating protocols are essential to ensure a safe and reliable supply of energy.

The key technology enablers deployed to date in the EDI are reflected below:

- Asset Management
- Billing/Revenue collection
- Energy Management
- Grid/network management
- Smart Meters

To improve the return on investment in technology deployed will require more focus on the integration of the enablers across the respective utilities with the objective to enhance business efficiency. There is also a need to introduce benchmarking, consistent definitions of measurement and performance assessment. As the demand for sustainable energy continues to increase and new participants enter the ESI, it is anticipated that new assets will have to be created. However, neglecting the existing and ageing assets will have a detrimental impact on the sustainability of the ESI. It is therefore essential to consider how to best strengthen, upgrade, modernise or down rate/retire the existing infrastructure. The effective application of technology can play a significant role in extending the life of assets or in the re-purpose of specific plant/equipment. In the context of the EDI, it is important to address grid/network visibility, in particular at the lower voltage levels. The use of advanced functionalities provided through advanced metering infrastructure (AMI) can play a major role in improving energy management and revenue management.

Considering the status of the EDI assets, it is necessary to utilise technology to improve asset management, inclusive of real time asset performance monitoring, evaluation, and predictive maintenance execution. This implies that the industry must embrace a new dispensation of data collection via sensors, scanners, loggers, and reports to complement the data management that will inform decision making. Leveraging data coupled with artificial intelligence (AI) based predictive analytics will assist utilities in making confident investment and business decisions. Without these interventions it will not be possible to optimise the asset lifetime and operating costs. It is therefore essential to take a holistic view when technology deployment interventions are motivated and evaluated. Key areas where the real return on investment can be measured over time will be in capital deferment because of asset life-time extension, asset reliability improvement, and increased utilisation of infrastructure to facilitate new revenue streams. The value of data in general is underestimated in many utilities and therefore not leveraged to its full potential. In addition to the classic use of data for the purpose of billing, as an example, the consumption data collected can be used to inform capital investment decisions, asset deployment strategies, load rotation/load limitation, and predictive maintenance execution. In the context of the future EDI, it is necessary for utilities to invest in the digital transformation. Among others, real time and automated reporting will become of critical importance from an operational, management and effective governance perspective. Furthermore, for utilities to be able to effectively manage the future decarbonisation and net zero objectives, as well as the energy portfolio and related integrated elements of the grid/network, automated performance monitoring and reporting will be required.

While it is not in the scope of the SG Vision, it is regarded as prudent to sensitise the industry to the potential that the future dispensation might present new opportunities in respect of asset ownership and asset operation. The introduction of RE, IPP's, DER, battery energy storage systems (BESS), etc., will require investments. Therefore, it is to be expected that flexibility will be necessary while new partnerships and funding models will have to be considered. Reliable and accurate asset registers will in future be of greater importance than ever before. Need for decisive leadership, improved customer focus, ageing assets, ineffective asset management practices, absence of prudent business enablers and ineffective revenue management practices are among the key challenges facing the EDI. From a utility perspective, the most important benefits offered by the smart grid would be improved service delivery, effective revenue management, optimised energy management, leveraging renewable energy opportunities, energy storage, improved reliability and improved efficiency of operations and utilisation of resources. Table 3 reflects some of the most significant costs and benefits for utilities.

Table 3: Costs and benefits to utilities

UTILITY BENEFITS	UTILITY 'COSTS' OR CHALLENGES
Investments made by utilities to reduce operational and maintenance costs can add to the bottom line, at least until the next rate case. Smart grid investments create the opportunity to realise these savings, provide an opportunity to earn a return on the associated capital	Smart Grid monetary **investments** in the distribution system will be necessary to establish the capacity and unlock the benefits of wider high bandwidth communications to all substations, intelligent electronic devices (IED) that provide adaptable control and protection

UTILITY BENEFITS	UTILITY 'COSTS' OR CHALLENGES
investments, and have the potential to improve service delivery and therefore customer satisfaction. Utilities have an interest in reducing costs to keep rate increases as low as possible for their customer base. Given that much of the smart grid investment costs are expected to be recovered through a reduction in operational costs and assuming the utilities are able to recover the remaining costs from customers and earn a return on the investment, it would seem that the utilities would be motivated to implement a smart grid. This is particularly true if their customers also support (and believe in) the opportunities the smart grid is expected to deliver to them.	systems, complete distribution system monitoring that is integrated with larger asset management systems, collaborative distributed intelligence, including dynamic sharing of computational resources of all intelligent electronic devices and distributed command and control to mitigate power quality events and improve reliability and system performance.
Improved relationship with and compliance to Regulatory and Government expectations and requirements	A further downside for utilities is the concern over reduced sales of kWh's. The revenue required by utilities to ensure they recover their incremental costs is based on the projected volume of kWh's sold. Solutions to this dilemma, such as the notion of decoupling the revenue from sales, are currently under consideration by the DOE and NERSA.
Improved environmental performance and compliance to ensure improved energy sustainability	

The benefits from moving forward with the smart grid should mostly exceed costs, particularly if enterprise risks (e.g., safety, financial, economic, operational risks) can be managed.

1.4.3 Potential benefits for customers

Customers are generally divided into three categories—residential (all individuals[7] who reside in an electrified dwelling are classified under this category), commercial (e.g., offices, malls), and industrial (e.g., factories). Over 12 million residential households exist today in South Africa. This represents many residential customers and a sizable customer group in terms of electricity consumption (~17% of total consumption) and peak electricity demand (~35% of total peak demand). Given the size of this customer group and the political influence they hold as voters, it is very important to ensure that the value of the smart grid is clear and compelling to them.

[7] The categories are not mutually exclusive; a residential customer may also be a commercial or industrial customer.

Successfully achieving a smart grid may well depend on how compelling its value proposition is for residential customers. Residential customers are typically interested in how the smart grid will benefit each individual household. Commercial and Industrial customers (which include manufacturing, tourism, mining, agriculture and transport, amongst other 'sub sectors') represent the economic backbone of the country. It is therefore of enormous importance to ensure that the smart grid delivers value to them. The primary interest of this group relates to the benefits the smart grid offers to their respective customers, company profitability and shareholder interests. The smart grid benefits and costs to residential, commercial, and industrial customers are shown in Table 4.

Table 4: Costs and benefits to customers

CUSTOMER BENEFITS	CUSTOMER 'COSTS' OR CHALLENGES
Residential Customers	**Residential Customers**
More reliable service (including less interruptions, shorter time to restored functionality, improved power quality to electrical and electronic appliances). Real time energy management and optimization capabilities. Potential bill savings (savings from energy efficiency, and fewer price escalations). Information, control, and options for managing electricity more economically and more environmentally friendly. Opens up opportunities and possible options to sell customer-owned generation and storage resources into the market. Potential to offer internet and telecommunications access to all electricity customers. Potential transportation cost savings (PHEVs vs. CVs)	Possible, but undefined short-term increase in electricity rates. Although in all expectations, only marginally more than the rate increases required for unavoidable infrastructure upgrades. The uptake of Smart Grid technologies by customers, resistance to technology change given and the negative perception of the electricity industry are expected to present challenges for the acceptance of smart grids by customers.
Commercial and Industrial Customers	**Commercial and Industrial Customers**
Opportunity to reduce energy and demand charges on bills. The cost of electricity is	Many of the larger customers have already invested in interval meters and have implemented special rate designs for

CUSTOMER BENEFITS	CUSTOMER 'COSTS' OR CHALLENGES
often a significant portion of the operations budget for these larger users. More reliable service resulting in a reduction in the costs of lost production and lost productivity. Poor reliability, outages and power quality disturbances can create significant costs to business operations when production and productivity are interrupted, ultimately resulting in lower profits or increased prices for goods and services. Opens up opportunities and possible options to sell customer-owned generation and storage resources into the market.	energy and demand that enable them to reduce their energy bills. Additionally, many have invested in back-up generating units, uninterruptible power supplies, and redundant power feeds that mitigate the impact of unexpected outages on their operating cost.

1.4.4 Potential benefits for society

In evaluation of a smart grid, it is essential to move from a utility-centric evaluation of costs and benefits to a broader societal value proposition. The South African electricity ratepayers (directly) and society as a whole (indirectly through possible inflation impacts) will effectively bear the initial infrastructure investment costs for the smart grid, but the value proposition projected for society is strong. Beyond the tangible, it also offers intangible benefits that are subject to a societal assessment of worth. This may differ for different aspects of society. The deployment of energy management technology enablers would appear to be a leading technology deployment practice in South Africa. In the context of the high cost of energy, generation shortage and the high aggregated technical and non-technical losses experienced in the industry, this is a very encouraging confirmation. For South Africa, the following are key considerations, see Table 5.

Table 5: Costs and benefits to society

SOCIETAL BENEFITS	SOCIETAL 'COSTS' OR CHALLENGES
Reduced losses to society from power outages and power quality issues.	It is anticipated that increasing electricity tariffs to cover the costs of infrastructure investments will result in an initial economic impact i.e., both direct and

SOCIETAL BENEFITS	SOCIETAL 'COSTS' OR CHALLENGES
▪ Reducing the probability of regional blackouts can prevent significant losses to society. ▪ Reducing by even 20% the cost of outages and power quality issues that is currently estimated at a cost of R75 for every kWh of unserved energy, will contribute.	indirect inflationary impacts. International case studies have shown that the costs are recovered rapidly through significant cost savings and benefits.
Improved operating efficiencies for utilities will reduce operation and maintenance and capital costs, keeping downward pressure on electricity prices for all customers. • Reducing transmission and distribution losses • Reducing transmission congestion costs • Reducing operation and maintenance spending. • Eliminating or deferring large capital investments in centralized generating plants, substations, and transmission and distribution lines.	
Improved National Security ▪ Has the potential to reduce the South African dependence on foreign oil if the use of PHEVs can be accommodated and integrated. ▪ Reducing the probability (and consequences) of widespread and long-term outages due to terrorist/theft activity could prevent significant societal costs.	

SOCIETAL BENEFITS	SOCIETAL ‘COSTS’ OR CHALLENGES
Improved Environmental Conditions ▪ Reduction in total emissions — through conservation, demand response, and reduced transmission and distribution losses. This reduction in energy production provides a corresponding reduction in all types of emissions. ▪ Reduction in CO_2 emissions — the smart grid and its ability to support renewable energy, distributed generation, electric vehicles and optimised resource utilisation/energy efficiency, could significantly reduce emissions. ▪ Improved public health — the impact of vehicle particulate emissions in urban areas can be reduced as the number of kilometres driven by CVs is offset by kilometres driven by electric vehicles. ▪ Reduction in the number of injuries and deaths due to contact with grid assets.	

Although it is often difficult to monetise all the tangible and intangible societal benefits, it can be shown and has been shown in existing smart grid applications that the extent and magnitude of these benefits are potentially large. Further work is needed to quantify these opportunities and benefits and due consideration should be given in the Business Case development.

2 Vision and Objectives

2.1 Vision

The purpose of the Vision is to define a common, national blueprint for the Smart Grid before industry stakeholders and participants commit to an investment programme of this magnitude and complexity. The Vision is intentionally ambitious and aspirational to provide a common vision of the Smart Grid which can be realised over time, aligning efforts across all sectors of the industry. It should also serve to align national efforts across all related activities including skills and capacity building, technology development and localisation of industries where relevant. The Vision considers the objectives of the Smart Grid and the contribution it is expected to make to the respective stakeholder groups with the aim of identifying the priority interventions and characteristics of the Smart Grid.

The Vision defines, through a process of careful consideration and consultation, a common picture of a Smart Grid that is relevant to South Africa and the challenges the industry faces. Having an agreed definition or collective understanding of the Smart Grid Vision in South Africa is imperative for alignment of effort and integration into a coherent national system. A clear vision will enable numerous industry role players and stakeholders involved in various solutions and applications over an extended period to "pull in the same direction". The Strategic vision for a smart grid:

"An economically evolved, technology enabled electricity system that is intelligent, interactive, flexible, effective, efficient, will enable South Africa's energy use to be sustainable for future generations".

Clarity is provided on the meaning of certain of the words in the Vision statement below.

- Economically evolved – affordable electricity system that meets the growing needs of the economy;
- Technology enabled – fit for purpose ICT, processes, sensors, systems and applications;

- Intelligent – from data to knowledge;
- Interactive – ability to monitor, control and manage using two way communications throughout the complete value chain;
- Flexible – appropriate, scalable and adaptable based on common standards;
- Electricity system – the complete value chain of all interconnected equipment and components from generation to end use;
- Effective – aligned to municipal business objectives (doing the right things);
- Efficient – cost efficient service delivery (doing things right);
- Sustainable – optimised Smart Grid objectives, costs and benefits.

2.2 Objectives

Objective	Rationale	Targets
Improvement in System Efficiency	By optimizing the distribution of electricity and reducing energy waste, the implementation of smart grids in South Africa can help improve the overall efficiency of the energy system, reduce costs, conserve resources, and promote sustainable energy practices.	By 2030, reduce electricity demand by at least 5%, increase electricity efficiency by at least 10%, and reduce technical and non-technical losses to 6% or less
Increase Renewable Energy Integration	By managing the variability of renewable energy sources and promoting the growth of the renewable	By 2030, increase the contribution of renewable energy sources to the electricity mix to at least 32%, and

	energy industry, smart grids can help South Africa transition to a more sustainable and low-carbon energy system.	increase the installed capacity of solar and wind power to 17,800 MW and 11,400 MW, respectively
Enhance Grid Resilience	By using advanced technologies to detect and respond to disruptions in real-time, smart grids can help improve the reliability and resilience of the grid, reducing the likelihood of power outages and other disruptions.	By 2030, reduce the number and duration of power outages by at least 60% and increase the reliability of the electricity supply to at least 95%
Empower Customers	By providing customers with more information and control over their energy usage, smart grids can help reduce energy bills, encourage energy conservation, and promote a more engaged and informed energy consumer base.	By 2030, ensure that at least 70% of households have access to reliable and affordable electricity, and increase the adoption of smart meters and other technologies that enable customers to manage their energy consumption more effectively

The above objective targets are drawn from the South African government's Integrated Resource Plan (IRP) 2019, South African government's National Development Plan (NDP) 2030.

2.3 Framework

The Vision forms part of a comprehensive framework that is being created for a smart grid in South Africa as illustrated in Figure 3. In addition to the Vision (1), the framework consist of an "as is" analysis (2) of the industry status at present; a gap analysis (3) to identify the variance between the current status and the defined Vision; a strategy and roadmap (4) broadly suggesting the approach for achieving the ideal national position as described by the smart grid Vision; supported by a business case or value proposition (5) for establishing a national smart grid. The business case, combined with pilot findings and lessons learned, informs clear direction on the required and prioritised functionalities (6) and implementation guidelines (7) to aid role players and stakeholders with appropriate technology system selection and implementation where required.

The Smart Grid Vision Statement was developed through an interactive process and participation by key stakeholders during 2017. In the context of the changes experienced in the industry, the Vision Statement was reviewed during quarter four of 2022. The Vision Statement was found to be still relevant and in line with the systemic approach adopted in defining the smart grid journey for South Africa. Consultation is inevitably an iterative process that requires time, but brings about a collective understanding, stakeholder alignment and the motivation for change amongst the relevant role players. The SASGI workgroup, among others, provides the platform for the process to advance the Vision and, subsequently, other critical aspects of the smart grid framework (e.g., the business case and roadmap):

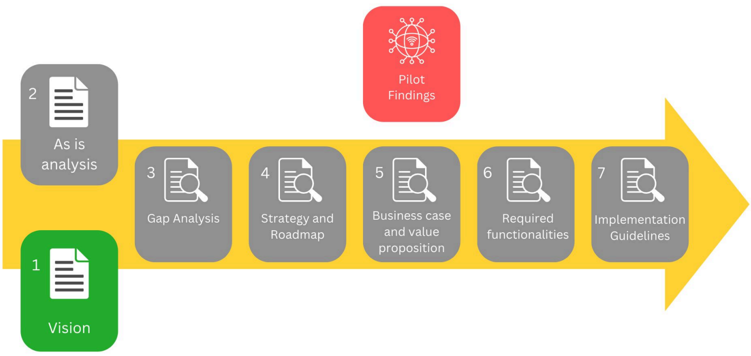

Figure 3: Comprehensive Framework to guide the Smart Grid implementation in South Africa

Implementation experience and performance feedback from the industry will continually serve to refine the implementation approach, again following an iterative process to develop the most appropriate guidelines for South Africa. The objective of the approach as described, is to bring together all parties involved in smart grids in South Africa to collaborate towards a focussed, integrated and optimal smart grid journey for the country. The parties referred to include policy makers, regulatory authorities, technology research institutions, technology developers, manufacturers, and technology end-users. The Vision also aims to provide insight and inspiration to all industry participants so that they may join and support this journey. The industry participants refer to parties directly involved in electricity generation, transmission, distribution, and energy trading. Considering the target audience, the attainment of the Smart Grid 2030 Vision depends on the serious commitment of every stakeholder.

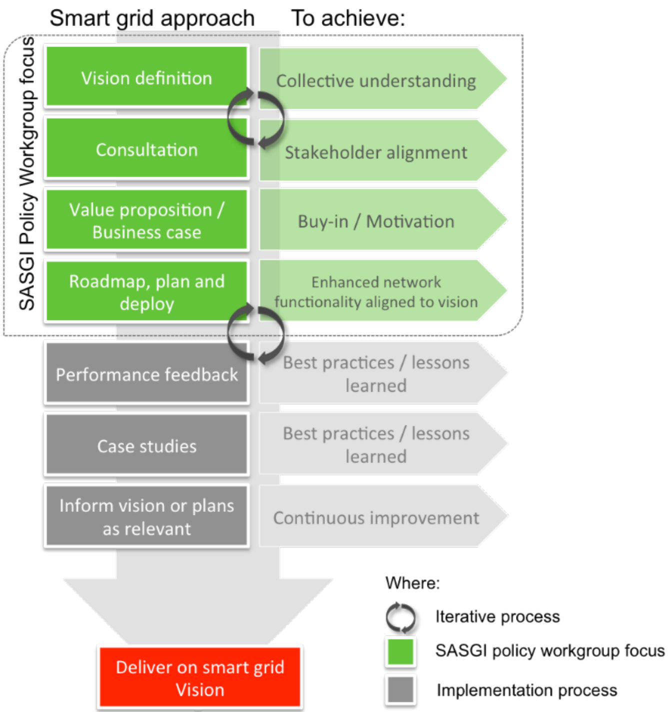

Figure 4: Vision development approach

While the strategy and roadmap will flow from the Vision, the Vision does assume that the implementation of smart grid applications can be approached in a modular way i.e., any role player has the freedom to prioritise the implementation of any aspect of the smart grid to suit specific leverage opportunities or areas of constraint or need. This suggests that while the national Vision strategy and roadmap will provide the overall direction, the respective utilities in the industry could start their specific journey at any point within the context of the Vision that will create the greatest immediate benefit for them. Implementation of the full, envisaged scope and realisation of the full benefits of the smart grid may therefore be achieved over an extended, but non-prescribed, timeframe. The approach adopted must also be seen in the broader context of the structure of the electricity supply industry in South Africa. The industry currently consists of a dominant player who incorporates a vertically integrated business (Generation, Transmission, Distribution and Retail) and numerous autonomous bundled distribution utilities. An analogy used by NETL for this 'systems approach' is that of a catalogue versus a novel. A catalogue can be constructed by collating many technology data sheets and arranging them in some order, such as alphabetic. A catalogue may present valuable content, but no clear direction.

A novel is approached with an overall Vision, followed by a storyline onto which the components and building blocks of the novel (characters, plots, chapters, and narrative) are built and integrated in a way that supports the Vision and goals that were defined in order to deliver a coherent, meaningful story. It is proposed that the South African grid should be advanced in a similar fashion; not by gathering a collection of interesting technologies and calling it modern, or smart, or intelligent, but by first defining a vision and then building the construct of a grid that serves a defined purpose. The Vision will hold up a view of the smart grid against which future decisions can be checked in terms of whether it "works" and whether it "fits" with the Vision and will allow progress against the Vision to be gauged along the long and arduous journey to realization.

This means that the Vision may be ambitious without compromising on critical requirements because of resource constraints, but it also emphasises the need for the Vision to give clear direction that will ensure that disconnected, independent implementation of applications is aligned and can be integrated into the national network/system. The smart grid architecture model is selected to guide the structuring of the smart grid for South Africa. It is adopted from the CEN-CENELEC-ETSI Smart Grid Co-ordination Group.

3 Background and Context to the Vision

3.1 Overview

The bulk of the South African electricity supply (generation, transmission and distribution) infrastructure was designed several decades ago in a vastly different political, societal and technology context, to respond to relatively 'simplistic' supply. The same aging infrastructure is now struggling to support rapidly growing and changing '21st century' network requirements. A background of the power sector is given to set the context in which this Vision is born.

3.2 Generation and Transmission Grid

An efficient, reliable transmission system has had, and will continue to have, an essential role in satisfying South Africa's growing desire for electricity, being the most flexible and useable form of energy. Advanced digital technology, as well as power electronics, can raise transmission to a new level of performance, even as the emergence of remote renewable energy farms and increasing electricity market applications create new challenges.

The development and integration of large central station wind and solar farms as a national priority, will be held back until existing transmission capacity is increased using new technology (FACTS, optimized transmission dispatch, high capacity conductors, advanced storage, etc.) along with the addition of new high capacity high voltage direct current (HVDC)—800 kV—and high voltage alternating current (HVAC) — 765 kV lines. The bottom line is that while it is true that today's transmission is more advanced than distribution, the transition to a Smart Grid requires much more transmission capability and now is the time to make the necessary investments.

To place this in context, we should first understand the historic role of transmission, which was to connect remote generation to load areas and to interconnect isolated power systems. Interconnection provides multiple benefits by exploiting the diversity that can exist between differing systems:

- Diversity between the times that peak loads occur, allowing the same generation equipment to supply more than one system's load;
- Diversity of outages, allowing spare equipment to support more than one system;

- Diversity of fuel sources, allowing the most economical fuel choice for any given situation.

However, new and emerging requirements find transmission in roles it was not designed to perform. One example is the role of a market channel, connecting buyers and sellers across very large geographic regions. Excessive variability in transmission use and far less predictability is the result. Further complicating factors come with the penetration of renewable generation such as wind and solar. The emergence of the plug-in electric hybrid vehicle (PHEV), while initially an increased demand consideration, could one day play a significant role as a system energy storage resource. The PHEV could be used for storage and demand side management (an asset) in a Smart Grid environment or it could create significant new uncontrolled demand (a liability) during peak load periods in the absence of a Smart Grid's control characteristic. Coordinated operation of storage, demand response and distribution-level generation will all be needed to address these and other 21st-century issues.

While recognising that transmission and generation challenges are large, the first requirement for any such system remains the same—it must be extremely reliable. The importance of this aspect is perhaps best illustrated by the events of the 2008 Cape Town blackout which cost the south Africa economy in the region of R50 billion. Regulators and utility planners discuss a term called the "value of lost load," referring to lost electrical load. In principle, it is the amount the average customer would pay to avoid an outage. Economic losses cost 15 to 133 times more than to produce the 'missing' electricity. The estimated cost over the three months of load shedding in early 2008 ranged from R50 billion to R119 billion at the time (estimated 5000GWh lost). These estimates would suggest a potential drop in nominal GDP growth of 2.5-6%, if the unmet electricity needs were sustained at a rate of every fourth day for a year. In general, these direct costs are considered to be underestimates of the total costs because they do not account for the effect on confidence. A single three-hour shutdown would lose the country around 2.25-3.55 billion Rand in today's value. What would that loss mean? The lower estimate is equivalent to losing 27,108 to 40,900 low cost houses or wasting one seventh of the annual low cost housing budget. It is equivalent to losing around 10,000 thirty-seat buses or a whole train (locomotive plus thirty coaches) with ten kilometres of rail from public transportation. At the minimum wage level, it would provide a year's employment to around 1,500 people or it could provide 9.2 days' worth of the entire social grant. One hour of lost electricity is worth 74 hours of social welfare (MONEYWEB: Garth Zietsman, Consultant Statistician).

Perhaps the most important aspect of any such power system upgrade is integration. It would be entirely possible to have very advanced systems in place but if there is no integration between these entities on a national or at least an interconnection level, then there is still the potential for another blackout on the scale of the 2008 incident. The same holds true for grid planning and energy/power markets. There is no way to optimise the planning of the interconnected power system if each entity does its own planning studies and makes its own recommendations for upgrades. This should be done on an interconnection-wide basis to maximise reliability and minimise cost. All solutions (FACTS, DR, distributed generation, etc.) should be considered along with new transmission lines but this should be done in a coordinated way. For wholesale power markets, the efficiency will only increase if there are more participants. The ideal power market would be a single market that spans the entire interconnection where all loads and all generators have equal access. This would create a more efficient market, better identify needed areas of investment, allow the maximum opportunities to manage or eliminate congestion and create opportunities for remote generation (like many renewables) to have the highest level of access to end users. In the final analysis, the right combination of new power lines and new technologies will be needed to meet the transmission mission such as those stated by Eskom.

Reliable and efficient, integrated grid operation requires the resources of all power plants to be available, without transmission constraints, to all parts of the system under a wide range of operating conditions and possible future scenarios in a broad variety of operating and market conditions. Given that transmission will need to become both smarter and bigger, the ability to build new transmission in a timely manner remains a key strategic issue, especially if large quantities of energy will need to be transported over large distances. Electric power transmission and distribution losses include losses in energy between sources of supply and points of distribution and in the distribution to customers (these losses also include pilferage). The electric power transmission and distribution losses in South Africa were 24,280,000,000 kWh in 2009, according to a World Bank report published in 2010. Electric power transmission and distribution losses (% of output) in South Africa were 9.84 as of 2009. Its highest value over the past 38 years was 10.00% in 2004, while its lowest value was 4.20% in 1986.

Since the industry reform announcement by Government in October 2019, progress was made towards the unbundling of Eskom. Among the key unbundling developments will be the establishment of an independent transmission system and market operator. This development will facilitate open access to the transmission grid, generation capacity competition, extensive bi-directional energy flow opportunities, and a new energy and capacity procurement regime. These changes will introduce a new business environment for the current electricity distribution utilities and promote private sector, customer, and prosumer participation. It is therefore reasonable to expect that the ESI will experience substantial changes during the period up to 2030. The figure below reflects the high-level unbundling agreed to in respect of ESKOM.

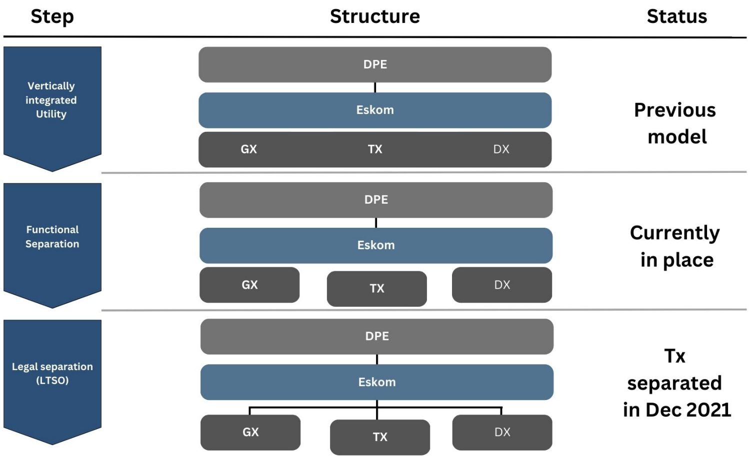

Figure 5: Unbundling of Eskom as per the DPE (2019)

In the context of the changes confronting the ESI, the Smart Grid Vision is intended to be outcome based i.e., the Vision aims to create an overall picture of the aspired business environment, network qualities, capabilities, and functionalities, but it is not intended to be prescriptive in terms of the implementation approach, technology specifications or timelines. The expectation is that each role-player's need shall determine the applications prioritised for implementation. It is therefore accepted that not every industry role-player will start at the same point or follow a linear process, but rather will be guided by the Vision and smart grid framework to select suitable applications and to build in the same direction towards the same national, integrated objectives.

While it is acknowledged that substantial work is still required to finalise the ESI market structure, it is anticipated that the structure to be introduced will bring about the necessary changes to the future business. In principle, the Market Operator (MO) will provide the much-needed platforms or trading mechanisms for power/electricity market participants. A concept relatively new to the current industry is the Central Purchasing Agency ("CPA"). It is envisaged that the CPA will take ownership of energy purchased under legacy contracts, stranded investments, and be a transition mechanism from the current Single Buyer model (with Eskom as only buyer) to a competitive market. From a power system perspective, it is essential to ensure real-time management and balancing of supply and demand, inclusive of day ahead (DA) requirements. Furthermore, it is necessary to procure ancillary services and to deploy resources as required from a system management perspective. These activities will be among the responsibilities of the designated System Operator ("SO"). Figure 6 below reflects the interpretation of the arrangement as described above.

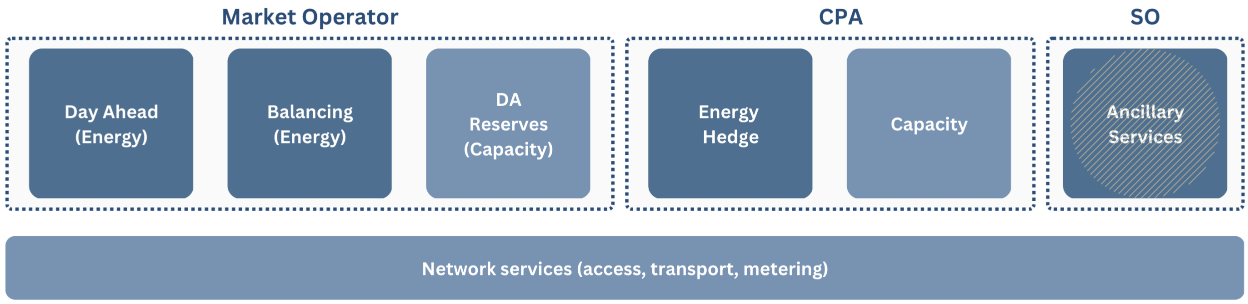

Figure 6: Proposed market mechanism (Eskom 2021)

To yield optimal results will require an integrated approach in developing the ESI interfaces throughout the value chain. The ESI is dynamic with each of the different components within the value chain requiring a specific strategy to ensure that the ESI is sustainable, future proof and can serve the best interest of South Africa. However, without an integrated holistic and systemic approach the ESI value chain will continue to fail the country. While the challenge of responding to the changing energy system requirements is not unique to South Africa, South Africa is in a favourable position where this coincides with the need for infrastructure investments to maintain a stable platform for current and growing economic activity. Smart grids are an essential part of these inevitable industry changes (e.g., replacement of aging infrastructure, clean energy, embedded generation, securing supply, improved interoperability, introduction of electric vehicles and distributed generation), in addition to many other challenges and doing so while managing escalating energy costs. Furthermore, being in a position as an industry to consider the most appropriate, collective approach prior to making an investment of the required magnitude, presents a defining opportunity to leverage global and local knowledge, experience, and technology for the most appropriate, integrated solutions before embarking on this journey. Aligning on this Vision may further present opportunities for leveraging economies of scale, localisation, and the exchange of best practice.

3.3 Distribution Grid

While it is acknowledged that it is essential to take a holistic industry view, the focus of the current Smart Grid plan is on the distribution component of the electricity supply industry (ESI). Due to the generation challenges, which surfaced during 2007/08, significant attention is given to the generation-related challenges. The transmission infrastructure in general performs well and it is underpinned by a well-defined investment plan. The latest Eskom annual report results contain the performance of, amongst others, their transmission system as well as their distribution system. From these results, it is clear that the distribution system requires urgent attention. The South African electricity distribution industry (EDI) is confronted by numerous and significant challenges that impact directly on the sustainability of the industry and the ability to provide a reliable service to electricity customers. While the distribution grid has previously served South Africa well in many aspects, the electricity grid is aging, outmoded and stressed. Estimated maintenance, refurbishment and strengthening backlogs in the distribution network were calculated at R27, 5bn (2008 values) and growing at a rate of R2, 5bn per annum. During 2007 the National Energy Regulator of South Africa (NERSA) conducted a survey on the condition of the electricity distribution infrastructure deployed by utilities in the South African electricity distribution industry (EDI). The report on the state of the EDI infrastructure revealed that in general, the assets needed urgent rehabilitation and investment. Unless an immediate and direct intervention is initiated, it will be very difficult to recover the industry from its downward trajectory.

All indications are that the electricity distribution operating environment will change significantly over the next couple of years. There are various indications, amongst others, such as the introduction of electric vehicles, a drive to enhance the use of renewable energy options, interest in distributed generation and customer involvement, which reinforce the observation in respect of the predicted changes in the industry. Most of the existing distribution grid is not designed to accommodate, for example, distributed generation, renewable solutions, or electric vehicles. This should however, not be a surprise, since the current grid was not constructed with the 21st century power supply challenges in mind.

The cost to the economy due to electricity/power interruptions cannot be over emphasised. During the latter part of 2007 and the first quarter of 2008, unprecedented power outages, because of generation constraints, resulted in significant financial losses. An illustration of the situation being that on 25 January 2008 AngloGold Ashanti released a press statement stating, "Following notification from Eskom regarding interruptions to power supplies, AngloGold Ashanti has halted mining and gold recovery operations on all of its South African operations. Only underground emergency pumping work is being carried out. According to Eskom, the current situation arises from reduced generating capacity aggravated by problems associated with coal supplies to power stations caused by unusually heavy rainfall. Eskom has not yet indicated how long the present situation will continue but the company is in contact with the electricity supply body".

While the availability of a more intelligent grid would not have removed all the challenges, it would have enabled the electricity supply industry to better respond to situations where such generation capacity constraints are experienced. At best, the existing distribution industry in some areas does have view of a portion of the medium voltage networks/grid. However, there are no examples yet of low voltage grid intelligence, which can be deployed, from a system operations perspective or to enhance customer service/interface.

Without investment in the infrastructure and the introduction of intelligence in the grid, the unreliability of the electricity supply will continue. Therefore, without the desired interventions, the cost to the economy as well as the end customers because of distribution-related outages will continue. Furthermore, the current grid is vulnerable to attack (predominantly physical, but potentially also cyber where intelligence is introduced) and natural disaster with limited "self-healing" capability.

The demand for electricity is projected to increase substantially towards 2030 and the cost to build new generation is increasing dramatically. Electricity prices have increased drastically over the past couple of years and the approved tariff plan suggests that above inflation increases will continue into the foreseeable future. Without addressing the grid intelligence i.e. making it smarter, the projected economic growth targets are at risk. The current grid and technology deployed cannot support the projected economic growth or respond effectively to the broader dynamics affecting the grid.

South Africa has committed to the declining of CO2 emissions by 2035. To achieve this necessitates a substantial integration of Renewable Energy into the Electricity Network. It is important to note that the distribution grid, which includes all networks/grids operating at the 132kV level and below, will be critical in the realisation of this objective. Without a substantial level of grid intelligence, the renewable opportunities cannot be effectively pursued.

Based on a sample of electricity distributor utilities in South Africa, results reflect the poor outage management and reliability of supply. The results highlight an inability to effectively report on incidents affecting the grid and deficient management of infrastructure. See Table 6.

Table 6: Outage management and reliability of supply

Municipality	**No. of Outages (Monthly)**	**Average downtime per disruption**
# 3	0 (Planned) 20 (Unplanned)	3 hrs to 1 week

Municipality	No. of Outages (Monthly)	Average downtime per disruption
# 5	20 (Planned) 30 (Unplanned)	Planned – < 8 hours Unplanned – < 1 hour
# 11	6 (Planned) 6 (Unplanned)	6 – 48 hours
# 14	8 (Planned) 150 (Unplanned)	Not available
# 19	1 (Planned) 3 (Unplanned)	½ hour
# 21	2	1 Hour
# 22	Not available	Not available
# 23	1 (Planned) 2 (Unplanned)	2-3 Hours

The inability to effectively manage, control and report on network dynamics also directly contributes to energy waste, leading to unnecessary CO2 emissions and rising costs. While the reasonable target for combined energy losses should be in the order of 8%, industry data (refer Figure 7) suggests an average loss of approximately 14%. In the graph, the kWh purchased refers to the energy procured from Eskom, while the kWh sold refers to the energy sold by the respective entity to the end customers. The green line in the graph represents the percentage energy loss between what was purchased by the respective entity for resale and what was ultimately sold to the end customers. This graph highlights the energy savings/improvement opportunity. However, without upgrading and adding intelligence to the current grid, it would be very difficult to realise these opportunities.

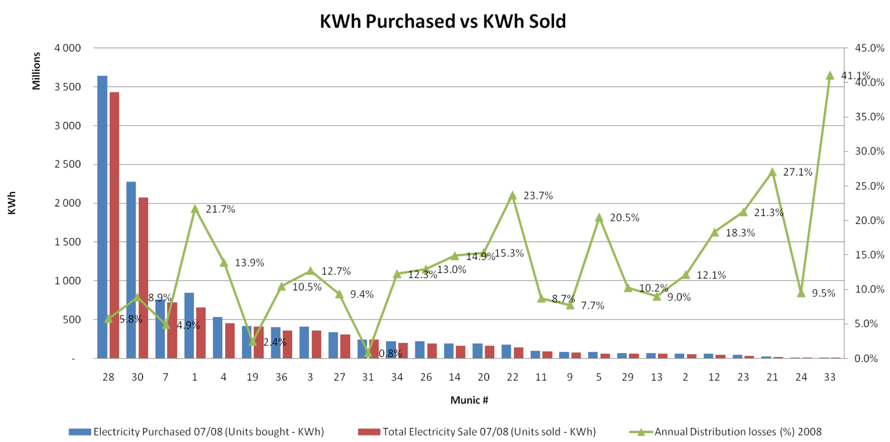

Figure 7. Electricity Industry Losses Performance Data

The ESI stands at a critical juncture requiring urgent and significant infrastructure investment to maintain security and quality of supply to respond to growing supply demands and new challenges. Perhaps the biggest challenge will be to find the right economic and environmental balance between these imperatives:

- Changing and more demanding customer expectations;
- Secure supply of electricity now and in the future;
- Diversified (and distributed) energy mix with a cleaner, more sustainable supply;
- Affordable infrastructure capable of supporting economic growth and rapid technology advancements.

The transformation required of the ESI to support this evolving landscape can be illustrated as in Figure 8, in the growing complexity of the existing and anticipated demands on the energy system.

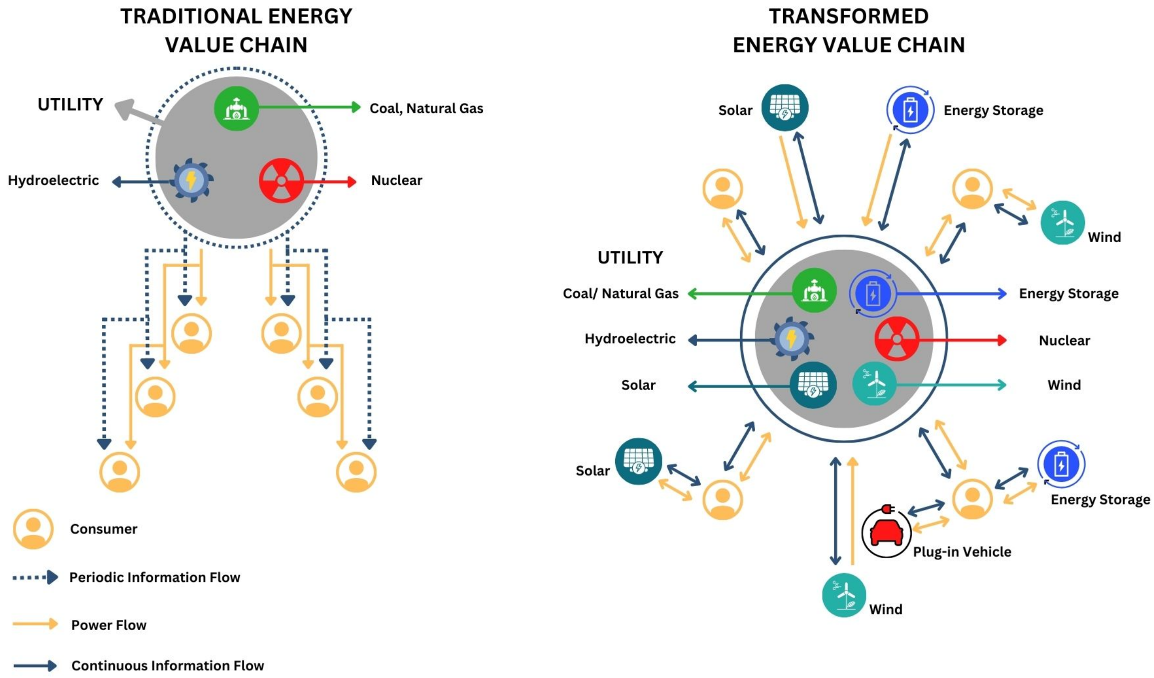

Figure 8: Conceptual Model of Holistic and Transformed Energy Systems (Source IBM)

While the challenge of responding to the changing energy system requirements is not unique to South Africa, the country is well positioned as this coincides with the need for infrastructure investments to maintain a stable platform for current and growing economic activities. Smart Grids are an essential part of these inevitable industry changes (e.g. replacement of aging infrastructure, clean energy, securing supply, introduction of electric vehicles and distributed generation), in addition to the many other challenges such as managing escalating energy costs. Furthermore, being in a position as an industry to give consideration to the most appropriate, collective approach prior to making an investment of this magnitude presents a defining opportunity to leverage global and local knowledge, experience and technology for the most appropriate, integrated solutions before embarking on this journey.

3.4 Smart Grids

Smart Grid deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardisation usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental edicts. As a concept, the Smart Grid is intuitive and elegant and an obvious progression for the electricity grid to increase automation, improve performance, improve efficiency and integrate more applications. But, as with most major technological change, the development phases of the initial, emerging Smart Grid technologies were not without growing pains and hard lessons learned. However, by 2011, the Gartner Hype Cycle (Figure 9) for Smart Grid technologies showed most related technologies had advanced far towards widespread adoption.

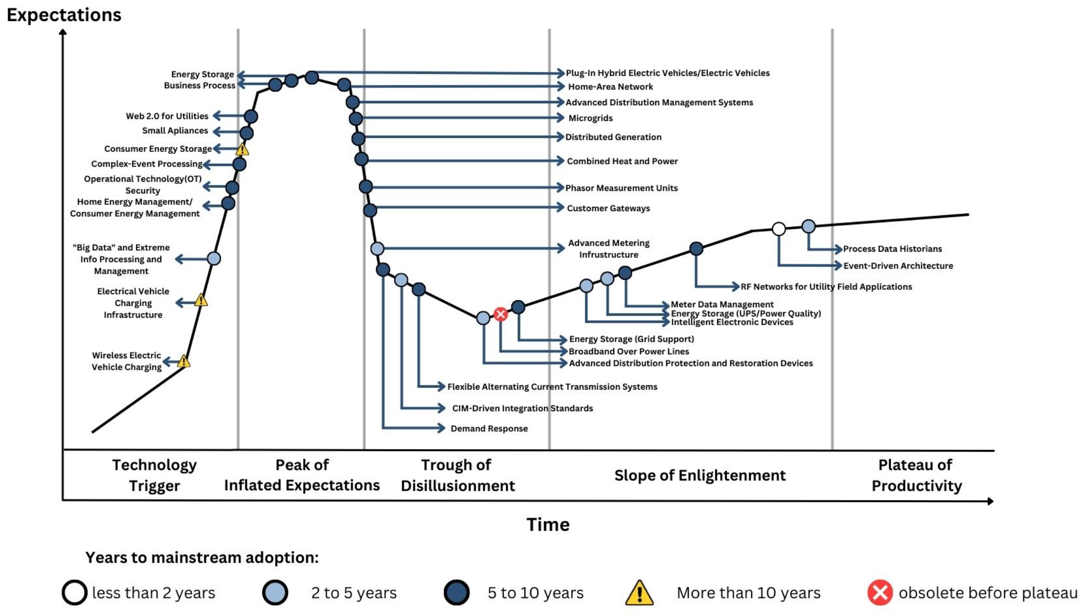

Figure 9: Gartner Hype Cycle for Smart Grid Solutions (Source Gartner)

Until recently, South Africa has lagged behind the world in the adoption of Smart Grid technologies. As a result, the country now has the opportunity, at a convenient time in our investment cycle, to leapfrog several technology development cycles and lessons learned by the front-runners in implementation. From this vantage position, the focus should be on capitalising on the improved global understanding of Smart Grid and to adopt applicable best practices to achieve full and relevant benefits for South Africa.

3.5 Policy Context

In South Africa, the electricity sector has become the focus of heightened policy interest in the context of escalating concerns over carbon emissions, security of supply, energy demand and economic growth. The most pertinent policies and regulations are highlighted to demonstrate the importance of a capable electrical infrastructure and the context to which a Smart Grid would significantly contribute to sustaining it. (Refer to Appendix C for a more comprehensive list). The National Energy Act, 2008 (No. 34 of 2008) sets out specific goals with respect to energy security and security of supply:

- Ensure uninterrupted supply of energy to the country;
- Promote diversity of supply and energy resources;
- Facilitate effective management of energy demand and its conservation;
- Promote appropriate standards and specifications for the equipment, systems and processes used for producing, supplying and consuming energy;
- Ensure collection of data and information relating to energy supply, transportation and demand;
- Provide for optimal supply, transformation, transportation, storage and demand of energy that is planned, organised and implemented in accordance with a balanced consideration of security of supply, economics, customer protection and a sustainable development;
- Commercialise energy-related technologies;
- Ensure effective planning for energy supply, transportation and consumption;
- Contribute to the sustainable development of South Africa's economy.

The Energy Security Master Plan – Electricity (2007- 2025) echoes these goals and provides for a good reference point to evaluate the current performance of the electricity supply industry against the defined Vision expectations. The Master Plan presents the following priorities for South Africa:

- Supporting economic growth and development;
- Improving the reliability of electricity infrastructure;
- Providing a reasonably priced electricity supply;
- Ensuring the security of electricity supply as set by a security of supply standard;
- Diversifying the primary energy sources of electricity;
- Meeting the renewable energy targets as set in the EWP;
- Increasing access to affordable energy services;
- Reducing energy usage through energy efficiency interventions;
- Accelerating household universal access to electricity;
- Clarifying some of the policy issues in the context of an evolving electricity sector.

The aging and stressed infrastructure of the ESI is challenged to deliver on many of these goals and national priorities. Investment in the grid refurbishment and expansion, and particularly investment in support of a Smart Grid, will contribute directly to the realisation of the objectives and goals of both the National Energy Act and the Energy Security Master Plan.

The National Climate Change Response Policy White Paper (Department of Environmental Affairs, 2011) reaffirms South Africa's undertaking and international commitments to slow down, and in due course, reduce carbon emissions. To achieve this necessitates a substantial integration of renewable energy into the electricity grid. It is important to note that the distribution grid, which includes all networks/grids operating at the 132kV level and below, will be critical in the realisation of this objective. Without a substantial level of grid intelligence, the renewable energy opportunities cannot be effectively pursued.

Government Regulation (GN) 773, published in terms of section 35 of the Electricity Regulation Act, establishes norms and standards for reticulation services in order to:

- Maintain the quality of electricity supply;
- Ensure the stability of the electricity network;
- Minimise electricity load shedding and avoid blackouts.

The Regulation includes specific measures for the roll out of smart metering to all customers with a monthly consumption of 1,000 kWh and above and for a "time of use" (TOU) tariff to be applicable to these customers by 1 January 2012. The Regulation is in effect since 2008, but the specified timeframe and details regarding Smart Grid and TOU tariff implementation as allowed for in the Regulation is under review. This Regulation establishes an important precedent for the introduction of a Smart Grid in South Africa and clearly demonstrates the national intent to move towards Smart Grid infrastructure.

During 2008, a comprehensive study was undertaken by EDI Holdings to determine the status of the assets in the electricity distribution industry. The study revealed, among other issues, that there is a significant underinvestment in infrastructure maintenance, refurbishment and strengthening. This was applicable across most of the electricity distribution utilities in South Africa. Furthermore, an urgent need was identified in respect of people recruitment and development while there was a glaring absence of business efficiency and the optimal deployment of technology. It is estimated that South Africa will have to invest approximately R35bn (2012) in assets and management tools to address the current infrastructure related backlogs. ADAM was approved in 2012 by Cabinet (National Government) to be introduced as an asset turnaround strategy for the electricity distribution industry. While ADAM is not an end solution, it presents significant opportunities to enhance the performance of the EDI. The introduction of a Smart Grid Vision embedded in the roll out of ADAM could bring about significant cost savings while contributing to a more holistic and integrated solution.

Electricity presents inherent and unique safety risks, requiring stakeholders to prioritise the health and safety of employees and the general public. Smart Grids offer the electricity industry opportunities to enhance employee and public health and safety by improving grid safety, providing better network information and reducing exposure time to faulty networks. With due consideration to training and change management, a Smart Grid will facilitate compliance with the requirements of the Occupational Health and Safety Act (No. 85 of 1993) and reduce electricity related incidences amongst employees and the public. A Smart Grid therefore represents an enormous opportunity to contribute towards, and enhance delivery on, these policy objectives and national initiatives.

4 Key Strategic Focus for South Africa

Smart grid technology has been deployed in various countries around the world, including the United States, China, and Europe. In the United States, the Department of Energy has supported the deployment of smart grid technology through funding and research initiatives. In China, the government has invested heavily in the development of smart grid technology, with the goal of improving the reliability and sustainability of the country's power grid. In Europe, the deployment of smart grid technology has been supported by the European Union through initiatives such as the Smart Grid Task Force and the Smart Grid Coordination Group. The focus of this section is to present options to the industry in South Africa in respect of technologies that could be leveraged and that will effectively contribute to the journey towards being future proof.

4.1 Smart Revenue Enhancement

Revenue collection is a critical function of local governments and Eskom in South Africa. Effective revenue collection provides municipalities with the necessary funds for the delivery of essential services such as water and sanitation, electricity, and waste management. However, municipalities in the country face a myriad of challenges when it comes to revenue collection, which has a significant impact on their ability to deliver these services efficiently. Some of the existing challenges include:

- High level of debt owed to municipalities by consumers. This debt is often due to a combination of factors, including a lack of financial literacy among consumers, poor billing systems, ineffective energy management, and an inability to pay due to high levels of poverty and unemployment.

- Prevalence of non-payment of services, especially in informal settlements, where residents often have limited means to pay for services or may be unwilling to pay due to a lack of trust in the municipality. This non-payment also contributes to the high levels of debt owed to municipalities by consumers.

- Outdated technology and systems for revenue collection, making it difficult to accurately bill and collect revenues. This is exacerbated by a lack of skills and capacity among municipal employees responsible for revenue collection, leading to errors and inefficiencies.

- Mismanagement in municipal revenue collection challenges in South Africa. This not only affects revenue collection but also erodes public trust in municipalities and their ability to deliver services.

The challenges facing municipal revenue collection in South Africa are multifaceted and require a concerted effort by all stakeholders to address. This includes investing in new technology and modernised systems/platforms, providing financial education to consumers, and addressing poverty and unemployment through targeted economic development programs. It also requires a commitment to ethical and transparent governance, which can help restore public trust in municipalities and their ability to deliver essential services to their communities.

4.1.1 Smart Grids for Improved Revenue Enhancement

Smart grids can help with revenue enhancement by timely implementation of new tariffs, introduction of Time of Use (TOU) metering, facilitating bi-directional energy flow, improving energy balancing, enhancing planning data, early detection of meter tampering, improving the accuracy and timeliness of billing, reducing non-payment of bills, and optimising the use of electricity resources. Smart grids have several features that can help municipalities address their revenue collection challenges:

- They enable the collection of real-time data on energy consumption, which can be used to accurately bill consumers based on their actual usage. This eliminates the need for estimated billing, which often results in billing errors that can lead to consumer disputes and non-payment of bills.

- Smart grids can also help reduce non-payment of bills by providing consumers with real-time information on their energy usage and costs. This can help consumers better manage their electricity consumption and avoid bill shock, which is a common reason for non-payment of bills.

- Smart grids can help optimize the use of electricity resources and early detection of meter tampering, thereby reducing costs and improving revenue collection for municipalities. For example, smart grids deploy advanced algorithms to predict and manage energy demand, ensuring that there is always enough power to meet consumer needs without overloading the system. This can help reduce the need for costly infrastructure upgrades and maintenance, thereby freeing up resources that can be used to improve revenue collection and service delivery.

- Smart grids also have the potential to enable new revenue streams for municipalities. For instance, they can facilitate the integration of renewable energy sources such as solar and wind power, which can be sold back to the grid at a premium. This can help municipalities to reduce their average energy and capacity purchase costs and generate additional revenue, while also reducing their dependence on non-renewable energy sources.

4.1.2 Smart Grid Deployment Strategy for Revenue Enhancement

While there is already a substantial base of "smarter" meters deployed in the industry, the extent to which the functionality of the installed meters is optimally deployed is debateable. However, it is acknowledged that irrespective of the size of the installed smart meter base, to get all the installed meters plus the additional meters required, installed and functional by 2030 is an ambitious goal that will require careful planning, coordination, and execution. To achieve this goal and to protect the substantial investment already made, an Advanced Metering Infrastructure (AMI) solution that will be able to accommodate multiple meter types (already installed and new) will be required. Furthermore, a deployment strategy should be developed that considers multiple distribution utilities, the unique characteristics of South Africa's electricity distribution network, the needs of consumers, and the capabilities of available technology. The following deployment strategy provides a high-level overview of the steps that should be taken to achieve this goal:

- Assess the current state of the electricity distribution network: Before deploying smart meters, it is important to assess the current state of the electricity distribution network in South Africa. This assessment should include an evaluation of the existing infrastructure, the level of technical expertise of the workforce, and the readiness of consumers to adopt new technology.

- Assess potential applicable metering related technology solutions available that will promote cost efficiency through accommodating multiple distributors on a single system, multiple meter vendors and meet the revenue enhancement strategic objectives.

- Develop a comprehensive deployment plan: Based on the results of the network assessment, a comprehensive deployment plan that considers the unique needs of each municipality should be developed. The plan should outline the rollout schedule, installation procedures, and cost estimates.

- Select the appropriate smart meter technology: There are several types of smart meters available in the market, each with different capabilities and features. The appropriate technology should be selected based on the needs of the municipality, the existing infrastructure, and the available budget.

- Train personnel: The deployment of smart meters will require a skilled workforce that is capable of installing and maintaining the new technology. Personnel should be trained in the installation and maintenance of smart meters, as well as in the use of associated software and hardware.

- Pilot project: Before deploying smart meters on a large scale, it is important to conduct a pilot project to test the effectiveness of the technology in a controlled environment. The pilot project should be conducted in a representative sample of municipalities to identify any potential issues that may arise during the rollout.

- Rollout: Following the successful completion of the pilot project, the rollout of smart meters should commence. The rollout should be conducted in a phased approach, starting with municipalities that are best equipped to handle the new technology.

- Consumer engagement: The success of the smart meter deployment will depend on the active engagement of consumers. Consumers should be educated on the benefits of smart meters and how they can use the technology to better manage their energy usage.

Deploying smart meters by 2030 will require a well-coordinated and comprehensive deployment strategy that takes into account the unique needs of each municipality, the capabilities of available technology, and the readiness of consumers to adopt new technology. With proper planning, investment, and execution, the deployment of smart meters can help improve the efficiency, reliability, and sustainability of South Africa's electricity distribution network while also improving revenue collection for municipalities.

The importance of measurement cannot be overemphasized in the rapid technological developments (such as the Smart Grid) and emergence of information technology. Industry and consumers, at large, make decisions based on measurement results. The accuracy of these results is extremely important as it has economic and personal well-being impact. Furthermore, the accuracy of the results assists in judging the actions and efficiency of public authorities, enterprises, and NGOs.

Correct and traceable material measures and measuring instruments can be used for various measurement tasks that correspond to reasons of safety, protection of environment, levying taxes, fair trade (as IPPs, ESKOM and consumers are likely to trade between each other), public health, etc., which directly or indirectly affect the quality of life of citizens, and may require legally controlled measuring instruments. Since manufacturers or importers or sellers of most products to be used in the smart grid are responsible for the associated measurement processes, the consumers (citizens and companies) are generally not well informed about the measurement processes and are very likely to be disadvantaged with regard to the measurement results and their interpretation thereof. Thus, fair, and accurate measurements that are traceable to a neutral public entity of a country's quality infrastructure (e.g., National Metrology Institute of South Africa) ensure fair trade and competition and gives confidence to the consumers.

4.1.3 Generic Project plan for Deployment

A project plan is an essential tool for managing the deployment of 30 million smart meters in South Africa. Figure 10 provides a high-level framework for managing the deployment strategy.

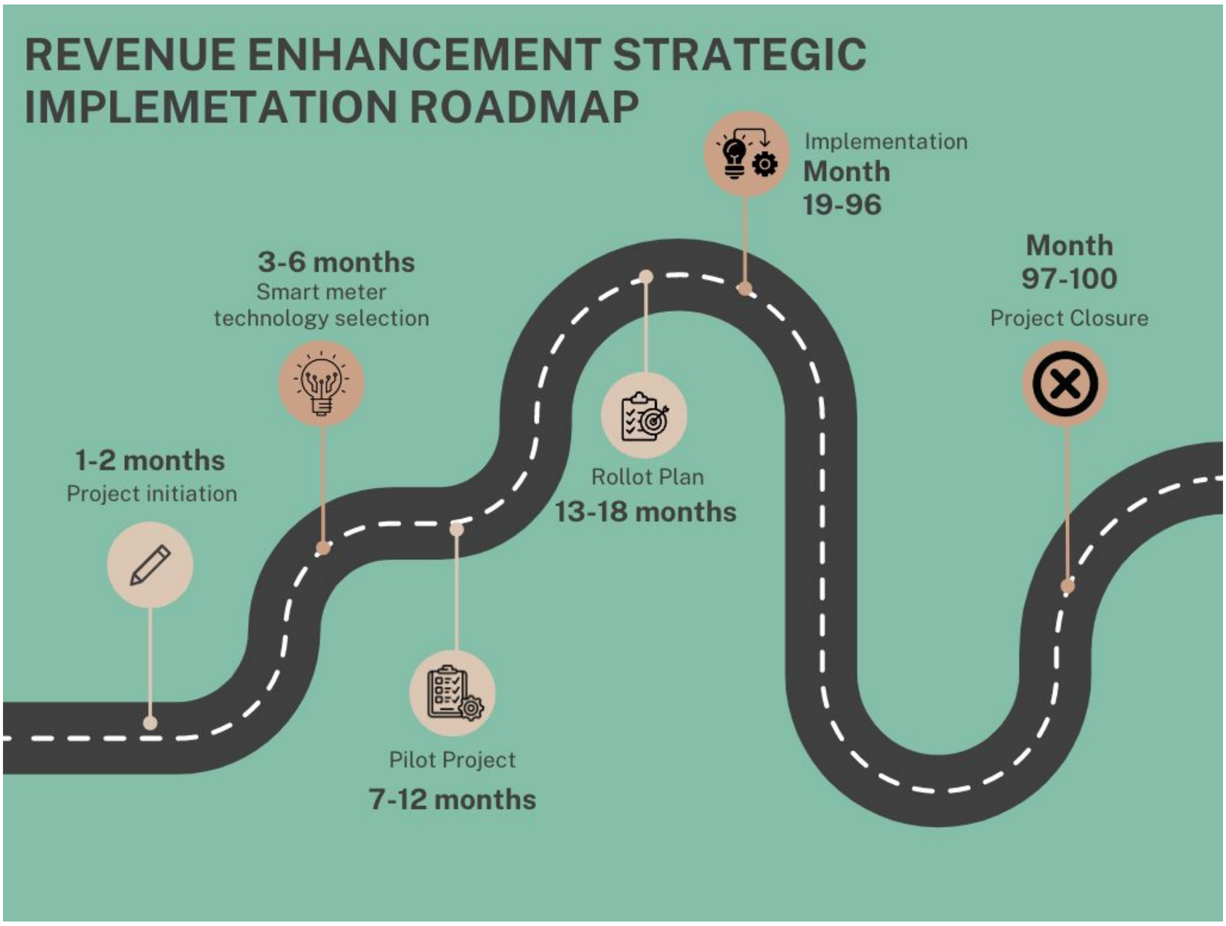

Figure 10: Revenue Enhancement Strategic Roadmap

A 100 month project plan is an essential tool for managing the deployment of 30 million smart meters in South Africa.

Project initiation (Month 1-2):

- Conduct an initial assessment of the existing electricity distribution network.
- Develop a project charter, which outlines the scope, objectives, and key stakeholders of the project.
- Establish a project team that includes representatives from municipalities, the electricity regulator, and technology providers.
- Define the project schedule, budget, and resources required.

Smart meter technology selection (Month 3-6):

- Evaluate available smart meter technologies and select the appropriate technology based on the needs of the municipalities, existing infrastructure, and budget.
- Develop specifications for the selected technology.

Pilot project (Month 7-12):

- Conduct a pilot project in a representative sample of municipalities to test the effectiveness of the technology and identify any potential issues.
- Develop an evaluation report based on the results of the pilot project.

Rollout plan (Month 13-18):

- Develop a comprehensive rollout plan based on the results of the pilot project and the evaluation report.
- Define the rollout schedule, installation procedures, and cost estimates.
- Develop a consumer engagement plan to ensure active participation in the rollout.

Implementation (Month 19-96):

- Execute the rollout plan in a phased approach, starting with municipalities that are best equipped to handle the new technology.

- Install smart meters in households and businesses, as per the defined rollout schedule.
- Train personnel in the installation and maintenance of smart meters and associated software and hardware.
- Monitor the progress of the rollout and adjust the plan as required.

Project closure (Month 97-100):

- Conduct a final evaluation of the project to determine the success of the rollout and identify areas for improvement.
- Prepare a final project report, which includes lessons learned, project outcomes, and recommendations for future initiatives.
- Conduct a post-implementation review to assess the impact of the smart meter deployment on revenue collection and service delivery.

A well-executed project plan is critical for the successful deployment of smart meters in South Africa. The above draft project plan outlines the key phases and activities required for the deployment strategy, but further detailed planning, stakeholder engagement and input from technology providers is needed to further refine the plan. Effective project management, stakeholder communication and the flexibility to respond to challenges will be essential to ensure that the deployment is completed on time and within budget, while achieving the desired outcomes of improving revenue collection and service delivery.

4.2 Smart Electrical Asset Management

Municipalities and Eskom made substantial investments in creating the current distribution asset base over many decades. Asset management is a critical component of utility responsibility to ensure reliable municipal service delivery in South Africa. Municipalities are responsible for managing a wide range of assets, including infrastructure, buildings, facilities, and equipment. Effective asset management ensures efficient service delivery and supports economic development. However, asset management for municipalities in South Africa is facing several challenges, which need to be addressed for sustainable service delivery. Smart electrical asset management is the use of digital technology to improve asset visibility and to optimize the performance and maintenance of electrical assets, such as power generation equipment, transmission lines, and distribution systems. Smart electrical asset management involves the use of sensors, data analytics, and other digital tools to monitor the condition and performance of electrical assets in real time, to predict and prevent potential failures or issues and to inform planning. Smart electrical asset management can help to improve the efficiency, reliability, and safety of electrical assets. For example, by monitoring the performance of power generation equipment in real time, asset managers can identify and address potential problems before they lead to outages or other issues. By using predictive analytics, asset managers can also anticipate when equipment is likely to fail, and schedule maintenance or replacements in advance, reducing the likelihood of unexpected downtime.

Figure 11: Smarter Asset Management [18-19]

Many municipalities lack the capacity and resources to manage assets effectively, leading to poor maintenance, underutilisation of assets, and a lack of investment in new assets. In addition, asset data is often incomplete, outdated or unreliable, leading to difficulties in making informed decisions. Some of the challenges include:

- Lack of investment in new assets. Many municipalities in South Africa have aging infrastructure and equipment, which require significant investment for upgrading and replacement. However, limited funding and capacity make it challenging to prioritise and fund these projects effectively.
- Lack of capacity and skills in asset management. Many municipalities lack the necessary skills, tools, and resources to manage assets effectively, leading to poor maintenance and underutilisation of assets. This leads to an increase in operating costs (e.g., over

time) high backlog of maintenance work, increased plant/equipment failure, and increased maintenance costs over time.

- Lack of accurate and up-to-date asset data is a significant challenge for municipalities. Without accurate and reliable asset data, municipalities find it challenging to make informed decisions regarding asset management, resource requirements and budgeting. This can result in poor maintenance planning, asset underutilisation and, ultimately, a failure to deliver adequate services to citizens.

By addressing these challenges, municipalities can manage assets effectively, reduce costs and deliver high-quality services to citizens.

4.2.1 Steps to get to Predictive Asset Management by 2030

The following steps are key to transition from the current state to predictive asset management by 2030. These include:

- Step 1: Establish Asset Management Policies and Procedures. The first step in achieving predictive condition monitoring of municipal assets is to establish a reliable asset register followed by asset management policies and procedures. This involves accounting for the assets, defining the goals, objectives, and principles of asset management, as well as the roles and responsibilities of those involved. The asset register, policies and procedures should also include guidelines for asset data management, maintenance, replacement, and renewal.

- Step 2: Develop Asset Management Systems/platforms that can support predictive condition monitoring. This involves investing in technologies such as sensors, data analytics, and machine learning to enable remote monitoring and analysis of asset data. The systems should also integrate with other municipal systems/platforms such as finance and procurement to enable a holistic approach to asset management.

- Step 3: Build Capacity. Skills Building capacity is critical for achieving predictive condition monitoring of municipal assets. This involves training staff in the use of new technologies and processes, as well as developing partnerships with academic institutions and industry experts. It also involves the development of apprenticeship programs to promote skills transfer and ensure continuity of knowledge.

- Step 4: Prioritize Asset Investment. To achieve predictive condition monitoring of municipal assets by 2030, there is a need to prioritize investment in asset management.

This involves setting clear targets for the replacement and renewal of aging assets and allocating funds for the development and implementation of new technologies and processes. The investment should also prioritize those assets that have the greatest impact on service delivery and economic development.

- Step 5: Continuous Improvement. Continuous improvement is critical for achieving predictive condition monitoring of municipal assets by 2030. This involves regularly reviewing asset management policies and procedures, systems, and performance data to identify areas for improvement. It also involves engaging with stakeholders and citizens to ensure that service delivery meets their needs.

Achieving predictive condition monitoring of municipal assets by 2030 requires a strategic approach that addresses the challenges facing municipalities. This involves establishing asset management policies and procedures, developing asset management systems, building capacity and skills, prioritising asset investment, and continuous improvement. By following this strategy, municipalities in South Africa can improve service delivery, reduce costs, and support economic development.

4.2.2 Generic Project plan for Deployment

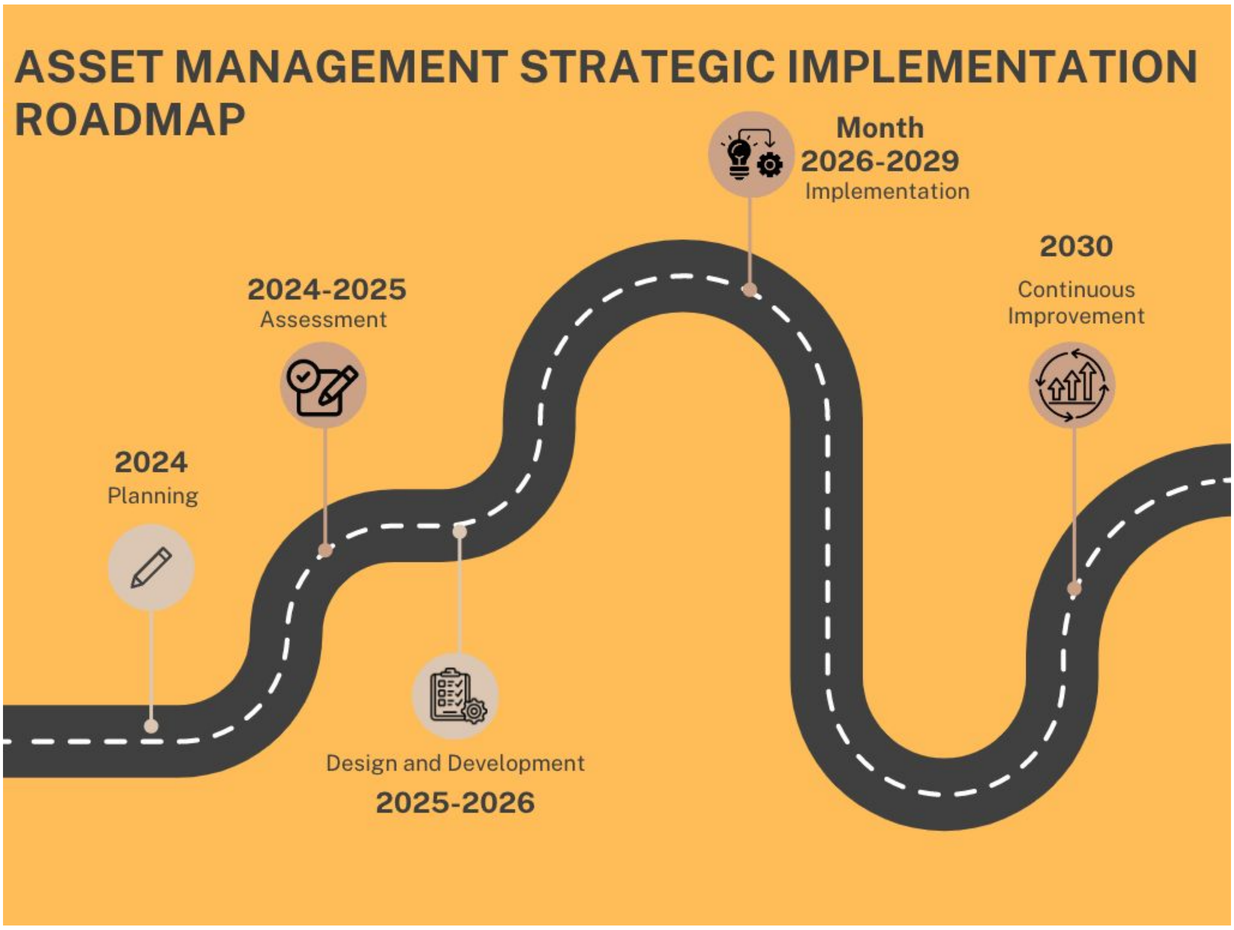

Figure 12: Asset Management Strategic Roadmap

The objective of this project plan is to develop and implement an asset management deployment strategy for municipalities in South Africa. The strategy aims to improve service delivery, reduce costs, and support economic development by achieving predictive condition monitoring of municipal assets by 2030. Possible phases and timelines are:

Phase 1: Planning (2024)

- Define project scope, goals, and objectives
- Identify key stakeholders and engage with them to gain input and support
- Develop project plan, including timelines, resources, and budgets

Phase 2: Assessment (2024-2025)

- Conduct an assessment of the current state of municipal asset management
- Identify gaps and challenges in the current system
- Evaluate existing assets and asset data to inform the development of asset management policies and procedures

Phase 3: Design and Development (2025-2026)

- Develop asset management policies and procedures that align with international best practices and industry standards
- Design and develop asset management systems that enable predictive condition monitoring of municipal assets
- Develop a capacity building and skills development plan for municipal staff to ensure they are equipped to manage the new systems and processes

Phase 4: Implementation (2026-2029)

- Implement asset management policies and procedures, asset management systems, and capacity building plan
- Prioritize asset investment plan based on need, impact, and budget availability
- Ensure that all stakeholders are trained and equipped to use the new systems and processes effectively

Phase 5: Continuous Improvement (2030)

- Develop a continuous improvement plan to ensure that the new systems and processes are sustainable and adaptable to changing circumstances
- Monitor and evaluate the performance of the new systems/platforms and processes
- Engage with stakeholders and citizens to ensure that service delivery meets their needs

Timeline:

- Planning phase: 6 months (Q1 2024 - Q2 2024)
- Assessment phase: 12 months (Q3 2024 - Q3 2025)
- Design and development phase: 18 months (Q4 2025 - Q1 2027)
- Implementation phase: 36 months (Q2 2027 - Q1 2030)
- Continuous improvement phase: 12 months (Q2 2030 - Q1 2031)

The asset management deployment strategy project plan aims to improve service delivery, reduce costs, and support economic development in municipalities in South Africa by achieving predictive condition monitoring of municipal assets by 2030. By following the revised project plan, municipalities can build capacity, adopt new technologies and processes, and ensure efficient service delivery to citizens. The revised timeline starting in 2024 provides a realistic and achievable timeframe for municipalities to implement the strategy successfully.

4.3 Distributed Generation

In South Africa, most electricity is generated by large, centralised power plants and distributed through a grid system. The frequent power outages and load shedding in recent years are due to a combination of factors, including inadequate maintenance of the aging infrastructure, delays in the construction of new power plants, and an increase in demand. To address these challenges, the South African government has been promoting the development of distributed generation as a way to increase the country's energy security and reduce its dependence on the national grid. In 2019, the government introduced a new regulatory framework that allows small-scale embedded generation (SSEG) projects with a capacity of up to 100MW to be connected to the grid without needing to obtain a license from the national energy regulator. The active promotion of SSEG, inclusive of rooftop photovoltaic (PV solutions can make a significant contribution in addressing the current shortage of capacity and energy. Municipalities can integrate distributed generation into their networks in a safe and efficient manner by following best practices and guidelines that have been developed for this purpose. Some key steps that municipalities can take to safely integrate distributed generation into their networks include:

- Conduct a feasibility study: Before integrating distributed generation into their networks, municipalities should conduct a feasibility study to assess the technical and economic viability of the project. The study should identify the most suitable locations for the installation of distributed generation systems, estimate the costs and benefits of the project, and identify any technical, regulatory or financial barriers that need to be addressed.
- Develop technical standards: Municipalities should develop technical standards for the interconnection of distributed generation systems with the grid. These standards should specify the technical requirements for the installation and operation of distributed generation systems, including issues such as voltage regulation, power quality, and protection against islanding.
- Establish a regulatory framework: Municipalities should establish a regulatory framework that defines the roles and responsibilities of the different stakeholders involved in the integration of distributed generation. This framework should include clear guidelines on the connection process, the licensing and permitting requirements, and the tariffs and incentives for distributed generation.
- Provide training and support: Municipalities should provide training and support to installers and operators of distributed generation systems to ensure that they understand the

technical and regulatory requirements for the installation and operation of these systems. This can include training on safety protocols, system maintenance, and troubleshooting.

- Monitor and evaluate performance: Municipalities should monitor the performance of distributed generation systems to ensure that they are operating safely and efficiently. This can include monitoring of power quality, voltage regulation, and system performance. It is also important to regularly evaluate the economic and environmental benefits of distributed generation systems to ensure that they are delivering the expected benefits to the municipality and its residents.

By following these best practices, municipalities can safely and effectively integrate distributed generation into their networks, helping to increase energy security, reduce greenhouse gas emissions, and promote local economic development.

4.3.1 New Revenue Streams from Distributed Generation integration

Municipalities can generate new revenue streams from the integration of distributed generation in several ways and improve their capacity and energy procurement profile. These include:

- Net metering: Municipalities can implement a net metering program which allows customers who generate excess electricity from their distributed generation systems to receive a credit on their utility bills. By charging a realistic administrative fee for managing the net metering program, municipalities can generate new revenue streams.
- Tariff structures: Municipalities can develop innovative tariff structures that encourage the installation of distributed generation systems. For example, a time-of-use (TOU) tariff could be implemented that incentivizes customers to generate electricity during periods of high demand, when the cost of electricity is highest.
- Power purchase agreements: Municipalities can enter into power purchase agreements (PPAs) with customers who generate electricity from distributed generation systems. Under a PPA, the municipality agrees to purchase the electricity generated by the customer at a fixed price, which can provide a new revenue stream for the municipality.
- Energy wheeling: Municipalities could transfer energy on behalf of third parties over the municipal network and yield revenue from wheeling charges.
- Lease agreements: Municipalities can lease public land or buildings for the installation of distributed generation systems. By charging a lease fee, the municipality can generate new revenue while also promoting the development of renewable energy.
- Carbon credits: Municipalities can generate revenue by selling carbon credits associated with the reduction in greenhouse gas emissions achieved by the integration of distributed generation systems. This can be particularly relevant if the municipality has set carbon reduction targets.

In addition, municipalities can also partner with private sector developers or investors to implement distributed generation projects that can generate shared revenue streams. For example, a municipality can enter into a joint venture with a developer to install solar panels on public buildings, with the revenue from the sale of electricity being shared between the two parties. By implementing these and other strategies, municipalities can generate new revenue streams from the integration of distributed generation, while also promoting the development of renewable energy, increasing energy security, and reducing greenhouse gas emissions.

4.3.2 Strategies that Municipalities can adopt to significantly increase the penetration of Renewable Energy by 2030

To significantly increase the penetration of renewable energy by 2030, municipalities can adopt the following strategies:

- Set ambitious renewable energy targets: Municipalities can set ambitious targets for the share of renewable energy in their overall energy mix, and develop a comprehensive renewable energy strategy to achieve these targets. This strategy should be developed with input from stakeholders and experts, and should take into account the unique local energy context and resources.
- Implement supportive policies and regulations: Municipalities can implement policies and regulations that support the development and deployment of renewable energy technologies, such as solar, wind, and geothermal. This can include measures such as tax incentives, net metering programs, streamlined permitting processes, and feed-in tariffs.
- Develop innovative financing mechanisms: Municipalities can develop innovative financing mechanisms that enable residents and businesses to invest in renewable energy technologies, such as community solar programs, green bonds, and revolving loan funds.
- Promote energy efficiency: Municipalities can promote energy efficiency measures, such as building retrofits, efficient lighting, and smart grid technologies, which can reduce energy demand and make it easier to integrate renewable energy into the grid.
- Engage the community: Municipalities can engage the community in the transition to renewable energy, by providing education and outreach programs, hosting public meetings and events, and involving residents and businesses in the development and implementation of renewable energy projects.
- Collaborate with other municipalities and stakeholders: Municipalities can collaborate with other municipalities and stakeholders, such as utilities, industry, and non-governmental organizations to share knowledge and resources, and to advocate for supportive policies at the regional and national levels.

By adopting these and other strategies, municipalities can significantly increase the penetration of renewable energy by 2030, while also promoting local economic development, reducing greenhouse gas emissions, and increasing energy security. However, achieving these goals will require a sustained and concerted effort from all stakeholders, as well as a commitment to innovation, collaboration, and bold leadership.

4.3.3 Generic Project plan for Deployment

The objective is to increase the share of renewable energy in the municipality's energy mix to 32% by 2030.

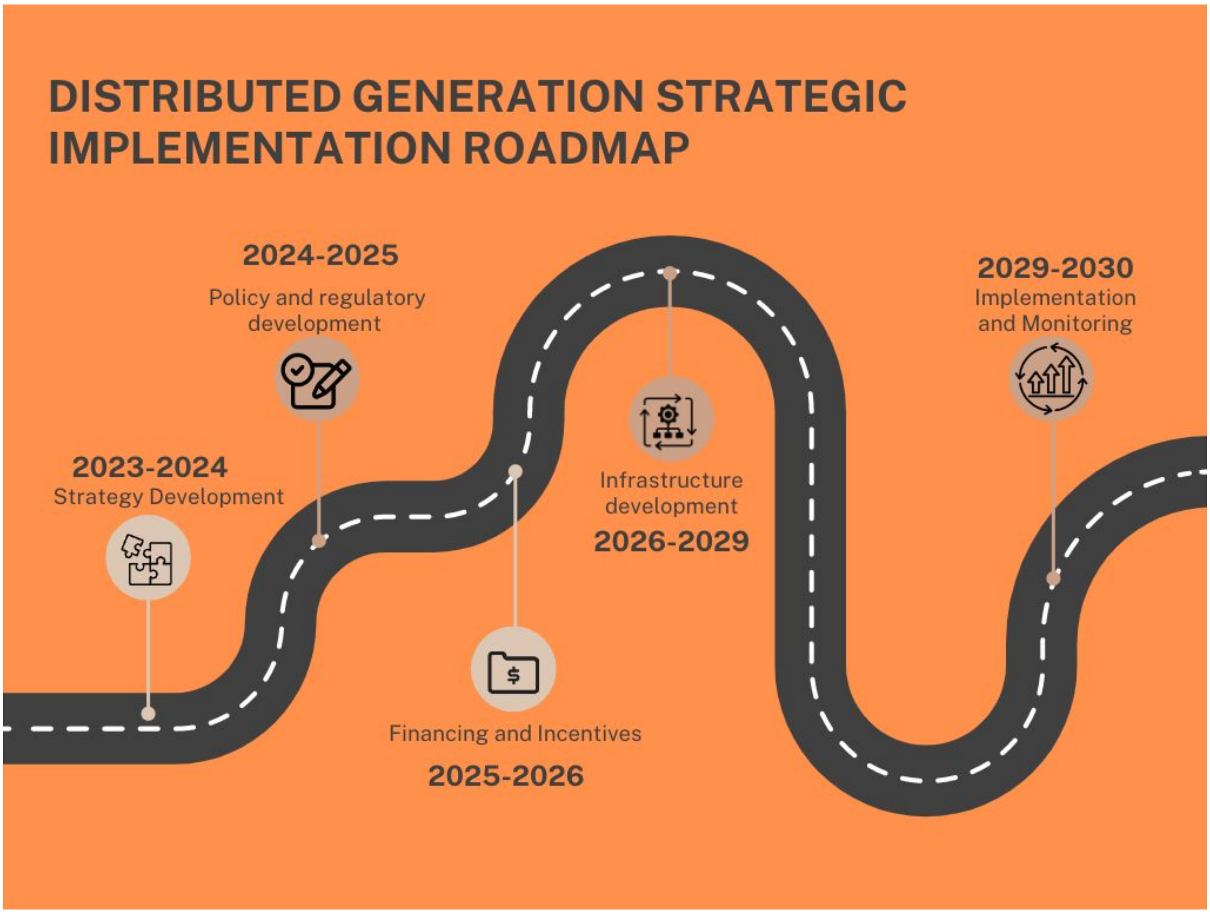

Figure 13: Distributed generation Strategic Roadmap

Phase 1: Strategy development (2023-2024)

- Conduct a comprehensive energy audit to establish a baseline for energy consumption, demand, and emissions.
- Engage stakeholders, including residents, businesses, utilities, and NGOs to develop a renewable energy strategy that takes into account local energy resources, technical and economic feasibility, and community priorities.

- Develop a roadmap for achieving the renewable energy targets, including timelines, milestones, and metrics to measure progress.

Phase 2: Policy and regulatory development (2024-2025)

- Review and update municipal policies and regulations to promote the development and deployment of renewable energy technologies, such as solar, wind, and geothermal.
- Develop new policies and regulations, as needed, to incentivize the adoption of renewable energy technologies, such as tax incentives, net metering programs, streamlined permitting processes, and feed-in tariffs.

Phase 3: Financing and incentives (2025-2026)

- Develop innovative financing mechanisms that enable residents and businesses to invest in renewable energy technologies, such as community solar programs, green bonds, and revolving loan funds.
- Develop and promote incentive programs that encourage the adoption of renewable energy technologies, such as rebates, grants, and tax credits.

Phase 4: Infrastructure development (2026-2029)

- Identify and prioritize renewable energy projects that align with the renewable energy strategy and roadmap, and ensure that they are integrated with other municipal plans and infrastructure investments.
- Work with utilities, industry, and other stakeholders to develop the necessary infrastructure, such as new transmission lines, energy storage systems, and smart grid technologies, to support the integration of renewable energy into the grid.
- Provide technical assistance and capacity building to developers, installers, and operators of renewable energy systems, to ensure that they meet the required technical and regulatory standards.

Phase 5: Implementation and monitoring (2029-2030)

- Implement the renewable energy projects and programs, and monitor progress against the established metrics and milestones.
- Continuously engage with stakeholders and the community, providing education and outreach programs, hosting public meetings and events, and involving residents and businesses in the development and implementation of renewable energy projects.

- Evaluate the economic, environmental, and social impacts of the renewable energy programs and projects, and adjust the strategy and roadmap as needed to ensure that the objectives are achieved.

This is a high-level project plan that can be tailored to the specific needs and resources of the municipality. To implement this plan, the municipality will need to establish a dedicated team to manage the project, secure funding and resources, and engage with stakeholders and partners. The project plan should also be reviewed and updated periodically, to ensure that it remains relevant and effective in achieving the municipality's renewable energy objectives.

5 Key Success Factors

When considering the smart grid journey in South Africa, the industry experience suggests that there are utilities in South Africa that are making progress in respect of technology deployment. However, the progress is dominated by Eskom, some of the metropolitans and a small number of secondary municipalities. Improved planning, which emanates from effective technology maturity and needs assessment, underpinned by well-defined business cases and funding support will be the game changer in respect of technology deployment at utility level. The absence of well-defined business cases and the inability to articulate the benefits/value proposition clearly impact on the ability to get the required buy-in and funding support. The establishment of suitable structured collaboration platforms is of critical importance in ensuring effective technology deployment in the ESI. Figure 14 reflects the indicative technology implementation success drivers.

The smart grid is expected to set the foundation to deliver on the anticipated electrical network's resilience, efficiency and environmental benefits. The transition to a smart grid should focus on achieving value with respect to six key success factors.

The key success factors and enablers for a smart grid establish a basis for specific performance requirements and for measuring progress and benefits. Technology enablers are widely recognised as synonym with leading and best practice utilities. While there is no absolute and defined starting and endpoint in selecting technology enablers, business benefits should play an important role in selecting enablers that will provide the highest return to the business/utility in respect of the investment in technology.

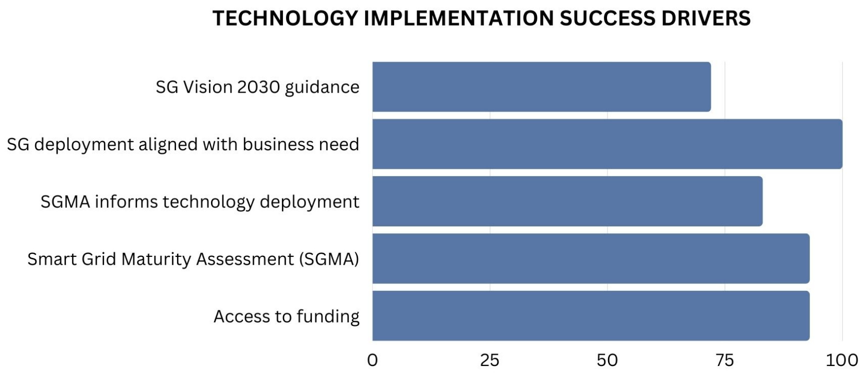

Figure 14: Technology implementation success drivers

Table 7: Key success factors for the smart grid

KEY SUCCESS FACTOR	DESCRIPTION
The grid must be more **reliable**	A reliable grid provides power when and where its users need it, and of the quality they value and are willing to pay for. It provides ample warning of growing problems and withstands most disturbances without failing. It takes corrective action before most users are affected.
The grid must be more **secure**	A secure grid withstands physical and cyber-attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers quickly from disturbances.
The grid must be more **economical**	An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.
The grid must be more **efficient**	An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilization, while providing customers with options for managing their energy usage.
The grid must support greater **environmental sustainability**	An environmentally responsible grid reduces environmental impacts through improvements in efficiency and by enabling the integration of a larger percentage of intermittent renewable resources than could otherwise be reliably supported.

The grid must be **safer**	A safe grid does no harm to the public or to grid workers and is sensitive to users who depend on it for medical necessities. It furthermore serves to improve the safety of the workplace.

6 Principal Characteristics

Meeting the stated performance requirements requires the Smart Grid to include certain important characteristics or features. The Vision describes seven broad principal characteristics which constitute the Smart Grid as follows:

Characteristic 1- Anticipates and responds to system disturbances (self-heals)

The grid must perform continuous self-assessments to detect, analyse, respond to, and as needed, restore grid components or network sections. It must establish a network capable of delivering:

- Real-time monitoring (of voltage, currents and critical infrastructure) and reaction (rapid and effective response to monitored events);
- Anticipation ("fast look-ahead simulation");
- Isolation, where failures do occur (to prevent cascades) and mitigation around failures.

It must be capable of healing itself by performing continuous self-assessments to detect and analyse issues, take corrective action to mitigate them and, if needed, rapidly restore grid components or network sections. It must also handle problems too large or too fast-moving for human intervention. Acting as the grid's "immune system," self-healing is required to help maintain grid reliability, security, affordability, power quality and efficiency.

The self-healing grid must minimise disruption of service by employing modern technologies that can acquire data, execute decision-support algorithms, avert or limit interruptions, dynamically control the flow of power, and restore service quickly. Probabilistic risk assessments based on real-time measurements will identify the equipment, power plants, and lines most likely to fail. Real-time contingency analyses will determine overall grid health, trigger early warnings of trends that could result in grid failure and identify the need for immediate investigation and action.

Communications with local and remote devices will help analyse faults, low voltage, poor power quality, overloads, and other undesirable system conditions, following which appropriate control actions will be taken, automatically or manually as the need determines, based on these analyses.

Characteristic 2- Enables active participation by customer (motivates, empowers, and includes the customer)

Customer choices and increased interaction with the grid bring tangible benefits to both the grid and the environment, while reducing the cost of delivered electricity.

The Smart Grid must give customers information, control, and options that allow them to engage in new "electricity markets." Grid operators will be able to treat willing customers as resources in the day-to-day operation of the grid. Well-informed customers must have the ability to modify consumption based on balancing their demands and resources with the electric system's capability to meet those demands.

Demand-response (DR) programmes present an opportunity to satisfy a basic customer need — greater choice in energy purchases. The ability to reduce or shift peak demand allows utilities to minimise capital expenditures and operating expenses while also providing substantial environmental benefits by reducing line losses and minimising the operation of inefficient peaking power plants. In addition, emerging products like the plug-in hybrid vehicle will result in substantially improved load factors while also providing significant environmental benefits.

The grid must be able and suitably flexible to accommodate existing and anticipated technology developments adopted by customers.

Smart Grid technologies should enable customers to make more intelligent decisions about their energy consumption and further encourage energy optimisation through incentive schemes

Characteristic 3- Operates resiliently against attack and natural disaster

The Smart Grid must operate resiliently against natural disaster, must deter or withstand physical or cyber-attack and must contribute to improved public safety.

The grid must incorporate a system-wide solution that reduces physical and cyber vulnerabilities and enables a rapid recovery from disruptions. Resilience is critical to deter would-be attackers, even those who are determined and well equipped. The decentralised operating model and self-healing features must be designed to make it less vulnerable to natural disasters than the existing grid.

Security protocols should contain elements of deterrence, detection, response and mitigation to minimise impact on the grid and the economy. A less susceptible and more resilient grid will make it a more difficult target for thieves, hackers and terrorists.

Characteristic 4- Provides power quality for 21st century needs

Digital-grade power quality for those who need it avoids production and productivity losses, especially in digital-device environments.

The Smart Grid is required to provide power quality (PQ) for the digital economy. It must monitor, diagnose, and respond to power quality deficiencies, leading to a reduction in the business losses currently experienced by customers due to insufficient power quality. New power quality standards will balance load sensitivity with delivered power quality. The Smart Grid might be required to supply varying grades of power quality at different pricing levels.

Characteristic 5- Accommodates all generation and storage options

Diverse resources with "plug-and-play" connections multiply the options for electrical generation and storage, including new opportunities for more efficient, cleaner power production.

The Smart Grid is required to seamlessly integrate all types and sizes of electrical generation and storage systems using simplified interconnection processes and universal interoperability standards to support a "plug-and-play" level of convenience. Large central power plants including environmentally friendly sources, such as wind and solar farms and advanced nuclear plants, will continue to play a major role even as large numbers of smaller distributed resources, including plug-in electric vehicles, are deployed.

Various capacities from small to large will be interconnected at essentially all voltage levels and will include distributed energy resources such as photovoltaic, wind, advanced batteries, plug-in hybrid vehicles and fuel cells. It will most likely be easier and more profitable for commercial users to install their own generation such as highly efficient combined heat and power installations and electric storage facilities. The grid must be capable of facilitating these developments in a cost-effective manner.

Characteristic 6- Enables new products, services, and markets

The Smart Grid will enable an open-access market that reveals waste and inefficiency and helps drive them out of the system while offering new customer choices such as green power products and a new generation of electric vehicles. Smart Grids also reduce transmission congestion that in turn leads to more efficient electricity markets.

The Smart Grid will link buyers and sellers across the value chain. It will support the creation of new electricity markets from the home energy management system at the customers' premises to the technologies that allow customers and third parties to plug into the electricity market.

Customer response to price increases felt through real-time pricing is expected to mitigate demand and energy usage, driving lower-cost solutions and spurring new technology development. New, clean energy-related products will also be offered as market options.

The Smart Grid must support consistent market operation across regions. It will enable more market participation through increased transmission paths, aggregated demand response initiatives and the placement of energy resources including storage within a more reliable distribution system located closer to the customer.

Characteristic 7- Optimises assets and operates efficiently

Desired functionality at minimum cost must guide grid operations and allow fuller utilisation of all assets. The smart grid must allow more targeted and efficient grid maintenance programmes that will minimise equipment failures and provide for safer operations.

Operationally, the smart grid is required to improve load factors, lower system losses, and provide for a step change improvement in outage management performance. The availability of additional grid intelligence must give planners and engineers the knowledge to build what is needed, when it is needed, extend the life of assets, repair equipment before it fails unexpectedly, and more effectively manage the workforce that maintains the grid. Operational, maintenance, and capital costs should be reduced thereby keeping downward pressure on electricity prices.

Table 8: Comparison of the Existing and Envisaged Grid in terms of Principal Characteristics

Existing grid	Principal characteristics	Envisaged Smart Grid

Customers have limited information and opportunity for participation with power system unless under direct utility control.	**Enables informed and greater participation by customers**	Informed, involved, and active customers – demand response and distributed energy resources.
Dominated by central generation – many obstacles exist for distributed energy resources interconnection and operation.	**Accommodates all generation and storage options**	Many distributed energy resources with plug-and-play convenience; distributed generation with local voltage regulation capabilities to support high penetration on distribution systems; responsive load to enhance grid reliability, enabling high penetration of renewables; frequency- controlled loads to provide spinning reserve.
Limited wholesale market, not well integrated – limited opportunities for customers.	**Enables new products, services, and markets**	Mature, well-integrated wholesale markets; growth of new electricity markets for customers; interoperability of products.
Focus on outages and primarily manual restoration – slow response to power quality issues, addressed case-by-case.	**Provides power quality for the range of needs in the 21st century**	Power quality is a priority with a variety of quality/price options – rapid resolution of issues
Limited integration of operational data with asset management – business process silos limit sharing.	**Optimises assets and operates efficiently**	Greatly expanded data acquisition of grid parameters – focus on prevention, minimising impact to customers.

Responds to prevent further damage – focus is on protecting assets following a fault	**Addresses disturbances – automated prevention, containment, and restoration**	Automatically detects and responds to problems – focus on prevention, minimising impact to customers, and automated restoration.
Vulnerable to inadvertent mistakes, equipment failures, malicious acts of terror and natural disasters.	**Operates resiliently against physical and cyber-attacks and natural disasters**	Resilient to inadvertent and deliberate attacks and natural disasters with rapid coping and restoration capabilities.

7 Key Technology Application

Deployment of appropriate technology applications is the key to achieving the stated success factors, performance requirements and principal characteristics of the Smart Grid. Identifying the relevant applications will influence and improve how the Smart Grid is planned, designed, operated, and maintained throughout the value chain. The focus here is therefore on which technology applications to implement and at what pace to achieve a cost-effective, sustainable and beneficial Smart Grid solution for South Africa.

These applications should incorporate and prioritise those technology solutions that will provide a positive return on investment over the deployed asset life cycle. This is achieved through energy demand reductions, savings in overall system operation costs, delayed capital investment, requiring smaller generation reserve margins, lower maintenance and servicing costs (e.g. reduced manual inspection of meters), reduced grid losses, new customer service offerings and improved customer service levels.

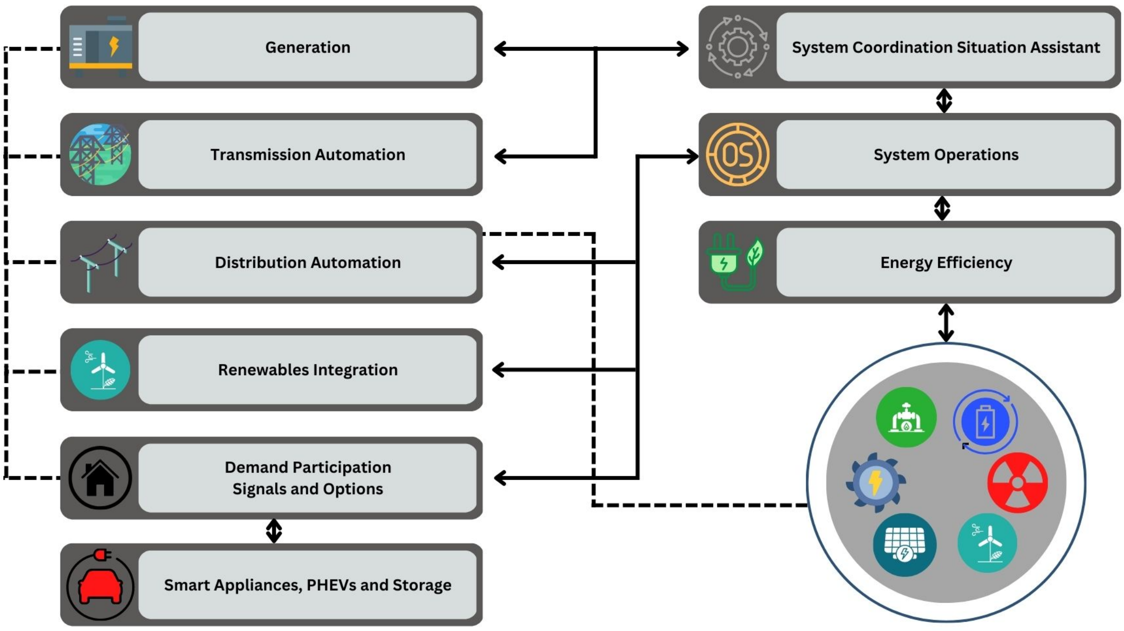

Figure 15: Envisaged Smart Grid Initiative and Interfaces for South Africa

The following applications are included in the identified Smart Grid solution for South Africa:

- Advanced Metering Infrastructure (AMI)
- Customer Side Systems (CS)

- Demand Response (DR)
- Distribution Management System/Distribution Automation (DMS)
- Transmission Enhancement Applications (TA)
- Asset/System Optimization (AO)
- Distributed Energy Resources (DER)
- Information and Communications Integration (ICT)

The deployment of these applications directly correlates to achieving the key success factors of reliability, economics, efficiency, environmental, safety and security as shown in Figure 16:

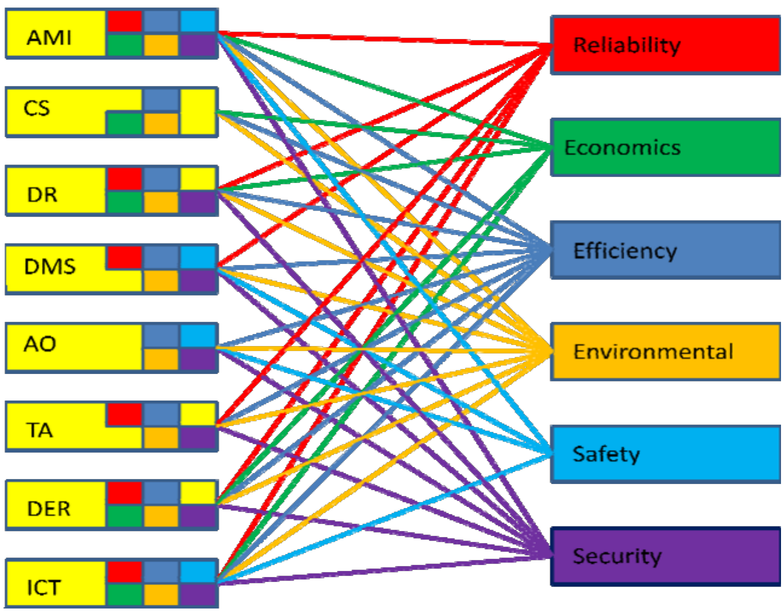

Figure 16: Illustrating the Correlation between Applications and Key Success Factors

The applications are roughly aligned to four functional areas of the Smart Grid. The four functional areas are defined as Customer Enablement (CE), Advanced Distribution Operations (ADO), Advanced Transmission Operations (ATO), and Advanced Asset Management (AAM) and correspond with the applications as illustrated below:

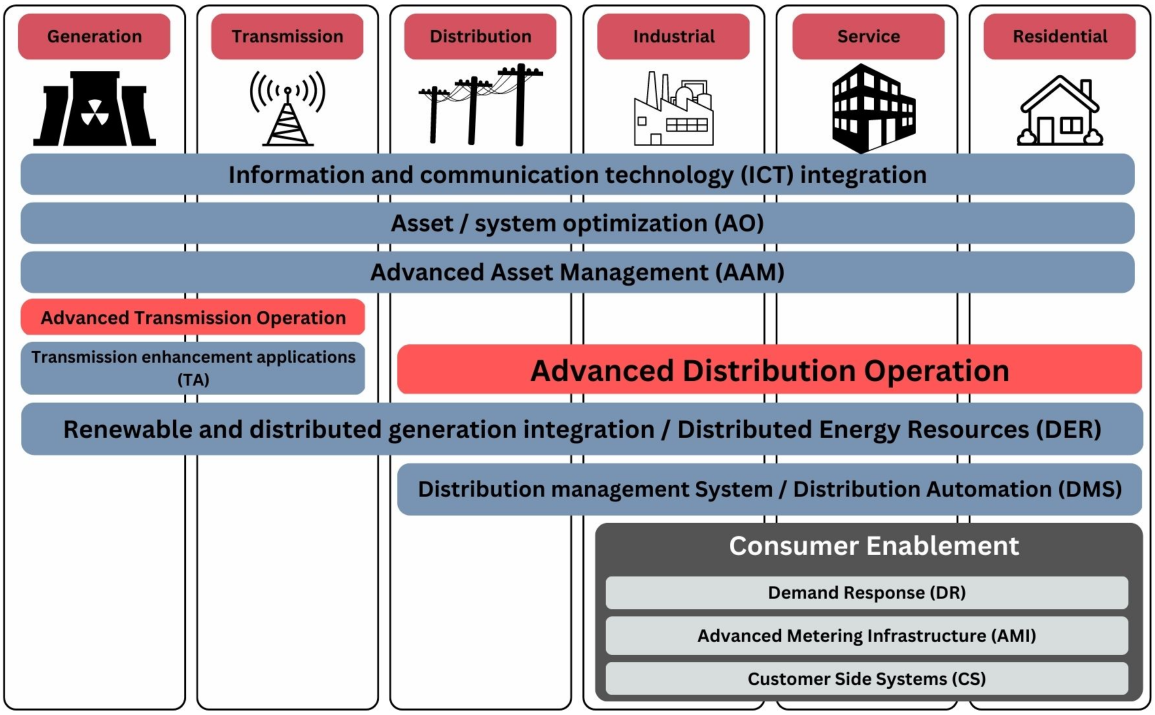

Figure 17: Correlating the Prioritised Applications with the Four Functional Areas

The final realisation of a Smart Grid is a system that demonstrates all seven of the principal characteristics across all four functional areas as shown in Table 9 below.

Table 9: Correlation between smart grid principle characteristics and functional areas

PRINCIPAL CHARACTERISTIC	CE	ADO	ATO	AAM
Enables informed and greater participation by customers	X	X		
Accommodates all generation and storage options	X	X	X	
Enables new products, services, and markets	X	X	X	
Provides power quality for the range of needs in the 21st century	X	X	X	X
Optimizes assets and operates efficiently	X	X	X	X
Addresses disturbances – automated prevention, containment, and restoration	X	X	X	X
Operates resiliently against physical and cyber-attacks and natural disasters	X	X	X	

The functional areas can be used to structure a "roadmap" of an ordered and cost effective strategy towards a smarter grid while keeping the Vision goals/targets in mind. It is possible to use each functional area to develop a business case and then integrate these four business cases together to determine the most productive transformation plan for South Africa with its own limitations, priorities and cost concerns. In a general sense, sequencing of the Smart Grid implementation within the functional areas with consideration of a "roadmap" can help in implementing and maximising the benefits (see Figure 20). A "roadmap", based on this proposed approach, will be developed as part of the Smart Grid framework to provide industry guidance in terms of the Vision, but will not prescribe the journey that each utility should take.

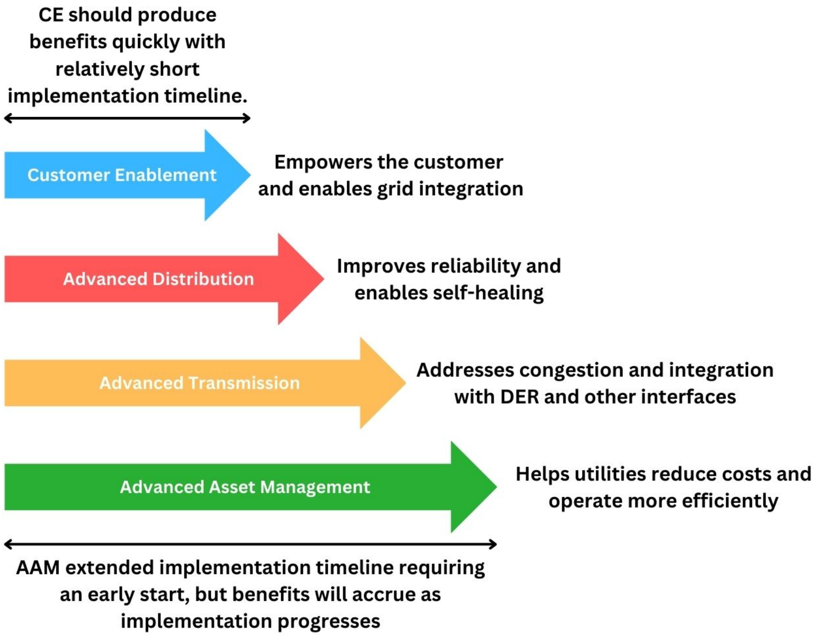

Figure 18: Indicative Smart Grid Sequencing Roadmap

It should be recognised that Smart Grid benefits are optimised when applications across the respective functional areas are combined across the ESI (from generation to residential) as shown in Figure 18 above. As the functionalities from various applications combine, the potential benefits from the Smart Grid increases exponentially to all stakeholders. There is however a point when further investment in applications deliver smaller returns (see Figure 19). The Vision and overall SASGI Smart Grid framework aim is to assist with unlocking optimal benefits for the given investments.

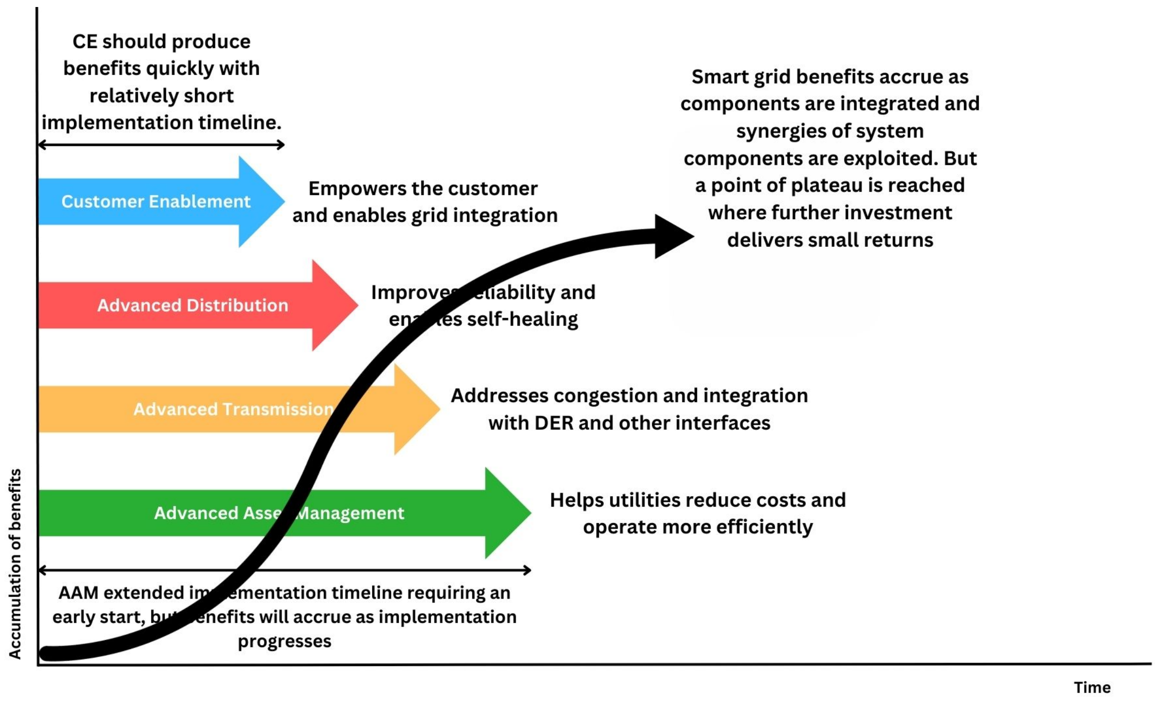

Figure 19: Accumulation of Benefits as Smart Grid Components are Incorporated

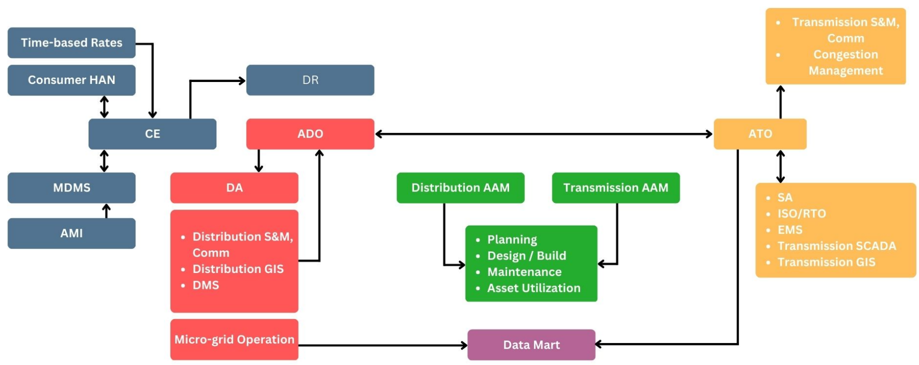

Figure 20: Comprehensive View of Smart Grid Applications in each Functional Area

As indicated previously, a cohesive Smart Grid framework will allow each utility to identify functional areas with the most severe challenges in the utility network and to prioritise the selection of applications in terms of the most urgent need and greatest anticipated return. Each of the listed applications is therefore described briefly in the context of the functional area (CE, ADO, ATO, AAM) to which it is allocated.

8 Metrics

Metrics and targets provide a framework against which to monitor the transformation of the national electricity infrastructure into the envisaged Smart Grid and to gauge the value of the resulting contribution to the country; it is therefore a critical aspect of the Vision. At a high-level, the Smart Grid objectives will serve as the metrics to track progress towards delivering on the South African Smart Grid Vision. However, it recognises that these metrics will be composed of several sub metrics that will require aggregation across industry sections and across entities/role players. It is also recognised that the metrics would represent an industry average with varying targets and statuses for individual entities.

A monitoring system that can evaluate performance of the Smart Grid applications against these metrics should continually guide the national roll out. It is anticipated that performance against these metrics will be composed of a more detailed framework of KPIs across the industry that will be tracked and aggregated across the industry to report performance at this level. It is proposed that a standard framework and standard definition of metrics is agreed on as part of the process to develop standards for Smart Grids.

Metrics should serve to gauge the impact of the Smart Grid and guide adjustments and refinements to improve the contribution of the grid. The following should be given consideration in developing the comprehensive metrics in support of the stated Smart Grid objectives:

- Peak demand reduction for system and energy efficiency: Smart Grid technologies of AMI, energy management systems and grid-responsive devices and appliances coupled with dynamic pricing programmes will enable informed customer participation in demand response as a key focus for peak demand reduction. Key performance measures include cyber security standards for smart metering to address security concerns at all stages of AMI deployments, development of smart appliances responsive to grid conditions and pricing signals, feasibility demonstration of peak demand reduction at select prototypical feeders and an interim measure to track the progress trend toward the Vision targets.
- Grid reliability and resilience: Distribution/feeder automation, micro-grid and modelling tools will enable advanced distribution operations to reduce outage durations and frequencies, provide fast responses to outage events and provide the differentiated reliability services to meet individual customer needs. Key performance measures include simulation tool development and integration of models into an operational distribution management system for planning/outage management/customer information services and feasibility demonstrations of advanced distribution operational designs (adaptive circuit

reconfiguration, distributed energy storage, and micro-grids) to provide differentiated reliability services and critical load protection.

- Operational and system efficiency: Dynamic sensing, monitoring and control technologies will reduce energy losses and enhance utilisation of available assets, all driving to improve the overall load factor. Key performance measures include a near-term reduction in line losses through conservation voltage reduction, smart chargers with grid awareness to charge PHEVs at off-peak periods per customer choice and diagnostic tools for condition-based maintenance to reduce the O&M costs.
- Distributed and renewable energy integration for increased reliability, efficiency and system security: Standards, voltage regulation and protection coordination schemes are critically important for high penetration levels (>15%, as a rule of thumb) of distributed generation into the grid. Key performance measures include development of voltage regulation conditioners to address variability of renewable generation, protection solutions at both the utility and customer sides for voltage and frequency deviations under conditions where the distributed generation capacity varies with respect to the connected loads together with DC distribution architectures for buildings or communities to connect DC generation sources directly with DC loads.
- Public and worker safety: The grid through its advance sensors will provide the utility solutions for managing potential risk to both the utility and public. These would involve detection of contact incidents at substation level with feeder identification capability, detection of dead-side return ("back-feed") to broken conductors with the load side on the ground (a particularly significant problem), embedded technologies to improve present working practices by real time work management systems and isolation of faults to limit potential risk on public.

9 Stakeholder Acknowledgement

SANEDI would like to acknowledge the following people for contributing to this document:

Vally Padayachee	Association of Municipal Electricity Utilities
Gerhard Brown Kadri Nassiep Leila Mahomed Weideman	City of Cape Town
Devesh Mothilall	City of Johannesburg
Humbulani Manyaga Malerato Mohlala Palma Maluleke Tshidiso Ngoedi	City Power
John Isaac	Council for Scientific and Industrial Research
Lesego Mazibuko Vusani Nemaxwi	Department of Mineral Resources and Energy
Barry MacColl	Electric Power Research Institute
Azwimbavhi Mamanyuha Edison Makwarela Ken Hales Malcolm van Harte	ESKOM
Jonathan Hunsley	eThekwini Municipality
Mluleki Hlatshwayo	Gauteng Provincial Government
George Malotane	Mogale City Local Municipality
Dorcas Rakgalakane Moefi Moroeng Mondli Shozi	National Energy Regulator of South Africa
Linoh Magagula	National Metrology Institute of South Africa
Hendri Geldenhuys	South African Institute of Electrical Engineers
Keorapetse Kgaswane Prathaban Moodley Simphiwe Mokonza Teslim Muhammed Yusuf Titus Mathe Unarine Mudau	South African National Energy Development Institute

Crescent Mushwana	Southern Africa Energy Program
Deon Louw	Stellenbosch Municipality
Raj Naidoo Vera Kriel Willem johannes De beer	University of Pretoria
Charlotte Talane Erlin Moll Gordon Dindi Imran Chotia Shane Bessenger Thulebona Memela	SASGI and Other Organisations

SANEDI would like to acknowledge the following people for contributing to the first Vision Document published in 2017:

Hannes Roos	Association of Municipal Electricity Utilities
Marius Van der Westhuizen Kadri Nassiep Siya Gqwede	City of Cape Town
Alex Bhiman Thabo Mahlasti	City of Johannesburg
Ronny Mazibuko Sicelo Xulu Xolani Lembede	City Power
James Masonganye Junior M. Tlabela Robert Masawanganyi	City of Tshwane
Adnan Abu Mahfouz Clinton Carter Brown Ntsibane Ntlatlapa	Council for Scientific and Industrial Research
Costas Angelides Rebecca Maseremule Thabang Audat	Department of Mineral Resources and Energy
Mark Wilson	Ekurhuleni
Maxwell Mthembu Jonathan Hunsley Sandile Maphumulo	eThekwini
Amal Khatri Comfort Masike Gerhard Botha Nick Singh Philip Groenewald Vic Lawrence	ESKOM
Bernard Bekker Bruce Raw	Green Cape
Lucky Nhlanhla Ngidi Ronald Chauke	National Energy Regulator of South Africa
Humphrey Mthimkhulu Mvuleni Bukula Peter Neilson Tando Tsepane	Nelson Mandela Bay Municipality

John Mtombeni Paul Johnson Willa Breed	South African Bureau of Standards
Mike Cary Paul van Niekerk	South African Institute of Electrical Engineers
Linda Manyuchi Tubasti Moloi	South African Local Government Association
Minnesh Bipath (RIP) Nombulelo Faleni Teslim Mohammed Yusuf	South African National Energy Development Institute
Tsakani Mthombeni Yatish Sewgoolam	Technology Innovation Agency

References

1. National Energy Technology Laboratory (NETL) for the United States Department of Energy (USDoE) June 2009, *A Vision for the Smart Grid, The Modern Grid Strategy*, National Energy Technology Laboratory and the US Department of Energy Office of Electricity and Energy Reliability.
2. Electric Power Research Institute (EPRI) 2004 and 2010, *Power Delivery System of the Future*, EPRI.
3. Miller, Joe 2012, *What is a Smart Grid?*, Smartgridnews.com January 2012, viewed 22 February 2013, http://www.smartgridnews.com/artman/publish/commentary/What_Is_the_Smart_Grid-567.html#.USeLulqtw7Q
4. Electricity Regulation Act: Electricity Regulations for Compulsory Norms and Standards for Reticulation Services (GN 773), DME 2008.
5. National Energy Technology Laboratory (NETL) for the United States Department of Energy (USDoE) February 2008, *Modern Grid Initiative Powering our 21st-Century Economy*, US Department of Energy National Energy Technology Laboratory
6. University of San Diego School of Law 2006, *The Energy Policy Initiatives Centre*,
7. Salaris, G.M. Udine April 2011, *From Smart Metering to Smart Grids: The Enel Vision*, IEEE ISPLC
8. PriceWaterhouseCoopers 2011, *Smart from the start: Managing smart grid programmes*, Energy, Utilities and Mining roundtable discussion paper, PWC.
9. Giglioli, E Panzacchi, C and Senni, L, 2010, *How Europe is approaching the smart grid*, McKinsey & Company
10. OECD, 2013, *OECD Economic Surveys: South Africa 2013*, OECD Publishing. http://dx.doi.org/10.1787/eco_surveys-zaf-2013-en
11. South Africa Cities Network (SACN), 2011 State of City Finance Report, 2011
12. Auditor General, 2012, *Consolidated General Report on the audit outcomes of Local Government 2010 – 11*, RP216/2012, ISBN: 978-0-621-41079-2, SACN
13. Andersen TB and Dalgaard CJ, February 2012, Power Outages and Economic Growth in Africa, Department of Business and Economics, University of Southern Denmark, 2012.
14. Department of Energy 2011, *Cost of Unserved Energy (COUE) – IRP Input Parameter information sheet*, DOE
15. Subramoney K 2012, *Advanced Metering Infrastructure (AMI) in South Africa, Eskom's Challenges and Lessons Learned*, 7th Annual metering billing / CRM Asia 2012, Bangkok, 9 May 2012.
16. EPRI 2011 Estimating the Costs and Benefits of the Smart Grid, Electric Power Research Institute

17. “Solutions that realize next-generation transmission distribution through iot technologies product/technical services — transmission distribution — toshiba energy systems solutions,” www.global.toshiba. [Online]. Available: https://www.global.toshiba/ww/products-solutions/transmission products-technical-services/iot.htm

18. M. Jafari, A. Kavousi-fard, T. Chen and M. Karimi, "A Review on Digital Twin Technology in Smart Grid, Transportation System and Smart City: Challenges and Future," in IEEE Access, doi: 10.1109/ACCESS.2023.3241588.

19. A. Fuller, Z. Fan, C. Day and C. Barlow, "Digital Twin: Enabling Technologies, Challenges and Open Research," in IEEE Access, vol. 8, pp. 108952-108971, 2020, doi: 10.1109/ACCESS.2020.2998358.

20. B. Sicard, N. Alsadi, P. Spachos, Y. Ziada and S. A. Gadsden, "Predictive Maintenance and Condition Monitoring in Machine Tools: An IoT Approach," 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), Toronto, ON, Canada, 2022, pp. 1-9, doi: 10.1109/IEMTRONICS55184.2022.9795726.

21. A. K. Pandey, V. Kumar Jadoun and J. N. S., "Virtual Power Plants: A New Era of Energy Management in Modern Power Systems," 2021 8th International Conference on Signal Processing and Integrated Networks (SPIN), Noida, India, 2021, pp. 538-543, doi: 10.1109/SPIN52536.2021.9566063.