



energy

Department:
Energy

REPUBLIC OF SOUTH AFRICA

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

DRAFT SUBMISSION

It is hereby certified that the Smart Grid 2030 Vision was developed by South African Smart Grid Initiative (SASGI) under the guidance of the Department of Energy and the South African National Energy Development Institute (SANEDI). The document takes into account all the relevant policies, legislation and other indications of the national direction for the energy sector. The Vision Document will now be submitted to the Department for internal review.

This National Smart Grid Vision forms part of a set of working documents developed by the South African Smart Grid Initiative (SASGI). It serves to create a National framework and to guide the national approach to Smart Grid implementation in South Africa.

Disclaimer:

This publication has been produced with the assistance of the European Union. The contents of this publication are the sole responsibility of the South African Smart Grid Initiative and the implementing partner, Danish Management and can in no way be taken to reflect the views of the European Union.

Foreword

Adequate electricity availability is a fundamental requirement for supporting South Africa's economic growth and development targets. South Africa's electricity infrastructure countrywide is urgently in need of renewal and enlargement to meet growing electricity demands whilst integrating new, sustainable energy options. This presents significant industry challenges but also opportunities for modernisation and new development.

Appropriate national grid development solutions with a balanced leverage of proven and new technologies are an important part of the response to these challenges. An electricity network with greater intelligence will facilitate the integration of renewable energy, supporting national energy objectives and the transition towards a low-carbon economy. The development and application of smart grid solutions will enable the electricity network to bring considerable additional benefits to customers through improved quality of power supply, more accurate billing and better management of energy consumption. At the same time, it can also be a real source of employment and economic growth.

This Smart Grid 2030 Vision articulates the long-term aspirations and development objectives for the electricity supply industry in South Africa. This Vision does not define a final result but rather an accelerated journey with progress and goals towards continuously achieving the benefits of a smart grid as defined now and with any changes the future may bring.

The objective of the Vision is to bring together all parties involved in smart grids to collaborate towards a focused, integrated, optimal smart grid journey for the country. The Vision also aims to provide insight and inspiration to all industry participants so that they may join or support this journey. Attainment of the Smart Grid 2030 Vision depends on the serious commitment of each and every stakeholder. In this regard, Government solicits the fullest and unwavering support of everyone, so that together we achieve a successful transition that will support South Africa on its path towards excellence.

It is intended that this document be kept live and reviewed after the pilot studies are complete but also aligned to the political term priorities.

Department of Energy: Republic of South Africa

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Abbreviations and Acronyms

ADAM	Approach to Distribution Asset Management
ADO	Advanced Distribution Operation
AMI	Advanced Metering Infrastructure
AO	Asset System Operation
ATO	Advanced Transmission Operation
CC	Climate Change
CE	Customer Enablement
CSM	Customer Side Systems
CV	Conventional Vehicles
DEA	Department of Environmental Affairs
Department	Department of Energy (also referred to as the 'DoE')
DER	Distributed Energy Resources
DMS	Distribution Management System / Distribution Automation
DOT	Department of Transport
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')
EDI	Electricity Distribution Industry
EE	Energy Efficiency or Energy Efficient (as the context dictates)
EEDSM	Energy Efficiency Demand Side Management
ESI	Electricity Supply Industry
Eskom	Eskom Holdings Limited
FACTS	Flexible AC Transmission
FBE	Free Basic Electricity
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
Government	The South African Government

HAN	Home Area Network
HVDC	High Capacity High Voltage
IBT	Inclined Block Tariff
ICT	Information and Communications Technology
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
National Energy Act	National Energy Act of 2008 (as amended)
NEES	National Energy Efficiency Strategy
NERSA	National Energy Regulator of South Africa
NETL	National Energy Technology Laboratory (USA)
PEV	Plug-in Electric Vehicles
PHEV	Plug-in Hybrid Electric Vehicles
PQ	Power Quality
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
SASGI	South African Smart Grid Initiative
SME	Small and Medium Enterprise
TA	Transmission Enhancement Applications
UNIDO	United Nations Industrial Development Organization
WAMS	Wide Area Measurement System

EXECUTIVE SUMMARY

The Vision forms part of a greater framework that is being developed by the South Africa Smart Grid Initiative to guide effective transition to a coherent, modernised national electricity infrastructure. 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. 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 significant. If South Africa is to ensure an acceptable quality of life for all South Africans and economic growth, new investments must be made different from the business as usual way of doing things in the past. With these challenges comes an opportunity to incorporate greater intelligence and automation into the network that can optimally support the electricity requirements of the country.

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 Vision also describes the Smart Grid and the expectations thereof in terms of key success factors, performance requirements, principle characteristics and the key applications identified to deliver on these. Metrics and targets are furthermore suggested as 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 proposed that the South African grid should be advanced not by gathering a collection of interesting technologies and calling it modern or smart or intelligent but by first defining a vision and then constructing 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 realisation.

In conclusion, the Smart Grid Vision 2030 aligns to the Department of Energy’s medium term objectives which will pave the way towards achieving its vision to ensure that 30% of the energy is derived from clean energy sources.

1. VISION PURPOSE

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.

The purpose of the Vision is to describe the aspirational future state of the ESI in South Africa. 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 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.

In describing this vision, it is recognised that the electricity industry is dynamic and that a level of "grid smartness" exists and is currently being pursued/implemented. It is furthermore, recognised that energy supports and leads economic development and should be responsive to the ever-increasing complexity of power supply and consumption requirements. The Vision may therefore, continue to evolve in time but is intended to describe, as best possible with current information, what the aspirations are amidst the changing landscape.

The Vision forms part of a comprehensive framework that is being created for a Smart Grid in South Africa as illustrated in Figure 1 next page. In addition to the Vision (1), the framework will 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, will give a clear direction on the required and prioritised functionalities (6) and implementation guidelines (7) to aid role players and stakeholders with appropriate technology selection and implementation where required.

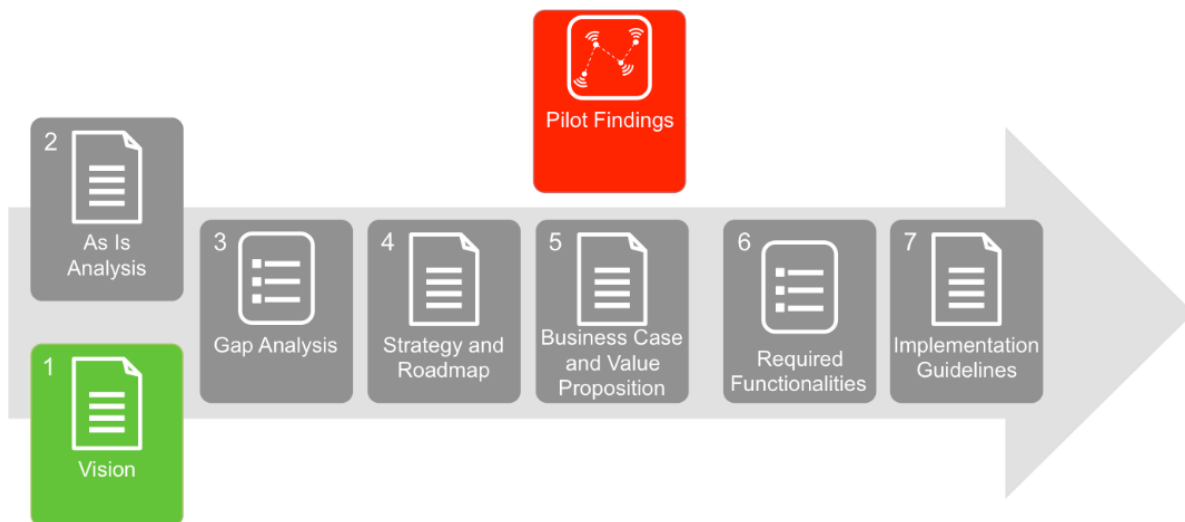


Figure 1. Logical Framework to Guide Smart Grid Implementation in South Africa

The development of the Vision will follow a consultative and inclusive approach to accomplish the necessary paradigm shift amongst all stakeholders (refer Figure 2). 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 South African National Energy Development Institutes (SANEDI) through its Smart Grids Programme is the secretariat supporting the day to day running of SASGI. The SASGI forum provides the platform for the process to develop the Vision Document and, subsequently, also other critical aspects of the Smart Grid framework (e.g. the business case and roadmap). 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.

While the strategy and roadmap will emerge from the Vision, the Vision does assume that the implementation of Smart Grid applications can be approached in a flexible way i.e. any role player has the freedom to leverage or prioritise the implementation of an aspect of the Smart Grid to suit specific 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.

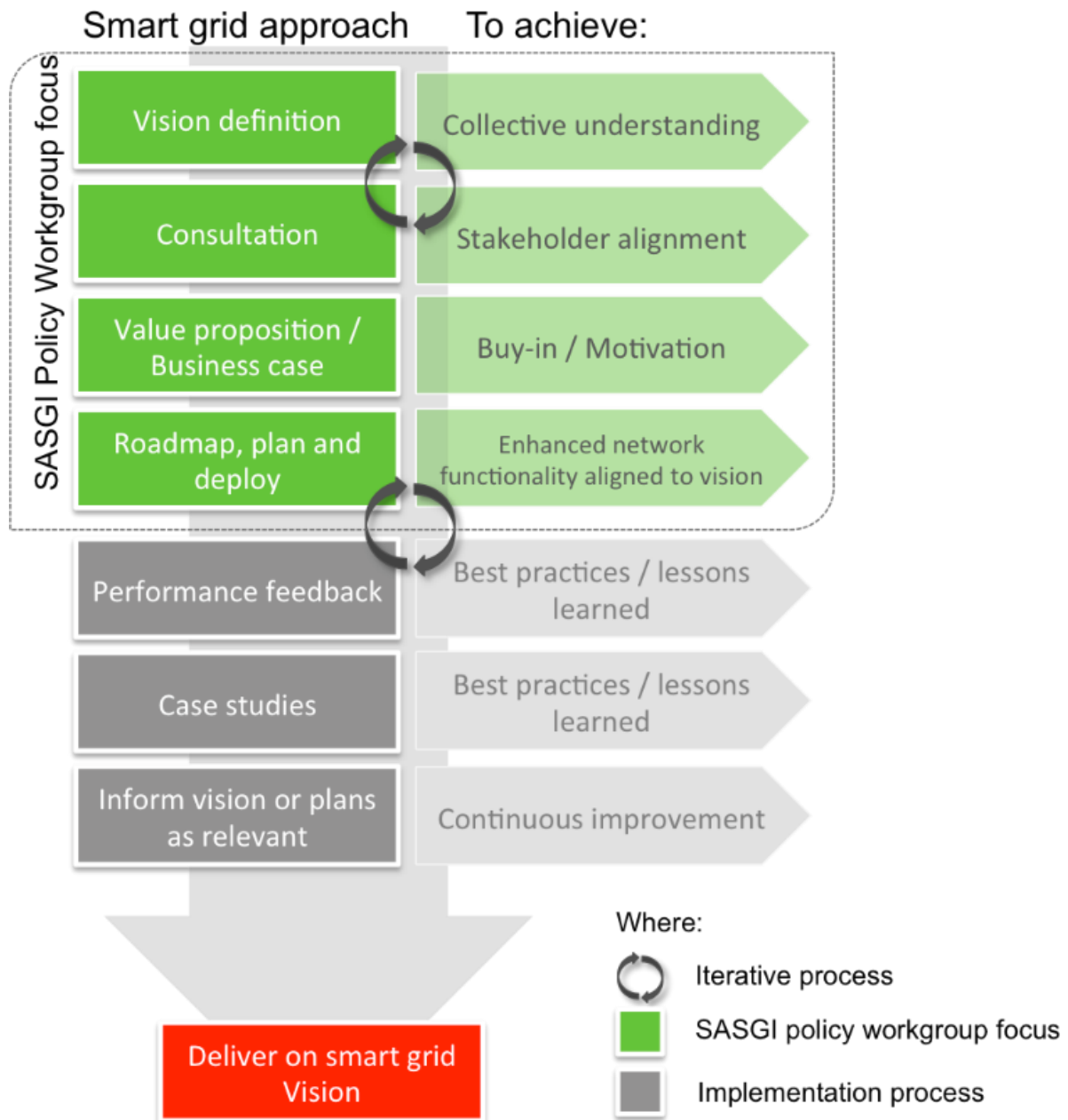


Figure 2. Smart Grids Vision Development Approach

An analogy used by National Energy Technology Laboratory (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 into which the components and building blocks of the novel (characters, plots, chapters, and narrative) are built and integrated in a way which

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 constructing 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 realisation.

Figure 2. above explains the steps to building the case for the introducing of change and the interactive processes of the implementation across value with focus to continuous improvement. This means that the Vision may be ambitious without compromising on critical requirements because of resource constraints. On the other hand, it also emphasises the need for the Vision to give clear direction that will ensure that disconnected, independent implementation of applications are aligned and can be integrated into the national network / system.

2. BACKGROUND AND CONTEXT TO THE VISION

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 needs (conceptually illustrated in Figure 3). 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.

2.1. GENERATIONS 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 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.

2.2. 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 report⁸ 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 such where 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, necessitate 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 1.

Table 1. Outage management and reliability of supply

Municipality	No. of Outages (Monthly)	Average downtime per disruption
# 3	0 (Planned)	3 hrs to 1 week
	20 (Unplanned)	
# 5	20 (Planned)	Planned – < 8 hours Unplanned – < 1 hour
	30 (Unplanned)	
# 11	6 (Planned)	6 – 48 hours
	6 (Unplanned)	
# 14	8 (Planned)	Not available
	150 (Unplanned)	

Municipality	No. of Outages (Monthly)	Average downtime per disruption
# 19	1 (Planned)	½ hour
# 21	3 (Unplanned)	1 Hour
# 22	2 Not available	Not available
# 23	1 (Planned)	2-3 Hours
	2 (Unplanned)	

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 3) 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.

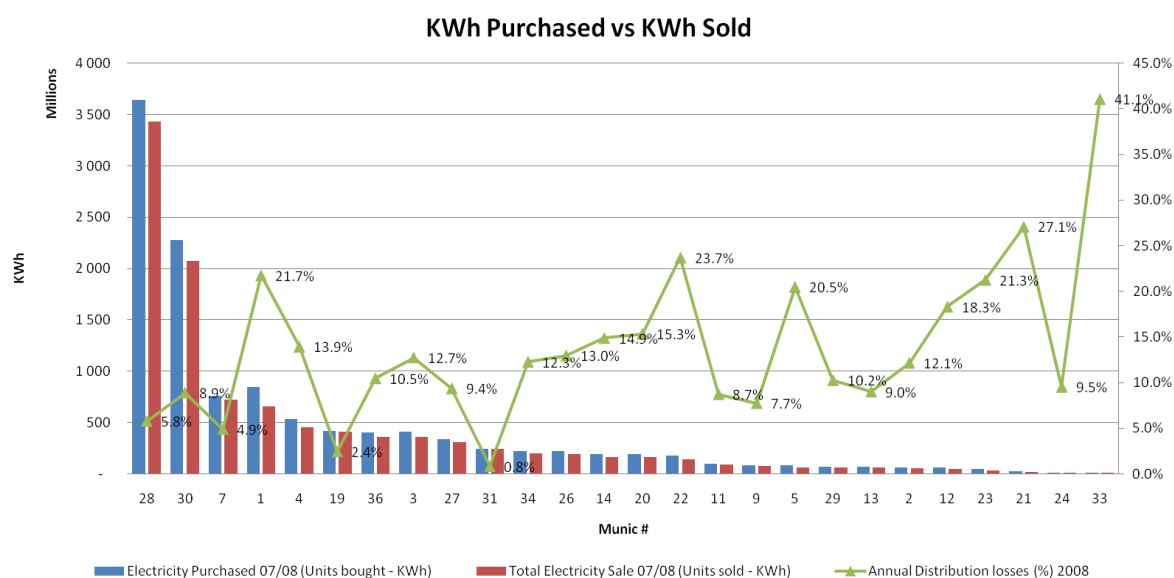


Figure 3. Electricity Industry Losses Performance Data

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 to 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 4, in the growing complexity of the existing and anticipated demands on the energy system.

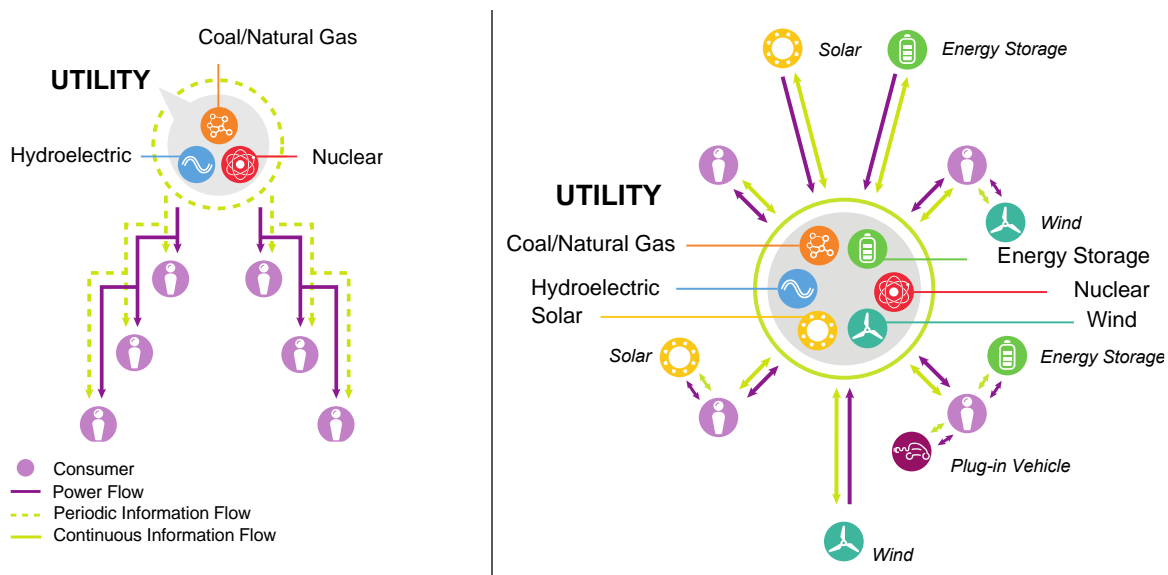


Figure 4. Conceptual Model of Holistic and Transformed Energy Systems (Source IBM)

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 at the same time 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.

2.3. SMART GRIDS

The concept of the Smart Grid has been around for many years and has evolved significantly over time covering a broad spectrum of technologies and functions. The electricity grid-related challenges experienced during the last decade in countries such as the USA, Europe, UK, etc. did however significantly accelerate the deployment of Smart Grid applications. While the drivers might have differed from country to country, the Smart Grid applications were successfully used to overcome and address the challenges at hand. As a result, there are many Smart Grid definitions and explanations. Some definitions describe the Smart Grid in terms of function and/or technology capability and/or benefits offered. From all these, a few key elements common to most definitions emerge: communication, integration and automation which is sustainable, economic and secure.

A definition that 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:

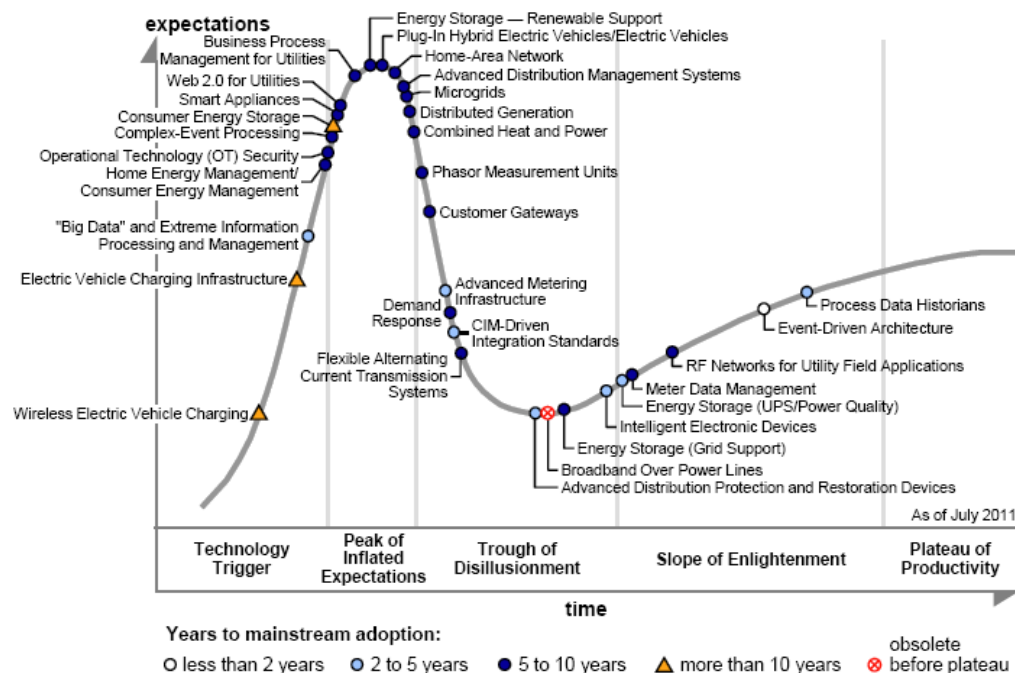
“A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies”.

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.

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 5) for Smart Grid technologies showed most related technologies had advanced far towards widespread adoption.



Source: Gartner (July 2011)

Figure 5. 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 of this, 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.

2.4. 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 are 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 it will contribute 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 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.

2.5. RELEVANCE TO SOUTH AFRICA

South Africa's electricity industry is facing significant structural changes (refer the shift illustrated in Figure 4, page 12) combined with the urgent need for major improvements to aging and inadequate (as a result of growing demand and increased footprint) infrastructure in the power supply and delivery system. Incorporating a greater intelligence into the new infrastructure presents an opportunity to create an energy system that is economically, socially and environmentally ethical, durable and resilient in the face of on-going global change.

The following specific considerations are driving the change to the electricity infrastructure for South Africa:

Table 2. Drivers for change and relevance of the smart grids to South Africa

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.

The renewable energy independent power producer procurement programme forms a significant component of the build programme and for the first time introduces significant RE into the South African energy mix and is a key component of the IRP2. The introduction of RE, IPPs and distributed points of generation will add significantly 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.

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.

¹EDI Holdings Ring-fencing Results 2008 to 2010

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 country². 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 deliver the electricity needs of the country had an estimated impact of R 50 billion on GDP. Similarly, a 2004 study³ 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

Refer Section 3.2 for the political drivers for improved electricity network infrastructure.

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 complicates the selection of appropriate, cost effective solutions

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).

from an overwhelming offering (as experienced by the Eskom AMI pilot initiative⁴)

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.

At best, the current distribution industry in some areas does have a view of a portion of the medium voltage networks/grid. However, there are no examples of low voltage grid intelligence, which can be 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

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

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, 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 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 which are more dependent on power that is free from sags, spikes, disturbances and interruptions. Improved power quality, possible with a more intelligent modernised grid, is therefore increasingly important.

In response to these change drivers, the Smart Grid offers improved operational efficiency, opportunities for energy efficiency improvements, improved customers satisfaction and enhanced ability to respond to the National Green Agenda.

Table 3. Smart Grid Respond to Industry Challenges

Operational Efficiency	Enhanced Energy Efficiency
<ul style="list-style-type: none"> ▪ Integrated distributed generation; ▪ Optimised network design; ▪ Infrastructure visibility and control; ▪ Improved asset and resource utilisation and optimisation; ▪ Skills development; ▪ Sustainable job creation; ▪ Knowledge management. 	<ul style="list-style-type: none"> ▪ Reduced technical and non-technical losses; ▪ Enables DSM offerings; ▪ Improved load and VAR management; ▪ Complements national energy efficiency policies and objectives; ▪ Supports IRP 2.
Improved Customer Satisfaction	Supports National Green Agenda
<ul style="list-style-type: none"> ▪ Reduction in outage frequency and duration; ▪ Improved power quality; ▪ Empowers customers to manage consumption patterns; ▪ Facilitates customer self-service; ▪ Reduced energy costs; ▪ Community improvement. 	<ul style="list-style-type: none"> ▪ Integrates RE generation and embedded / distributed generation; ▪ Enables wide adoption of alternative energy options; ▪ Further reduces GHG emissions via DSM, peak saving and electrification of public transport; ▪ Complements climate change policy and GHG legislation (inventory, reporting requirements).

Increasing the intelligence of the grid will enable the ESI to better respond to situations such as when generation capacity constraints are experienced, to better leverage technology to complement 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. The innovation and technology development due to a Smart Grid implementation may also spark a renewed interest in the electricity industry as a possible career opportunity, attracting employees into the market to develop new skills. Certainly, a Smart Grid will require skilled people to manage the development and maintenance thereof.

It is acknowledged that a Smart Grid will not address all network concerns and challenges, but for a relatively small additional cost (refer Appendix E: Cost case studies) to the planned electricity system infrastructure investment, it offers potential to improve operational

efficiencies and significantly enhance the electricity network infrastructure. It will support the changing industry requirements, the drivers for change and deliver on the Vision described in the subsequent section of this document. As such, a Smart Grid is a key enabler for the resolution of many of South Africa's industry challenges as shown in Figure 6.



Figure 6. Smart Grids as an Enabler to Address Industry Challenges

Forfeiting this opportunity to modernise and introduce intelligence into the grid whilst in the necessary process of infrastructure upgrading and strengthening can be compared to expanding the nation's telecommunications system without taking advantage of today's digital and wireless technologies.

3. SCOPE OF THE SMART GRIDS VISION

In contemplation to the Visions context and the broad goal to transform the existing electricity supply infrastructure to a more intelligent system, this Vision now crafts a Smart Grid aspiration with respect to the following system elements:

- Key success factors;
- Principle characteristics;
- Performance;
- Applications (technical solutions);
- Metrics.

This Vision is intended to be solution-based i.e. the Vision aims to create an overall picture of the aspired network qualities, capabilities and functionalities but 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. 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 aimed at achieving the same national, integrated objectives.

In the subsequent section of this document the Smart Grid Vision is described in terms of each of these system elements. This understanding of the Vision is initially compiled for discussion and consultation purposes but once consensus is reached it will serve as a key element of the national Smart Grid framework to guide coherent and focused implementation.

3.1. FUNDAMENTALS OF THE VISION

The fundamental steps towards Smart Grid transformation begins with a clear vision of the objectives. The Vision aims to describe an overall picture of the Smart Grid and, in doing so, takes a systems' view of the grid that will steer an integrated national solution.

To achieve this, the Vision describes the Smart Grid in terms of key success factors, performance requirements, principle characteristics, applications and metrics necessary to realise the Smart Grid. See Figure 7.

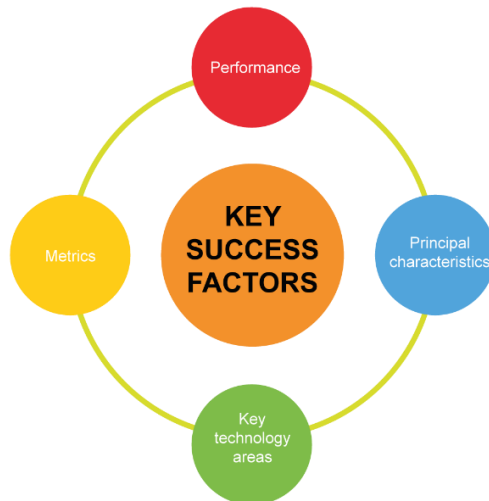


Figure 7. A Systems' View of the Smart Grid

The Vision for the South African Smart Grid is described comprehensively in subsequent paragraphs in terms of each of these system elements, but can be summarised into a Smart Grid Vision Statement as: -

“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.

3.2. OBJECTIVES

Implementation of a national Smart Grid in South Africa aims to enable the following objectives by 2030:

- 20% sustainable reduction in South Africa's peak energy demand relative to the 2012 national baseline projection;
- 100% grid availability to serve all critical loads as defined nationally and by each utility;
- 40% improvement in system efficiency (measured against the national and local 2012 technical and non-technical losses baseline) and asset utilisation to achieve a load factor of 70%;
- 8 GW electricity capacity integrated into the distribution networks from renewable energy sources;
- Improved service delivery and service reliability to customers to achieve a customer satisfaction index that exceeds 80%.

3.3. COSTS AND BENEFIT

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 as a whole.

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 R27.5 billion (2008 values). This study was redone in 2014 by the Department of Energy and the cost is estimated at R68 billion. This is a cost that must be incurred however, with a Smart Asset investment plan this investment does not have to occur as one lumpy investment, but rather staggered over multiple years. With a Smart Grid implementation. Incorporating greater intelligence into the grid might add to these costs, but should deliver benefits commensurate with, and in excess of, the additional investment.

An investment of this magnitude does however require the associated value proposition to be attractive to all stakeholders. The Smart Grid contributes value to stakeholders in four areas, as shown in Figure 8.

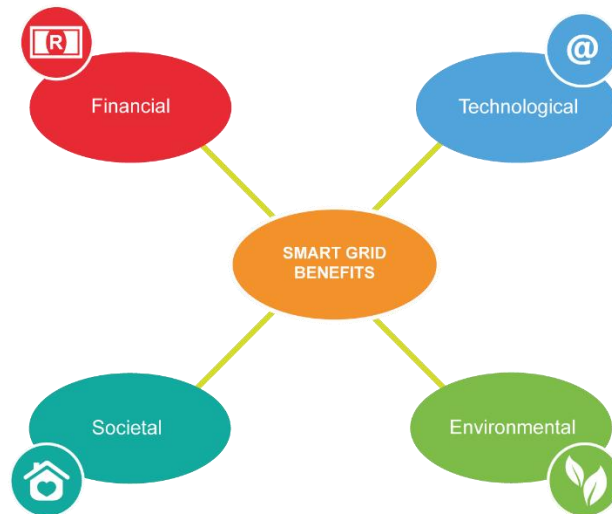


Figure 8. Smart Grids Value Contribution

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.

3.4. POWER GENERATION

Eskom is the main electricity generator in the country but a few small IPPs and utility generators, amongst others, also produce power. The national RE IPP procurement programme is however rapidly increasing the number of role players in the market.

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 network integration and system operation challenges for the existing electricity network infrastructure.

The introduction of a Smart Grid will facilitate the changing generation landscape, requiring investment while offering critical capabilities, see Table 4.

Table 4. Cost and Benefit to Power Generators

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.

3.5. ELECTRICITY UTILITIES

In South Africa, Eskom (National Transmission and Distribution), 174 municipalities and 9 metros are responsible for delivering electricity to end-users. 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.

The electricity industry is regulated by NERSA and historically the delivery of electricity has been approached on a least-cost basis.

From a utility perspective the most important benefits offered by the Smart Grid would be improved service delivery, revenue protection, improved reliability and improved efficiency of operations and utilisation of resources. Table 5 reflects some of the most significant costs and benefits for utilities.

Table 5. Cost and Benefit to Utilities

Utility benefits	Utility 'costs' or challenges
<p>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 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.</p> <p>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.</p>	<p>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 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.</p>
<p>Improved relationship with and compliance to Regulatory and Government expectations and requirements.</p> <p>Improved environmental performance and compliance to ensure improved energy sustainability.</p>	<p>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.</p>

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.

3.6. CUSTOMERS

Customers are generally divided into three categories—residential (all individuals who reside in an electrified dwelling are classified under this category), commercial (e.g. offices, shopping centres), 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.

Successfully achieving a Smart Grid may well depend on how attractive its value proposition is for residential customers who are typically interested in how the Smart Grid will benefit each individual household.

Commercial and Industrial customers (which includes 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 6:

Table 6. Cost and Benefit to Customer

Customer benefits	Customer ‘costs’ or challenges
Residential customers <ul style="list-style-type: none">▪ More reliable service (including less interruptions, shorter time to restored functionality, improved power quality to electrical and electronic appliances);▪ Real time energy management and optimisation 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;	Residential customers <p>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.</p> <p>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.</p>

Customer benefits	Customer 'costs' or challenges
<ul style="list-style-type: none"> ▪ 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). 	
Commercial and industrial customers	Commercial and industrial customers
<ul style="list-style-type: none"> ▪ Opportunity to reduce energy and demand charges on bills. The cost of electricity is 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. 	<ul style="list-style-type: none"> ▪ Many of the larger customers have already invested in interval meters and have implemented special rate designs for 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.

3.7. 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. For South Africa, the following key considerations are stated as such below,

Societal benefit 1 - Reduced losses to society from power outages and power quality issues

- 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.
-

Societal 'costs' or challenges

It is anticipated that rising electricity tariffs to cover the costs of infrastructure investments will result in an initial economic impact i.e. both direct and indirect inflationary impacts. International case studies have shown that the costs are recovered rapidly through significant cost savings and benefits.

Societal benefit 2 - 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;
 - Reduced operation and maintenance spending;
 - Eliminating or deferring large capital investments in centralised generating plants, substations, and transmission and distribution lines.
-

Societal benefit 3 - 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 benefit 4 - 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 CO2 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 kilometre driven by CVs is offset by kilometre driven by electric vehicles;
 - Reduction in the number of injuries and deaths due to contact with grid assets.
-

Societal benefits 5 - Improved economic growth

- Creation of new jobs would persist following implementation to support ongoing operation and maintenance of the Smart Grid;
 - Demand for new products and services — this demand will be created not only to build the Smart Grid but also to support customers who wish to participate with it;
 - Creation of new electricity markets — such markets will enable society to offer its electricity resources to the market, creating the opportunity to earn a revenue stream on such investments as demand response, distributed generation, and storage;
 - Improved conditions for economic development — economic development depends on a reliable source of electric power at a reasonable cost. A robust Smart Grid creates an environment attractive to new investment when compared to one with a poor track record;
 - Reduced wholesale electricity prices compared with business as usual. This reduction will be achieved through a reduction in peak loads and energy conservation;
 - Reduced consumption of kWh's through conservation, demand response, and reduced transmission and distribution losses –Besides providing an economic savings to society, this efficiency improvement provides for a better utilisation of our national resources.
-

Although often difficult to estimate financially all the tangible and intangible societal benefits, it can be shown, and has been shown in existing Smart Grid applications, 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.

4. KEY SUCCESS FACTORS

The Smart Grid is expected to set the foundation and be a key enabler to deliver on the anticipated electrical networks resilience, business sustainability, efficiency and environmental benefits. The transition to a Smart Grid should focus on intelligent selection and deployment of technology while achieving value with respect to six key success factors, see Table 7 below:

Table 7. Key Success Factors for the Smart Grids

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 potential problems and withstands most disturbances through proactive action before most users are affected.
The grid must be more secure	Through advanced grid visibility, 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 optimising the energy portfolio, fair prices and adequate supplies.
The grid must be more efficient	An efficient grid leverage technology deployment and employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilisation while providing customers with options for managing their energy usage.
The grid must support greater environmental sustainability	An environmentally responsible grid reduces environmental impacts thorough 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 and other necessities. It furthermore serves to improve the safety of the workplace and leverage grid sensors to enhance grid visibility.

The key success factors for a Smart Grid establishes a basis for specific performance requirements and for measuring progress and benefits. This implies the effective collection of data and the conversion of the collected data into management information which can be used to facilitate proactive interventions.

The principle characteristics, which consists of the main features that a modern grid needs to meet its essential performance requirements and the key technology areas that support the modern grid's principal characteristics, are described in Appendix G as they support the key success factors of a Smart Grid envisaged in South Africa.

5. PERFORMANCE

The addition of intelligence, the electricity network must enable enhanced performance with respect to the items stated below:

Emergency response

The Smart Grid must provide advanced analysis to predict problems before they occur and to assess problems as they develop. This should allow steps to be taken to minimise impacts and to respond more effectively.

Restoration

It can take days or weeks to return the current grid to full operation after an emergency. A Smart Grid must enable faster restoration and at lower cost by making better information, control and communications tools available to assist operators and field personnel.

Routine operations

The Smart Grid must provide operators with an understanding of the state and trajectory of the grid, should provide recommendations for secure operation and allow appropriate controls to be initiated. Operators should be able to depend on the help of advanced visualization and control tools, fast simulations and decision support capabilities.

Optimisation

The modern grid must provide advanced tools to understand conditions, evaluate options and exert a wide range of control actions to optimise grid performance from reliability, environmental, efficiency and economic perspectives.

System planning

Grid planners must be able to analyse projected growth in supply and demand to guide their decisions about what to build, when to build and where to build. Smart Grid data mining and modelling must provide much more accurate information to answer those questions.

6. PRINCIPLE 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, they as follows:

Characteristics 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:

- I. Real-time monitoring (of voltage, currents and critical infrastructure) and reaction (rapid and effective response to monitored events);
- II. Anticipation (“fast look-ahead simulation”);
- III. 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.

Characteristics 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 customer to make more intelligent decisions about their energy consumption and further encourage energy optimisation through incentive schemes

Characteristics 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.

Characteristics 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.

Characteristics 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.

Characteristics 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.

Characteristics 7- Optimises assets and operates efficiently

Desired functionality at minimum cost must guide grid operations and allows 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 work force 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 Principles Characteristics

Existing grid	Principle 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	Accommodates all generation and storage options	Many distributed energy resources with plug-and-play convenience; distributed generation with local

Existing grid	Principle characteristics	Envisaged Smart Grid
resources interconnection and operation.		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 principle 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 the 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 9. 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 10:

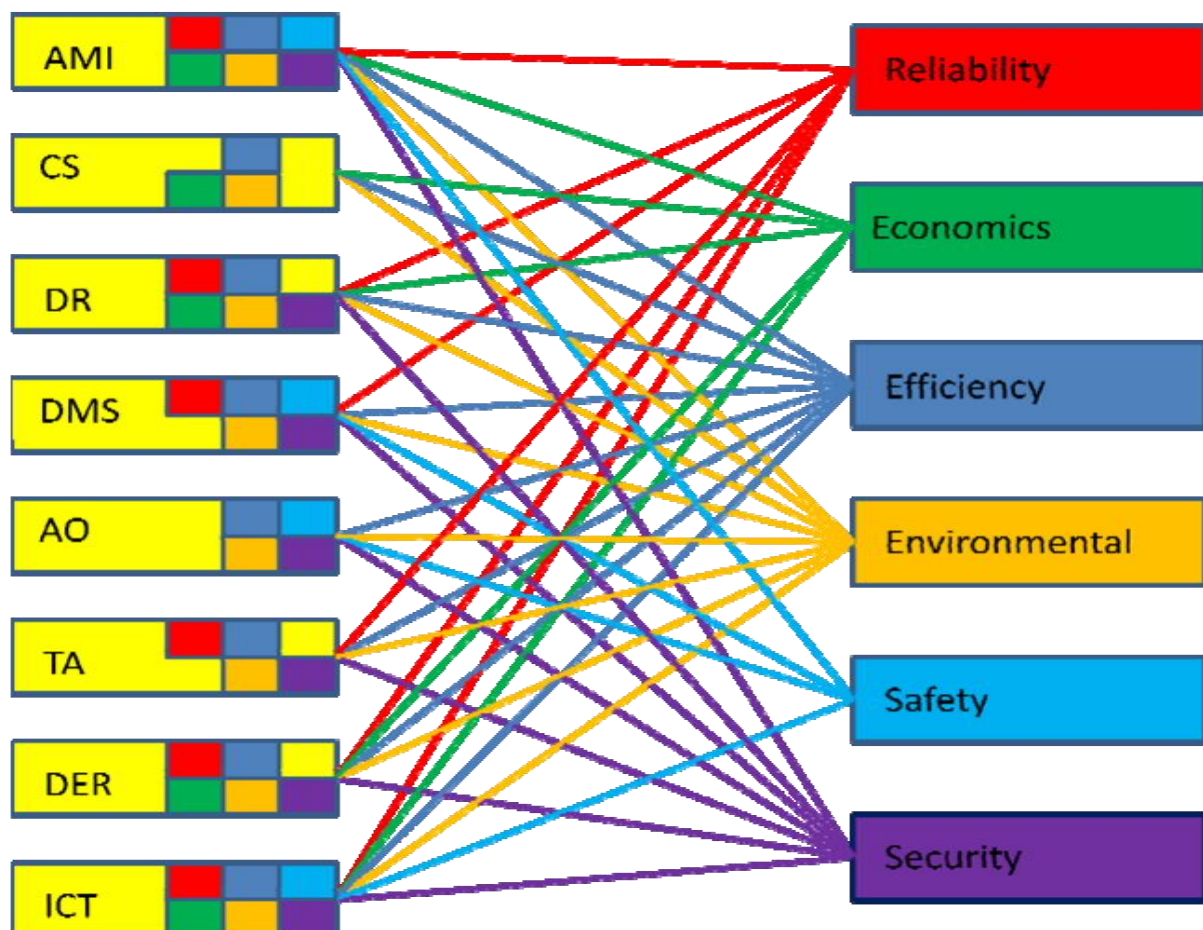


Figure 10. Illustrating the Correlation between Applications and Key Success Factors

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:

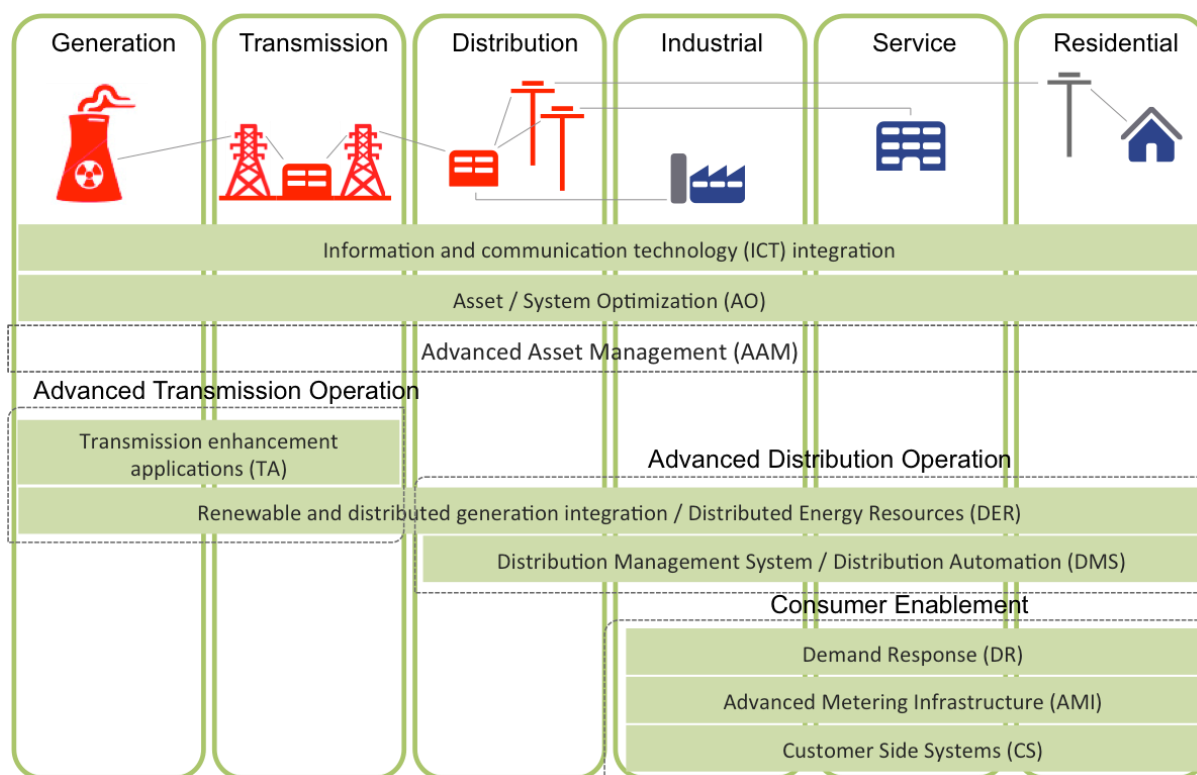


Figure 11. Correlating the Prioritised Applications with the Four Functional Areas

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

Principle characteristic	CE	ADO	ATO	AAM
Enables informed and greater participation by customers	✓	✓		
Accommodates all generation and storage options	✓	✓	✓	
Enables new products, services, and markets	✓	✓	✓	
Provides power quality for the range of needs in the 21st century	✓	✓	✓	✓
Optimizes assets and operates efficiently	✓	✓	✓	✓
Addresses disturbances – automated prevention, containment, and restoration	✓	✓	✓	✓

Principle characteristic	CE	ADO	ATO	AAM
Operates resiliently against physical and cyber-attacks and natural disasters	✓	✓	✓	

Figure 12. Correlation between smart grid principle characteristics and functional areas

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 the implementation and maximising the benefits (see **Error! Reference source not found.**). “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.

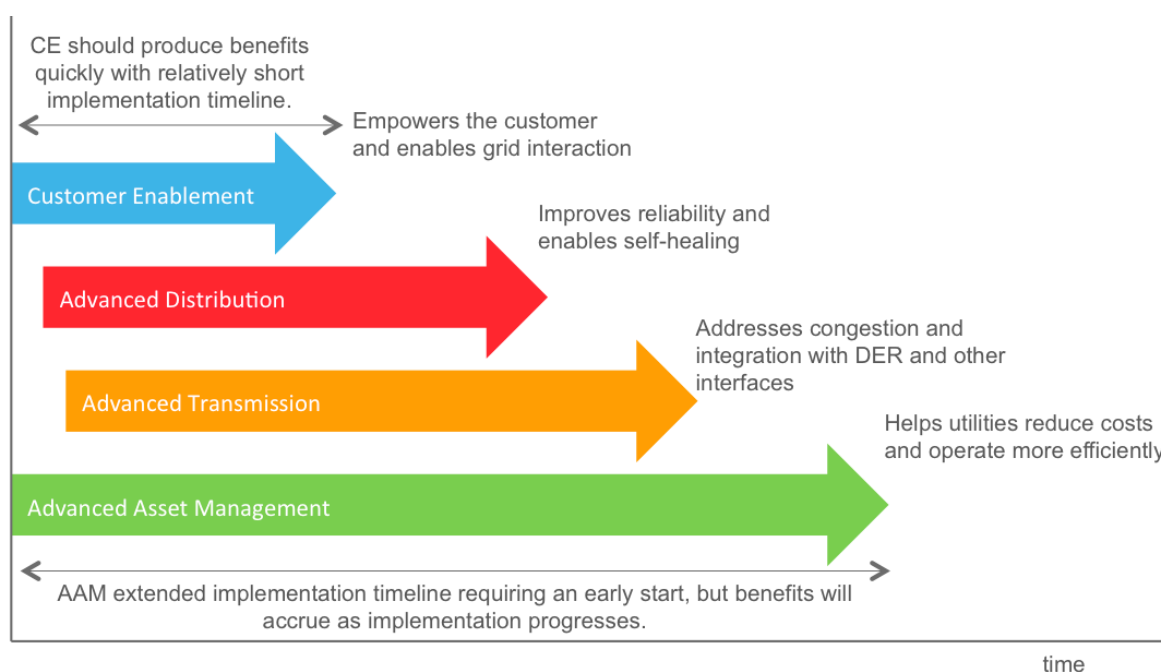


Figure 13. Indicative Smart Grid Sequencing Roadmap

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 13 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

14). The Vision and overall SASGI Smart Grid framework aim is to assist with unlocking optimal benefits for the given investments.

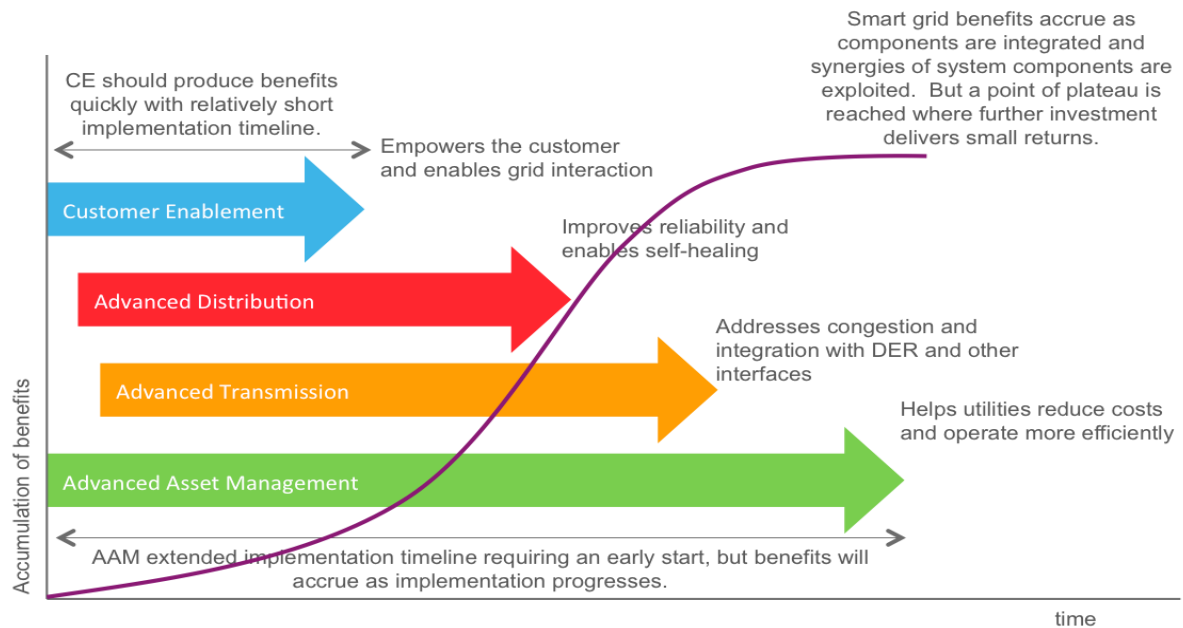


Figure 14. Accumulation of Benefits (Conceptual) as Smart Grid Components are Incorporated

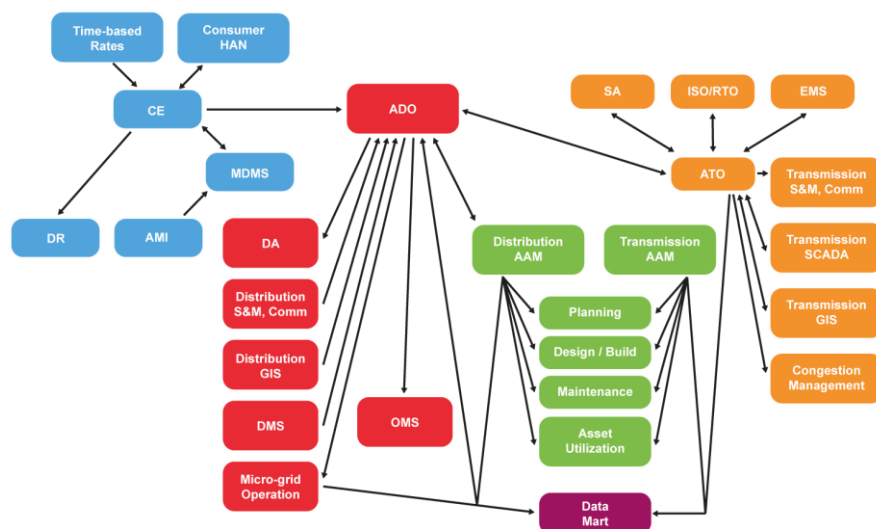


Figure 15. Comprehensive View of Smart Grid Applications in each Functional Area

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. CUSTOMER ENABLEMENT (CE)

CE is primarily aimed at the customer side of the Smart Grid by providing users/customers with information, control and options, mainly involving AMI and DR capability. AMI includes smart meters for advanced measurement, an integrated two-way communications infrastructure, and an active interface to give customers and their home area networks access to information, and a meter data management system to process the vast amount of new data. Additionally, AMI provides information about conditions on the grid and interfaces with other utility enterprise systems that can benefit from its functionality. AMI's communication infrastructure, data, and interfaces with other enterprise systems are all critical links to the other three functional areas. The general solution set for delivering Smart Grid solution within this functional area includes:

Smart meters that record interval energy usage, power quality parameters, other system operating parameters, and are equipped with remote connect/disconnect capability;

- Two-way integrated communication system with adequate throughput and acceptable latency to support the exchange of data and information among customers, other Smart grid users, and all appropriate Smart Grid processes, technologies and applications;
- Customer portal that supports a wireless home area network and in-home display that enables customers to easily set preferences, control their smart devices, and interface with the Smart Grid;
- Meter data management system that intelligently processes the vast amount of data produced by the smart meters, converts the data to information and integrates with other Smart Grid processes and technologies;
- Time based prices that reflect the real cost of electricity provided to customers at frequencies needed to support market transactions;
- Upgrades to utility legacy processes, technologies and applications needed to support the integration of other Smart Grid applications. For example, legacy customer information systems and information technology architectures might need modification to support the increased transactional load and cross-functional nature inherent in the Smart Grid vision;
- Customer educational programs to assist customers in their understanding of the benefits of the Smart Grid and how they can take advantage of the new opportunities and options it provides to them;

- Demand response programs that incentivise customers to participate in demand-reducing activities;
- Customer owned DERs that are interconnected, dispatched by grid operators and provide financial incentives to the owners;
- Customers benefiting from innovative incentive schemes to assist the grid during supply constraints and further reduce energy usage through real time feedback.

8.1. ADVANCED DISTRIBUTION OPERATIONS (ADO)

ADO is primarily aimed at the utility side of the Smart Grid, providing the increased information and granularity of control needed for a self-healing grid. ADO includes a distribution management system with advanced and ubiquitous sensors and distributed intelligence, advanced outage management capability, and distribution automation technologies.

It enables effective and efficient operation of a grid that employs extensive distributed generation of all types and sizes including perhaps millions of PHEVs and various types of micro-grids. It is also deeply integrated with a distribution GIS.

The ADO functional area provides important support to the Advanced Transmission Operations functional area. The general components to the delivery of an ADO includes:

Ubiquitous deployment of smart sensors that monitor distribution system operating parameters at all key locations;

High level of granularity of smart switches enabling the distribution to be sectionalised into optimum size parts when needed;

- DMS equipped with advanced analysis and control algorithms to enable two-way power flow on the distribution system used to take advantage of the ubiquitous system information and control capability to optimize operation and provide self-healing capability;
- Distribution automation that autonomously reconfigures the distribution system to minimize the impact of disruptions;
- Advanced Outage Management System that integrates ADO with CE to detect and diagnose local outages leading to a rapid dispatch of crews to repair the trouble – customers will no longer need to notify problems;
- GIS to provide where the dimension is needed to support ADO and CE;

- Micro-grid operation integrated with DMS and customer's Home Area Network (HAN) to identify when micro- grids should be operating in parallel or islanded mode;
- Advanced protection and control systems (e.g. voltage regulation, VAR support, distribution automation, fault current interruption) that adapt and support two-way power flow.

8.2. ADVANCED TRANSMISSION OPERATIONS (ATO)

The ATO functional area is primarily aimed at improving transmission reliability and efficiency, while managing congestion on the transmission system. ATO also integrates certain aspects of distribution system operations with transmission operations. It enables the security constrained economic dispatch models available for use by utilities to more effectively utilise the distribution system as a resource. ATO includes substation automation, advanced protection and control, modelling, simulation and visualisation tools, advanced grid control devices and materials, and the integration of all these tools with markets and utility operations and planning functions. The general approach to achieving intelligence in this functional area includes:

- Substation automation that collects information and control capabilities at each substation and communicates with other substations to ensure that broader system conditions are shared among these assets;
- Integration with and linkage among ATO, ADO and ultimately with CE;
- Wide Area Measurement System (WAMS) that are integrated with transmission operation centres to increase operator's situational awareness. WAMS will also reduce the time needed for key transmission algorithms to be solved giving operators new tools to better understand existing and projected conditions;
- Ubiquitous deployment of smart sensors that monitor transmission system operating parameters at all key locations;
- Modelling and simulation tools to enable operators to perform "what-if" scenarios and understand future operating risks;
- Advanced materials and power electronics devices to improve asset utilisation, voltage management, power quality and flow control of large blocks of power;
- Advanced protection systems that adapt to system operating conditions.

8.3. ADVANCED ASSET MANAGEMENT (AAM)

The AAM functional area is primarily aimed at improving the utilisation of transmission and distribution assets at the operational level and more effectively managing these assets from a life cycle perspective. AAM depends on the ubiquity of smart sensors that provide both operational and asset condition information which it acquires from the other three functional areas. The deep integration of that information significantly improves the effectiveness of enterprise asset management systems such as capacity planning, condition-based maintenance, resource and work management, engineering design and construction. The general solution to achieving a smart solution in this functional area includes:

- Ubiquitous deployment of smart sensors that monitor asset condition and health for all critical assets;
- Dynamic ratings of assets to optimize their utilisation;
- Condition monitoring algorithms that optimise when assets must be removed from service for maintenance to maximise their useful life;
- Integration of Smart Grid intelligence with key asset management processes including system planning, maintenance, engineering, customer service, work and resource management.

9. 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 as part of the process to develop standards for Smart Grids. Appendix E captures suggestions of would contribute to each measure.

It is furthermore recognised that the metrics would have to be reviewed as the national Smart Grid framework which SASGI is working on unfolds to ensure the targets remain both aspirational and realistic.

10. Department of Energy Medium Term Objectives

The stated vision of the Department of Energy as outlined in the Strategic Plan 2015 – 2020 is: “Improving our energy mix by having 30% clean energy by 2025.” It is the Department of Energy’s stated view that the vision will be achieved by having the outcomes as shown in Figure 16.

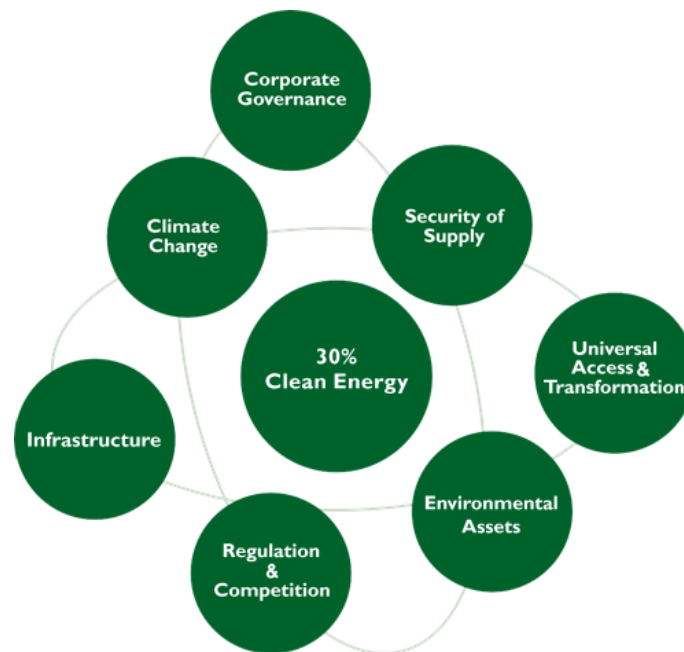


Figure 16. Factors Affecting the DoE Vision of 30% Clean Energy (Source DoE Strategic Plan)

To achieve the stated outcomes as outlined in the vision statement, the Department of Energy has identified the following medium term objectives:

10.1. DISTRIBUTED GENERATION (DG) (SOLAR, WIND, BIOMASS, BIOGAS AND LANDFILL GAS)

With South Africa on its way to meeting a 42% target for generating electricity from renewable sources by 2030, the share of electricity supply from renewable energy is on the rise. Intermittent renewable energy sources such as solar and wind adds an additional variable to the electricity network. To enable dynamic grid management, additional and flexible grid management infrastructure (such as smart meters) will be required. Such intermittent renewable energy electricity generators will be connected to the electricity distribution systems due to a lower maximum power capacity of 5 MW. In addition, electrification of transport will be needed in the future to further decarbonise the economy. To achieve a significant

deployment of electric vehicles, the security of energy supply will be required. As indicated earlier, and supported by various studies, there are significant benefits to be derived through the introduction of renewables into the distribution electricity grid.

It is, however, important to note that the current distribution grid was not designed to accommodate the introduction of DG. Furthermore, building regulations and designs to date do not cater for installation of roof top (Photovoltaic) PV panels, considering the weight of these panels. This should, however, not result in the industry not pursuing opportunities to leverage the potential to be derived from the introduction of roof top PV panels.

Grid connected PV systems cannot be integrated into the electricity grid without sufficient two-way communication and effective grid control capability. This functionality is essential to manage the interface between the relevant utility and the energy provider. Dynamic metering is required to facilitate consumption measurement, energy export and compensation. Therefore, for this project to be successful, a well-functioning advanced metering infrastructure (AMI) capability is required. The AMI platform is also required to facilitate Free Basic Electricity, the effective introduction of the Inclining Block Tariff and effective Energy Demand Side Management. Without a well-defined AMI, critical aspects such as two-way communication, net-metering, energy balancing, remote load flow monitoring, revenue management, customer consumption data storage, etc. will be a challenge to achieve.

10.2. FREE BASIC ELECTRICITY (FBE)

The FBE provides policy framework for Electricity Service Providers to allocate limited free units of electricity per month to qualifying households. The allocation is designed to assist poor households by giving them 50 kWh of free electricity per month. The policy falls in line with the Government's intention to support the indigent households by facilitating the provision of free basic services. The FBE will be provided specifically to qualifying households that have been identified by municipalities using indigent registers. The proposed levels of Free Basic Electricity are 50kWh per household per month for a grid-based system for qualifying domestic consumers and 50Wp per non-grid connected supply system for all households connected to the official non-grid systems. Only 50kWh per month would be provided free; extra units would be charged at an approved tariff.

10.3. INCLINE BLOCK TARIFF (IBT)

On the 24th February 2010, the National Energy Regulator of South Africa (NERSA) approved that Inclining Block Tariffs be implemented in the second Multi-Year Price Determination (MYPD2) for both Eskom and Municipalities. Inclining Block Tariffs divide the electricity price into several steps or blocks. The blocks increase in the price as more volumes are consumed, customers can save money by only buying the electricity they will use during the month. The introduction of IBT, therefore, forms an important step towards the efficient use of energy.

Incline Block Tariffs divide the electricity price into several steps or blocks. The first block of electricity is at the lowest price. As the customer purchases more electricity during the month, the electricity bought will eventually fall in the next block which attracts a higher tariff. The process to move from one block to the next is automatic and depends only on the amount of electricity that is acquired by the customer. The movement to the next block is not at all affected whether the purchases are spread over many transactions or if all the electricity is part of one transaction.

10.4. ENERGY EFFICIENCY DEMAND SIDE MANAGEMENT (EEDSM)

The National Energy Efficiency Strategy (NEES) of the Republic of South Africa (RSA) is herewith revised for the second time since its publication in 2005. In this edition, the steps necessary for a Strategic Process of sectorial Energy Intensity target review and the elements of a plan to achieve significant reductions in energy intensity are set out.

The RSA is ranked highly among the world's energy intensive nations, and consequently is amongst the highest in terms of national greenhouse gas emissions per capita. This can be attributed to the fact that the economy is predominantly coal based. Until recently, low electricity production costs have hindered investment in energy efficiency.

The Government is committed to implementing this Strategy for the RSA to achieve a reduction in energy intensity over the next two decades, where economically feasible, as a national priority. This strategy should realise the goals of improving economic competitiveness and job creation, along with the positive effect of reducing greenhouse gas emissions.

In this Strategy review process, the energy usage patterns of the component businesses and representative consumers of major sectors of the economy have been reviewed. Their susceptibility to adopting modern energy management practices and technologies and their potential have been identified. International advice and views have been solicited and confirmed the potential of reducing energy intensity over the period of 2012 to 2030.

The Strategy takes the state of energy supply and usage in 2000 as its baseline year and projects a path of energy intensity reduction improvement in the component sectors of the economy for a resultant projected improvement of 12% by 2015, and sets the scene for future energy intensity reduction targets.

Instruments, many of which are internationally used, have been reviewed for their suitability and application in the South African context, and have been set out in Sector Implementation Plans for deployment by government, business and civil society.

Whereas the first edition of the NEES was aimed at creating an awareness for the importance of efficient use of energy, the 2012 revision (second revision) takes a holistic and long term view at the contribution that all sectors in the South African society can make in the next 20 years towards creating a sustainable future where:

- Government and its respective departments will continue to develop appropriate policies, monitoring capabilities and supporting regulation and incentives;
- Private and public enterprises have committed themselves to the implementation of plans to achieve increased energy efficiency improvement goals.

The NEES attempts to focus the efforts of all stakeholders towards building the required capacity to achieve the long term national goal of improving the Energy Efficiency of the RSA economy.

10.5. APPROACH TO DISTRIBUTION ASSET MANAGEMENT (ADAM)

The Approach to Distribution Asset Management (ADAM) Turnaround Programme is a comprehensive, multi-year initiative targeted at addressing maintenance, refurbishment and strengthening shortcomings in key electricity distribution infrastructure throughout South Africa. At its essence, ADAM is about ensuring the integrity of critical electricity distribution infrastructure in South Africa to provide an environment that enables sustained economic growth, public safety and other essential public services.

During 2008 a comprehensive study was undertaken by Electricity Distribution Industry 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 human capital identification and development while there was a glaring absence of business efficiency and the optimal deployment of technology. It is estimated that South Africa must invest approximately R27bn (2008) in assets and management tools to address the

current infrastructure related backlogs. The study was again undertaken by the DoE in 2014 and the cost estimated at R68 Billion.

ADAM was approved in 2012 by South African 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 Electricity Distribution Industry. The introduction of a Smart Grid Vision embedded in the roll out of ADAM could bring about significant cost savings while it contributes 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 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.

10.6. ROLE OF SMART GRIDS IN ACHIEVING THE DOE STRATEGIC OBJECTIVES

In dealing with the DoE objectives using a Smart Grid solutions, the following projects will deal with the DoE medium term strategic objectives:

- AMI which effectively deals with RE-IPP net metering and billing, FBE, IBT, TOU billing;
- Enhanced Revenue management;
- Public buildings (EEDSM);
- Active network distribution system in DG operations and management;
- The role of integrated systems in achieving smart distribution asset management.

CONCLUSION

The motivation for incorporating a Smart Grid solutions into the existing and planned infrastructure upgrades and expansions lies with the associated benefits to the respective stakeholders and the expectation that the benefits outweigh the costs. Commercial and Industrial customers (which includes 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.

Increasing the intelligence of the grid will enable the ESI to better respond 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.

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 Smart Grid is expected to set the foundation and be a key enabler to deliver on the anticipated electrical networks resilience, business sustainability, efficiency and environmental benefits. It requires a collective call to action and the support from various stakeholders contributing in their own unique way to the shared vision of Smart Grids in South Africa.

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APPENDIX B: INTERPRETING TECHNOLOGY HYPE

A list of relevant legislation and policy that shapes Smart Grid implementation in South Africa, alphabetically and not order of importance:

Table 10. Relevant Legislation

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
DME Universal Access Plan, 2004	The South African President in 2004 stated the policy goal of universal access to electricity by 2012 (i.e. the targets aimed to be achieved in roughly 80% access by 2012). This goal requires a significant adjustment of annual connection targets and electrification budgets based on accurate knowledge of the number of electrified and non-electrified households.	Network expansion (and hence investment) is effectively a commitment under this plan. Adequate, accurate and available data is critical to tracking implementation of this plan. The first presents an opportunity to incorporate Smart Grid elements and the second suggests a need for grid intelligence.
DOE Strategic Plan	The Department's plan seeks to deliver results along eight strategic objectives that include promoting energy security through reliable, clean, and affordable sources, universal access to energy sources, transformation of the energy sector and strengthening the operations and management of the Department.	Smart Grid infrastructure directly supports all the objectives of energy security, reliability, cleanliness and affordability.
DST 10 year Innovation Plan	The grand challenge areas include: • Energy security - the race is on for safe, clean, affordable and reliable energy supply and South Africa must meet its medium-term energy supply requirements while innovating for the long term in clean coal technologies, nuclear energy, renewable energy and the promise of the "hydrogen economy".	A Smart Grid critically serves the identified energy security, reliability, clean energy and climate change challenges.

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
	<ul style="list-style-type: none"> • Global-change science with a focus on climate change. 	
Energy Efficiency Policy & Strategy, DME 2004	The vision of the strategy is to contribute to affordable energy for all and to minimise the effects of energy usage on health and the environment. It is implemented through sector programmes	The strategy has no direct reference to a Smart Grid but international experience has demonstrated large improvements in energy efficiency on the electricity grid and in the energy users' homes and offices with the introduction of a Smart Grid.
Energy Security Master Plan, DME	The plan is premised on achieving certain goals that have been set for the electricity sector. Due to the uncertainty over the planning horizon, some assumptions are made regarding demand projections and the economic outlook. After consideration of the Energy White Paper and the regulatory policy framework, the current electricity generation, transmission and distribution sectors are appraised in terms of the challenges confronting these sectors.	Focused research and development will enable technical performance and capacity expansion objectives to be met. Electricity/energy-based technology development and innovation is imperative to productivity and growth of the country.
Gauteng Integrated Energy Strategy	It aims to improve Gauteng's environment, reduce its contribution to climate change and tackle energy poverty, whilst promoting economic development.	
Green Paper on Climate Change Response Strategy	Climate change response objective: * make a fair contribution to the global effort to achieve the stabilisation of greenhouse gas concentrations in the atmosphere preventing dangerous	No direct reference but the Smart Grid will contribute significantly to data collection and GHG and carbon reporting capability and is critical to integration of clean energy (RE) and distributed

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
	<p>anthropogenic interference with the climate system;</p> <p>* effectively adapt to and manage unavoidable and potential damaging climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity.</p>	<p>generation into the electricity network.</p>
<p>Industrial Policy Action Plan (IPAP) 2010/11 – 2012/13, published Feb 2010</p>	<p>IPAP 2 Section 13.3 puts emphasis on the development of green industries in South Africa, specifically:</p> <ul style="list-style-type: none"> • SWH • Wind • Photovoltaic power • Concentrated Solar Thermal power • Industrial Energy Efficiency • Water efficiency • Waste Management • Biomass and waste management • Energy-efficient vehicles 	<p>All listed green industry priority areas would be supported by, and might rely heavily (e.g. energy efficient vehicles, integration of RE and utility services (waste, water and energy) integration) on, a Smart Grid.</p>
<p>Integrated Resource Plan for Energy, 2010</p>	<p>This policy-adjusted plan is recommended for adoption by Cabinet and for subsequent promulgation as the final IRP. This proposal is a confirmation of the RBS in that it ensures security of supply. It is a major step towards building local industry clusters and assists in fulfilling South Africa's commitments to mitigating climate change as expressed at the Copenhagen climate change summit. The plan</p>	<p>Section 7 - Research Agenda for Next IRP distributed generation, Smart Grid and off-grid generation.</p> <ul style="list-style-type: none"> • Harnessing South Africa's coal resource; • Decommissioning and waste management options; • Small and regional hydro options;

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
	includes the same amount of coal and nuclear new builds as the RBS, while reflecting recent developments with respect to prices for renewables. In addition to all existing and committed power plants (including 10 GW committed coal), the plan includes 9,6 GW of nuclear, 6,3 GW of coal, 17,8 GW of renewables and 8,9 GW of other generation sources.	<ul style="list-style-type: none"> • Biomass (including municipal solid waste and bagasse); • Storage; • Energy efficiency demand side management vision for 2050 Uncertainty and Risk factors.
Long-Term Mitigation Scenarios, DEAT, October 2007	Develops scenarios to mitigate greenhouse gas emission and form the basis of South Africa's national mitigation policy direction.	The scenario recognises the importance of a low carbon future and provides an indication of the effort that must be extended to change the energy mix and economic activity of South Africa to achieve the required reduction in carbon.
National Energy Act, 2008	To ensure that diverse energy resources are available, in sustainable quantities and at affordable prices, to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management requirements, international commitments and obligations and interactions amongst economic sectors; to establish institutions to be responsible for promotion of efficient generation and consumption of energy, energy modelling and planning, increased generation and consumption of renewable energies, energy research, contingency	<p>Chapter 4 focuses on the establishment of SANEDI. The institute is intended to:</p> <ul style="list-style-type: none"> • Encourage energy efficiency in the economy; • Increase the GDP per unit of energy consumed; • Ensure energy resources used in optimal manner; • Promote energy and technology innovation; • Increase players in the energy field; • Facilitate effective management of energy

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
	energy supply, holding of strategic energy minerals, adequate investment, appropriate upkeep of, and equitable access, to energy infrastructure; to provide measures for the furnishing of certain data and information regarding energy demand, supply and generation and to provide for matters connected therewith.	demand and its conservation.
National Energy Efficiency Strategy of the RSA	This strategy allows for the immediate implementation of low-cost and no-cost interventions, as well as those higher-cost measures with short payback periods. These will be followed by medium-term and longer-term investment opportunities in energy efficiency. The strategy acknowledges that there exists significant potential for energy efficiency improvements across all sectors of our national economy.	The South African National Energy Research Institute will be funded to carry out a dedicated programme of research and development for energy efficiency. The strategy will support appropriate research and the possible adaptation of internationally available technologies and processes.
Occupational Health and Safety Act (No. 85 of 1993), Amended 2008 and Electrical Installation Regulations, 2009	The focus of the Act is to provide for the health and safety of persons at work and for the health and safety of persons about the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of, or about, the activities of persons at work; to establish an advisory council for occupational health and safety and to provide for matters connected therewith.	The Smart Grid offers benefits for improved employee safety. New unfamiliar technologies do however bring safety concerns, necessitating a focused effort on training and change management to ensure employee safety.
White Paper on Renewable Energy, November 2003	Sets out Government's vision, policy principles, strategic goals and objectives for promoting and	The White Paper sets ambitious national targets for the introduction of RE into the

Legislation/Policy	Description of focus	Relevance to Smart Grids, EE, RE, DR, DSM
	implementing renewable energy in South Africa. Establishes the basic framework within which the renewable energy industry can operate and grow. Provides an overview of the renewable energy resource of the country.	national grid. It also identifies five key strategic areas to create an enabling environment, including technology development. Smart Grid technology is widely recognised as a key to integrating variable power sources such as RE into the electricity network.

APPENDIX C: METRICS

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.

APPENDIX D: CASE STUDIES

To develop and deploy a Smart Grid will add to the immediate investment requirements of the ESI, but if implemented pragmatically it should provide operational efficiencies and enhanced capabilities which will outweigh the additional costs.

Examples in Italy and the USA illustrate this experience with costs and benefits:

ITALY - FOCUS ON SERVICE DELIVERY AND COST REDUCTIONS

The Italian Smart Grid system (Telegestore), installed by Enel S.p.A. of Italy, could be regarded as one of the first Smart Grid deployments in the world. The installation was completed in 2005 at a project cost of 2.1 billion Euro. This project is providing an annual return of 500 million Euro and significant additional, non-quantified business and customer benefits are claimed. This resulted in a payback period of just more than 4 years.

The Telegestore system incorporates smart metering, network automation, workforce management, including all workers with hand-held tablet communications devices and asset management. Around a quarter of all the company's secondary substations are now remotely controlled, enabling much earlier interventions to correct faults. At the time of the case study compiled by PWC, the associated service level improvements were reported as, "supply interruptions being cut from 128 minutes in 2001 to 50 minutes in 2008 which, while it is still not comparable with some other countries, is quite good given the state of the network in Italy."

Enel reported a reduction in operational costs from 80 Euro per customer in 2001 to 49 Euro per customer in 2008 and ascribed this cost reduction largely to the introduction of the Telegestore system.

Another benefit has been that smart meters have enabled a more flexible tariff structure, with bi-hourly or flexible tariffs, day and night, peak and non-peak, etc. so that customers can save money and adapt their energy usage to fit supply circumstances.

SAN DIEGO, USA – COMPREHENSIVE SMART GRID IMPLEMENTATION

The Smart Grid roll out in San Diego reportedly has a project cost of 490 million US Dollars and an annual operation and maintenance cost of 24 million US Dollars. The total annual benefit of this project is 14 million US Dollars with projected benefits of 1,433 million over 20 years and social benefits to the value of 1,369 million US Dollars.

The San Diego Gas and Electric (SDG&E) Smart Grid programme (for which utility was awarded the Power 2012 Smart Grid award) “empowers customers, increases renewable generation, integrates plug-in electric vehicles (PEVs) and reduces greenhouse gas emissions while maintaining and improving system reliability, operational efficiency, security and customer privacy.”

With this programme, the utility is aiming to enable a “smart customer” who is able to make more choices and have more control over energy decisions, a “smart utility” that manages a host of ever-advancing supply- and demand-side resources and the grid that integrates the two parties together with a “smart market” for customers and energy suppliers which preserves power quality and reliability on the grid while increasing price transparency.

The San Diego Smart Grid rollout has been extensive. All customer meters (1.4 million electric and 850,000 gas) have been upgraded. 18,000 rooftop solar units totalling 138 MW (3% of peak demand) have been installed and integrated. 1,600 PEVs are driving in cities and plugging-in at numerous charging stations. In addition to this, a host of other less-visible advancements (e.g. extensive deployment of updated SCADA systems, weather sensors, and wireless communications infrastructure) are bringing the grid in San Diego out of the 20th Century and into the 21st Century.

All of this will help SDG&E meet the goal of supplying 33% of its electricity from renewable (mostly intermittent) sources while also accommodating potentially 200,000 PEVs by 2020 which would be difficult, if not impossible, to achieve without advanced technologies such as those being deployed as part of the Smart Grid programme.

CALIFORNIA, USA – FOCUS ON SECURITY OF SUPPLY AND COST SAVING

In California, Pacific Gas & Electric’s drive to rollout smart metering (the initial focus) was prompted mainly by the experience of rolling blackouts in 2000 and 2001. Blackouts occurred on summer days when peak load was at its highest and demand exceeded supply. There were ways to interact with commercial customers who drew the heaviest loads by offering them demand programmes but, without smart meters, it was not possible to have a more dynamic way of managing demand from small commercial and residential customers.

Since 2001 a smart rate tariff has been introduced with 25,000 residential customers active in the programme resulting in 16% peak demand savings on critical summer days.

Pacific Gas & Electric’s full deployment plan is a seven-year programme that will deliver substantial benefits. Operational cost savings of US\$170 million associated with savings in meter reading and management costs as well as reduced revenue losses arising from older, inaccurate meters are anticipated with full implementation.

APPENDIX E: LESSONS FROM INTERNATIONAL STUDY TOUR

The Government of South Africa has identified priority strategic projects which are overseen by the Presidential Infrastructure Coordinating Committee (PICC). The Smart Grid Programme can be directly linked to the Government of South Africa's strategic projects, namely:

- Strategic Integrated Project (SIP) 8, which seeks to promote green energy deployment in support of the economy of South Africa;
- Strategic Integrated Project (SIP) 9, which seeks to promote electricity generation in support of socio economic development;
- Strategic Integrated Project (SIP) 10, which seeks to rehabilitate electricity transmission and distribution infrastructure;
- Integration of the municipal infrastructure project, which seeks to provide basic services to the communities.

The Department of Energy is the custodian of the South African energy regulatory framework. Preliminary evaluation of the current Smart Vision for South Africa indicates that an enabling legislative environment must be created to ensure a successful Smart Grid deployment. In addition, the Smart Grid vision is part of the suite of energy policy interventions to reduce the cost of energy and cost to the economy.

In this context, the study tour was arranged to introduce the benefits of Smart Grid concepts to the selected public officials, to enhance the knowledge of policy makers and decision makers on the applicability of technical solutions offered by Smart Grids and to expose participants to best practices and lessons learned.

The following are key success factors identified during the interactions with industry role players during the international tour (2017):

- I. A widely-endorsed vision document is essential to the required technology deployment transformation for the efficient functioning of any electricity grid, especially in the current environment where, among others, renewable energy sources are being introduced, improved grid visibility is required and greater customer participation is essential;
- II. The need for an overarching task force which guides policy development;
- III. The need for stipulated functionalities and standards;
- IV. Integration of the energy producers directly to the distribution grids;
- V. Intelligent markets to curb volatility which requires flexibility and a link to wholesale and retail markets while ensuring that there is security of supply and protection of personal information;
- VI. Benchmarking to ensure that the correct performance metrics are measured;

- VII. Data protection and security for smart grids;
- VIII. A higher customer centric approach to utilities in the country;
- IX. Demand-side response solutions prove more acceptable to consumers the more DSM features they provide (in home display, comparison etc.);
- X. Future calls for bids targeting the development of load shedding in the residential sector should include an obligation to inform, raise awareness and support consumers with their electricity consumption to promote DSM and make load shedding systems worthwhile;
- XI. Considering the significant costs of distributed load shedding infrastructure, it seems preferable not to use load shedding alone to address capacity (reducing peak demand), where a pricing-based approach appears more appropriate;
- XII. Forecasting solar and wind production and consumption on a small geographical scale will improve local network management, favour the use of local sources of electricity and limit network reinforcement following the installation of new generating capacity;
- XIII. Considering current conditions (including the market price of electricity), no projects have so far highlighted an obvious business model for a storage system from the perspective of immediate deployment. The question of generating value from storage installations and creating the role of storage operator is thus essential for the development.

Key challenges must be addressed as existing infrastructure is already restricted. These include:

- I. Fluctuation renewable generation that can cause overloads;
- II. Larger renewable energy plants must be operated like conventional power plants, yet they lack flexibility due to the intermittent operation;
- III. With the increasing share of renewable energy plants, the grid needs to be reinforced;
- IV. The demand side is not a passive player anymore; it needs to be actively managed;
- V. Intermittent power from the renewable energy needs to be brought in when required; which is a challenge.

APPENDIX F: SMART GRID WITH SELF-HEALS PROPERTIES

(Anticipates and responds to system disturbances)

Key Success factor	Relationship with principle characteristic for South Africa
Improved reliability	The predictive nature of the Smart Grid, coupled with its ability to implement corrective actions in real time, will provide a major improvement in reliability at the transmission, distribution, and customer levels. The self-healing feature of the Smart Grid will go beyond the prevention and mitigation of outages and play a major role in grid optimisation. It will also include monitoring of system equipment and customer portals to identify both unhealthy equipment that requires immediate repair and emerging or actual power quality issues.
Improved security	Intelligent networking, advanced monitoring, demand response (DR) and distributed energy resource (DER) features will make the grid far more robust and hence more resilient to attack. Self- healing and effective grid visibility decreases the threat of a security attack because energy sources are distributed and self-healing technologies can maintain or restore service during and after attack.
Safety	Increased public safety will be a benefit of the Smart Grid. The grid will quickly locate and de-energise downed wires. Restoring power faster to more people will reduce the impact to “life-support” customers as well as maintaining HVAC to elder care facilities and critical installations. Additionally, fewer outages mean fewer opportunities for criminal acts.
Efficient	The self-healing grid will detect and correct power quality issues. Power quality related issues represent another large annual cost to the public and major customers.
Environmental	The self-healing grid will accommodate multiple alternative energy resources, both distributed and centralised, resulting in substantial reductions in emissions. In addition, the environmental impact associated with outages and major equipment failures will be dramatically reduced and a more efficient grid means lower electrical losses (hence lower emissions)
Economical	Reduction in economic losses incurred by businesses and individual customers when power is lost; improved grid visibility and more efficient operation will reduce electrical losses and maintenance costs.

APPENDIX G: SMART GRID QUALITIES

A smart grid resists attack

(System-wide solution that will reduce physical and cyber vulnerabilities and recover rapidly from disruptions)

Key success factors	Relationship with principle characteristic for South Africa
Improved reliability	Integration of DER improves reliability while its decentralised characteristic decreases the vulnerability of the grid. Use of advanced modelling and simulation tools to monitor grid dynamics and risks in real time can help to spot vulnerabilities and to prevent “normal” outages.
Improved security	Improve operational readiness during emergency by ensuring security of supply.
Safety	Minimising safety-related matters associated with a loss of power for extended periods of time.
Efficient	Enhanced grid management, inclusive of power quality, positively affects the plant/equipment life expectancy and efficiency of the grid itself.
Economical	Minimising the costs associated with lost products and lost productivity.

A smart grid Provides power quality for 21st century needs

Key success factors	Relationship with principle characteristic for South Africa
Improved reliability	The broad deployment of advanced electricity meters as grid sensors will provide extensive information regarding the quality of power throughout the grid. New sensing techniques will monitor the health of equipment and predict potential failures that can create PQ problems.
Safety	Better PQ leads to less power perturbations that can create safety risks due to power interruptions.
Efficient	Lower production costs by reducing downtime due to power aberrations.
Environmental	Intelligently improving PQ in the power system will be able to support clean, high-tech industries that demand high quality and reliable power.
Economical	Advanced control methods are designed to maintain the grid in a stable state and to provide extensive condition information.

A smart grid Accommodates generation and storage options

Key success factors	Relationship with principle characteristic for South Africa
Improved reliability	Integration of DER can reduce the grid's dependency on the transmission system; increase operational flexibility during routine, emergency, and restoration activities; improve power quality; and reduce distribution losses and congestion due to DER being located closer to the loads. Advanced technology deployment will enable grid flexibility and directly contributes to grid optimization.
Improved security	DER decentralizes and diversifies generation and storage resources, reduces the grid's vulnerability and gives operators more options in response to a security emergency.

Key success factors	Relationship with principle characteristic for South Africa
Efficient	DER gives system operators' new options to improve the utilisation of grid assets, gives system planners additional options to address future demand issues and reduces losses by locating sources closer to the load centres. Significant gains in efficiency can be realized when DER provides both power and heat.
Environmental	The Smart Grid will encourage the deployment of renewables and combined heat and power units (CHP) installations. It will enable a greater level of penetration of intermittent renewables than could otherwise be accommodated with today's grid. The Smart Grid will also reduce system losses, and improve the grid management capabilities, thereby reducing the overall amount of generation needed.
Economical	DER deployment adds to the Smart Grid's economic advantages by allowing the deferral of capital investments in generation, transmission, distribution, substations and lines, giving customers additional options for participating in the electricity market and reducing peak demand, transmission congestion, and peak prices. In addition, smaller DER units can be placed in service relatively quickly, while large central plants pose more risk and require long approval, financing, and construction periods. Collectively these benefits of DER can help put downward pressure on electric rates for customers.

A smart grid Enables markets

Key success factors	Relationship with principle characteristic for South Africa
Improved Reliability	As customers suffer interruptions, the load profile and generation profile shift as alternate load management and distributed generation schemes become more prevalent in the industrial, commercial, and residential sectors. These drivers and changes result in fewer and briefer interruptions.
Efficient	Open-access markets expose and shed inefficiencies while promoting participation from an energy provision perspective.
Environmental	New, clean energy related products will be offered as market options.
Economical	Customer response to price increases will mitigate demand. It will drive lower-cost solutions and spur new technology development. This change will necessitate a review of the current approach to cost of supply studies and the determination of business sustainability assessments.

A smart grid Optimises assets and operates efficiently

Key success factors	Relationship with principle characteristic for South Africa
Improved reliability	The improved utilisation of assets and the understanding of asset health will reduce reactive maintenance and, hence, improve reliability.
Improved security	A more robust grid is a more secure grid. Effective technology deployment increases grid robustness by operating in the most efficient and reliable manner. Improved monitoring capabilities can also provide advanced asset status information and video surveillance for critical assets.
Safety	Optimising maintenance through conducting less reactive maintenance and emergency repairs which reduces the exposure of workers to hazards.
Efficient	Optimising asset utilisation and more efficient grid operation will lead to an increase in the value of each rand spent on the grid. Use of advanced grid components such as power flow devices, sensors, distributed generation,

Key success factors	Relationship with principle characteristic for South Africa
	storage, and others will enable the realisation of these efficiency improvements. Advanced materials and the use of dynamic ratings will enable power transfer to increase.
Environmental	Reduced losses will enable a reduction in generation for a given load thereby reducing environmental emissions that would otherwise have occurred. Improved maintenance practices and the reduction in reactive maintenance reduce the potential for accidental grid related incidents.
Economical	Improving the efficiency of the grid will put downward pressure on electricity prices. The knowledge to build what is needed, when it is needed will result in the deferral of large capital investments.

Summary correlation

Key characteristics	Summary Relationship with key success factor for South Africa
Self-heal	Improve grid availability and supply reliability while it enhances cost savings, reliability and the profitable marketing of surplus power.
Customer participation	Customers use energy more wisely, helping utilities produce more efficiently resulting in a wide range of environmental benefits.
Resist attack	The grid deters or withstands physical or cyber-attack.
Power quality	Avoids productivity losses of downtime, especially in the intensive energy users and digital device environments.
Generation & 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.
Enable markets	The grid’s open-access market reveals waste and inefficiency and helps drive them out of the system while offering new customer choices such as green power products. Furthermore, it will open new revenue generating opportunities for utilities.
Optimise assets	Desired functionality at minimum cost guides operations and the effective use of assets.

APPENDIX H: CORRELATION BETWEEN KEY SUCCESS FACTORS AND PRINCIPLE CHARACTERISTICS

The following matrix illustrates the correlation between the Smart Grid key success factors (KSF) and the principle characteristics supporting performance requirements:

Correlation between:		Principle characteristic						
Key success factors		Self-heal	Customer participation	Resist attack	Power Quality	Generation & storage options	Enable markets	Optimise assets
	Reliability	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Security	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>
	Safety	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>
	Efficient	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Environmental	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Economical	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Barriers to be addressed

Key characteristics	Barrier to address to support the South African Smart Grid key success factors
Self-heal	<ul style="list-style-type: none"> The cost to develop and implement the needed technology changes is high. Addressing this cost will require the alignment of all related capital investments. Furthermore, stakeholder buy-in, including the government, will be required since many benefits of a self-healing grid are societal in nature. Utilities alone cannot justify the investment to attain the societal benefits. Some older equipment must be replaced as it cannot be retrofitted to be compatible with the requirements of the self-healing characteristic. This may present a problem for utilities and regulators since keeping equipment beyond its depreciated life minimises the capital cost to customers; early retirement of equipment may become an issue. However, the government approved Approach to Distribution Asset Management (ADAM) initiative presents a significant opportunity to be leveraged. Advances are needed in many technical areas such as intelligent electronic devices (including advanced sensors), DER, DR, ubiquitous communication infrastructure, and control devices to execute self-healing actions. Cooperation among utilities to install critical circuit ties and freely exchange information to implement modern grid concepts.
Customer participation	<ul style="list-style-type: none"> Cost-effective, secure, and reliable metering, communications, and supporting IT; Systems and processes that more fully recognised and incorporate the active customer role in grid management; The design of associated tariffs; Customer education: The transition from a passive, protected user to a proactive, informed consumer; Innovative rate structures; Slow process of technology deployment; Because of the complexity of the transformation required in the grid, it is important to carefully transition the industry using a deliberate approach.

Key characteristics	Barrier to address to support the South African Smart Grid key success factors
Resist attack	<ul style="list-style-type: none"> • Policies and regulations need to be developed to allow utilities and others in the electricity industry to recoup reasonable costs for security upgrades that are part of the overall system design.; • Industry lacks a standard approach to conducting security assessments, understanding consequences, and valuing security upgrades; • Perception that security improvements are prohibitively expensive; • Open communication and operating systems are flexible and improve system performance but are not as secure as proprietary systems. The increasing use of open systems must be met with industry-approved and adopted standards and protocols that consider system security.
Power quality	<ul style="list-style-type: none"> • Reducing the high costs of modern PQ-enhancing devices; • Implementing policies and regulations to encourage investment in PQ programs, including those that provide pricing related to grades of power; • Updating codes and standards.
Generation & storage options	<ul style="list-style-type: none"> • Total cost of ownership is high for DER; • The value proposition for the customer is not yet compelling - favourable price signals coupled with a reduction in the cost of DER for customer applications are needed to improve the "customer's business case" for investing in and operating DER.
Enable markets	<ul style="list-style-type: none"> • For electricity markets to function properly, near real-time information communication must flow seamlessly between market systems and monitoring and control systems throughout the region. This will require a much dispersed, highly reliable, multi-variant communications infrastructure. • Regulations are required to support full scale integrated markets to fulfil the needs of all customers. • Capital investment: generators must be convinced that they will be able to sell at higher prices and load-serving entities representing the customers must be convinced that they will be able to purchase power at cheaper prices. • Market participation skills. • A level of unbundling of the electricity supply industry is required and at minimum ring-fencing of generation, transmission, distribution and customer service (retail) is required. • A revised approach to cost of supply studies is required. • Opportunities must be identified for utilities to pursue additional revenue streams e.g. leveraging installed data/ communications capabilities.
Optimise assets	<ul style="list-style-type: none"> • Interoperability of communication systems and standards. • A strategy that supports a timely and low cost upgrading of existing assets so they can integrate with new Smart Grid technologies and processes. • Changes to regulatory policy may be needed to allow replacement of partially depreciated equipment that is not compatible with the newer Smart Grid technologies. • Effective change management processes. • Business cases and implementation plans.

APPENDIX I: SMART GRID ROLL-OUT ROADMAP

This section must be read in conjunction with the Smart Grid Business Case and “Smart Grid How to Guide” developed by SANEDI. This section focuses on the overall roll-out of the Smart Grid on a country level and is supported by the implementation plan for utilities as described in the “How to Guide”.

The importance of a roadmap development was emphasised by EWE NETZ, one of the largest utility companies in Germany, during the study tour in 2017. The utility developed a roadmap to ensure efficient management of energy flows as illustrated below:

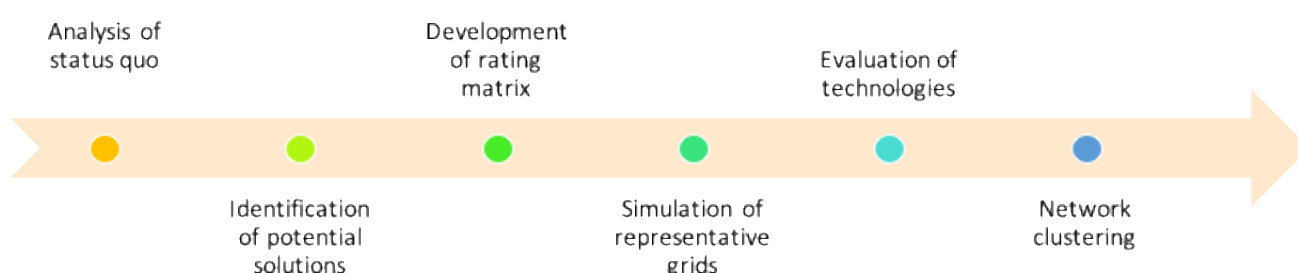


Figure 17. EWE NETZ Roadmap for Smart Grids Implementation

The following lessons regarding roadmap development were shared on the international study tour:

Lessons learned	Source
<ul style="list-style-type: none"> Research and pilot projects are needed; Strategic analysis of the lessons learned from the pilot projects should be conducted; A stated commitment to Smart Grid and development of a roll out plan is needed; There must be an extensive implementation of Smart Grid components in order to capitalise on the economies of scale; Invest prudently on the grid rather than to over – design the grid; Identify the regulatory pathways for developing the Smart Grid; 	EWE NETZ in Bremen and Oldenburg, Germany
<ul style="list-style-type: none"> Follow a phased approach – evolution rather than revolution; Importance of an overarching cost benefit analysis; 	Innogy in Oldenburg, Germany
<ul style="list-style-type: none"> Highlighted importance of governance and stakeholder management; Overarching policy guidance is important; Individual cost-benefit analysis must be taken by utilities ; Policy, standards and regulatory issues must be addressed for an enabling environment; 	Directorate of Energy, European Commission, Brussels, Belgium

Lessons learned	Source
<ul style="list-style-type: none"> • Biggest challenge is the gathering and the availability and the use of data; • Stronger customer centric approach than in the past; • Integration is crucial; • Regional and technical cooperation; • Coordination of Research and Development plans, innovation activities and the participation in Research programmes; • Transparency; • Informing and educating consumers/customers. 	<p>European Distribution System Operators Association (EDSO) in Brussels, Belgium</p> <p>The European Network of Transmission System Operators in Brussels, Belgium</p> <p>French Environment and Energy Management Agency (ADEME)</p>

During the study tour, it was also noted that implementation and operationalisation of Smart Grids will have to be adapted to the local conditions and to that effect a customised roadmap for South Africa taking into consideration the above lessons learned into consideration.

A Smart Grid is an enabler of overall energy sector objectives and should not be viewed in isolation and therefore requires an integrated and holistic approach to its roll-out supported by strong programme management.

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