GreenCape

CASE STUDY

From legacy to future ready:

Advancing data analysis and modelling capabilities in an energy utility

Abbreviations, terms & glossary

Data pipeline A method in which raw data is ingested from various data sources, transformed and then moved to a data store for analysis.

Decision support system An analytics software programme used to gather and analyse data to inform decision-making.

Demand flexibility The practice of adjusting load (or energy usage) to match the supply of electricity.

Distributed generation Electricity generation done by small-scale energy systems installed near the energy consumer.

Distribution network The network/grid owned and operated by a distributor.

Distributor A legal entity that owns or operates/distributes electricity through a distribution network.

Embedded generation A grid-tied power generation plant that is embedded in the distribution network using renewable energy sources or fuel-driven energy sources.

Energy systems modelling The process of building computer models of energy systems in order to analyse them; such models often use scenario analysis to investigate different assumptions.

Feasibility study A.k.a. Feasibility assessment. An assessment of the practicality of a project or system.

Grid constraints Limitations within the grid that hinder the efficient generation, transmission, distribution and integration of electricity. [ibm.com]

Low voltage Nominal voltage levels up to and including 1 000V [SANS 1019]

Medium voltage Nominal voltage levels greater than 1 000V and up to and including 44 000V [SANS 1019]

Renewable power plant A unit or a system of generating units producing electricity based on a primary renewable energy source e.g. wind, sun, water, biomass, etc. It can use different kinds of primary energy sources.

Scenario analysis The process of evaluating future scenarios and predicting potential outcomes.

Situational awareness An understanding of one's environment and the ability to predict how it might change due to various factors.

Substation (of a power system) A key node or assembly of equipment within the electrical power system used to connect, switch or transform electricity between different voltage levels.

System controller Shift personnel within the DSO Control Centre that monitors real-time data, manages system voltages, and performs emergency actions or manual switching to ensure the stability and reliability of the power grid.

System operator (SO) The legal entity licensed to be responsible for short-term reliability of the Transmission system.

Transmission system (TS) The TS consists of all lines and substation equipment where the nominal voltage is above 132 kV. All other equipment operating at lower voltages are either part of the Distribution System or classified as transmission transformation equipment. [SAGC]

Wholesale electricity market A market where electricity is bought and sold in bulk among generators, utilities and traders before delivery to retail consumers.

ADMS	Advanced Distribution Management System
AMI	Advanced Metering Infrastructure
BI	Business Intelligence
CCT	City of Cape Town
DER	Distributed Energy Resource
DSO	Distribution System Operator
EV	Electric Vehicle
GIS	Geographic Information System
MDUS	Meter Data Unification System
NERSA	National Energy Regulator of South Africa
PV	Photovoltaic
RPP	Renewable Power Plant
SAWEM	South African Wholesale Energy Market
SCADA	Supervisory Control and Data Acquisition
SEM	Sustainable Energy Markets (department in CCT)
SO	System Operator
TS	Transmission System
VPP	Virtual Power Plant

1 Summary

This case study explores the City of Cape Town (CCT) Energy Directorate's ongoing journey to build advanced data analysis and modelling capabilities and practices. These efforts are aimed at enhancing decision-making, supporting the operation of an increasingly complex electricity grid, and enabling a more agile response to a rapidly evolving energy landscape.

About the municipal innovation[1] case study series

The case study forms part of a broader series showcasing innovative initiatives undertaken within the Energy Directorate.

While the Energy Directorate encompasses many data-related-functions, platforms, and pockets of excellence, this case study does not attempt to provide a complete inventory of these capabilities. Instead, amidst a wider, ongoing evolution of Energy's data analysis capabilities through, for example, the broad-scale adoption of Business Intelligence (BI) tools, and organisational restructuring to streamline geospatial capabilities, this piece focuses on two separate business areas that have developed more specialised data analysis capabilities aligned to distinct needs of metropolitan municipalities.

Lessons learnt in the Distribution System Operator (DSO) and Energy Systems Modelling functions are presented as illustrative examples of how data-related capabilities are evolving within the Directorate.

The study captures practical lessons drawn from the experience of staff from the two business areas mentioned within Energy

What: This case study examines how the CCT's Energy Directorate has advanced specialised data analysis capabilities in response to a more complex and decentralised electricity environment. It focuses on two complementary areas: energy systems modelling for long-term planning and policy support within Sustainable Energy Markets (SEM), and operational data analytics within the DSO function.

Why: Rapid growth in distributed energy resources (DERs), increasing policy and investment complexity, and the limits of spreadsheet-based approaches have made advanced analytics essential across many areas of the Energy Directorate. In the two focus areas highlighted in this case study, these pressures have driven the need for advanced capabilities that support both strategic planning and near-real-time operations.

Such capabilities are also critical as the CCT prepares for participation in emerging energy markets, where mature data analytics capabilities are a prerequisite.

When: Capability building in these areas has progressed over the past five years, accelerating as the CCT has moved to diversify its generation mix, expanded embedded generation connections, and formalised DSO functions, alongside growing momentum toward future energy market participation.

What is innovation: Within the two areas explored, the CCT has moved beyond traditional utility data practices by automating data pipelines, advancing through successive generations of energy modelling tools, and evolving into more advanced data analytics and data science techniques.

While these approaches are tailored to specific functional needs, together they demonstrate how targeted data investments can support decision-optimisation, distributed flexibility, evidence based policy, regulatory readiness, and market preparation.

Key contributions: Together, these examples illustrate how municipalities can move beyond legacy, billing-focused data practices towards more mature capabilities that support strategic decision-making, operational responsiveness and future market participation. The study highlights practical lessons on capability design, resourcing, data integration, skills, governance and institutional sustainability that are relevant to other metropolitan municipalities and which are similar to data driven initiatives elsewhere in the Energy Directorate and in other utilities.

[1] Innovation in the CCT is the fostering of a sustainable organisational culture that stimulates creative thinking, risk taking and the implementation of new ideas for optimal service delivery and infrastructure development, aligning with the ISO 56000 definition.

2 Background

An energy system comprises the networks, assets, data flows and operating arrangements that make electricity supply possible. In municipal terms, this often covers the transmission interface through which bulk power is received, the distribution network through which electricity is delivered to end-users, and the generation assets that supply electricity into the system.

In the traditional utility model, generation was concentrated at large central plants connected mainly to the transmission system. In the modern system, however, smaller and more distributed generators increasingly connect at distribution level, altering both network behaviour and the data paradigm that municipalities need to manage.

Like many energy utilities, the CCT Energy Directorate has evolved from a predominantly billing-focused data environment to one that supports integrated monitoring and analysis of the electricity grid. Historically, monthly consumption data was sufficient for many core utility functions, particularly revenue management. The rise of Distributed Energy Resources (DERs), including rooftop solar and other forms of embedded generation, has introduced far greater variability in how electricity flows through the local network and how operational decisions must be made.

The DSO is an operational business unit within the Energy Generation and Distribution Department of the Energy Directorate, responsible for the real-time operation, reliability, and performance of the municipal electricity distribution network, including monitoring grid conditions, managing outages and constraints, and ensuring stable and efficient power delivery.

SEM is a department within the Energy Directorate that plays a forward-looking role focused on strategic planning and innovation, with one of its key functions being energy systems planning and analysis, including the use of energy systems modelling to explore future scenarios, assess trade-offs, and inform procurement, investment, and policy decisions.

Within the Energy Directorate, this change reflects a broader transition from managing a relatively passive power system to managing a more dynamic one. From a DSO perspective, this has required a move beyond spreadsheet-based calculations and manual tracking towards data systems capable of monitoring power flows, outages and constraints in much greater detail. While, within the SEM Department, the same shift has required more sophisticated energy systems modelling to support bid evaluation and strategic decision-making under uncertainty.

These specialist capabilities have developed alongside a broader improvement in the Directorate's general data-related activities. One visible example has been the wider use of BI tools and a move away from Excel-only analysis and reporting towards more structured operational and strategic dashboards. This broader development matters because specialist capability is more sustainable when it is supported by stronger organisation-wide data practices.

3 Introduction

Against this backdrop, advanced data analytics and energy systems modelling have become strategic imperatives in the Energy Directorate.

DER growth, energy transition complexity, regulatory requirements and the prospect of energy market participation have together raised the threshold for what constitutes *adequate* municipal data analytics and modelling capabilities. In this context, the ability to process large volumes of data is essential for participation in an increasingly decentralised energy environment.

This case study focuses on two distinct but complementary examples. The first is energy systems modelling in SEM, where modelling capability is used to answer novel research questions and support long-range planning, feasibility work and policy development. The second is DSO data analytics, where the emphasis is on operational problem-solving, faster response cycles and an increasingly data-driven approach to grid management. Although these examples typically serve different decision horizons, they point to a common conclusion: purpose-built data capability is now central to modern municipal energy practice.

Comparative overview

The two examples are related, but they do not address the same type of problem. SEM's capability is situated within a broader forward-looking function that combines planning, innovation, policy support, and market preparation. Within this context, energy systems modelling is a core analytical tool used to explore future scenarios, evaluate trade-offs, and support both long-term planning and medium-term decision needs such as procurement and investment assessments.

DSO data analytics, by contrast, is oriented towards focused operational problems and the need to support real-time or near-real-time decision-making. This distinction is important for municipalities because capability design, staffing and tooling should follow the nature of the decisions to be supported.

Table 1: Comparative summary of key attributes across different business units in the Energy Directorate.

Dimension	SEM energy systems modelling	DSO data analytics	Practical implication for municipalities
Primary purpose	Answer novel research and planning questions to inform strategic decision-making.	Solve defined operational problems and improve near-real-time decision support.	Be clear whether the immediate need is research-led planning, operational optimisation, or both.
Decision horizon	Typically, medium- to long-term; often scenario-based and investment-oriented.	Real-time, near-real-time, day-ahead and reporting cycles.	Capability design should reflect the time horizon of the decisions it must support.
Typical outputs	Scenarios, options analysis, feasibility comparisons and policy support.	Situational awareness, forecasts, dashboards, alerts, optimisation inputs and compliance reporting.	Different outputs require different data pipelines, staffing and governance arrangements.
Skill profile	Strong research capability and deep energy-domain understanding.	Strong data engineering, analytics and operational interpretation capability.	A single generic analytics role is unlikely to cover both functions adequately.
Team profile	Small, dedicated research team.	Due to its centrality to operational grid stability, the DSO is comprised of a larger team of engineering professionals.	Organisational arrangements should match the value chain.

4 Energy systems modelling for futures studies

The first example concerns the evolution of an energy systems modelling capability to support research and development for energy future studies.

Developed within the SEM Department, this capability has strengthened the Energy Directorate's ability to examine alternative futures, assess trade-offs and support strategic programmes associated with transition planning. It plays an important role in long-range planning and investment decision-making, particularly where the cost of sub-optimal choices may be significant.

The value of this capability lies in its ability to test assumptions, compare pathways and clarify the implications of different choices before major commitments are made. Where investment decisions are costly and path dependent, weak analysis can lock a municipality into sub-optimal outcomes for many years. For metropolitan municipalities facing budget constraints and growing system complexity, energy systems modelling is therefore a practical tool for improving decision quality. Energy system models (e.g., LEAP, PLEXOS, PyPSA) are quantitative tools often with optimisation capability that simulate how an electricity system and its markets operate over time, dispatching generation, storage, and demand response to technical constraints and market rules to produce outcomes such as prices, flows, emissions, and asset revenues.

Within the CCT, internal and service provider executed modelling has been used to support strategic investment decisions, optimisation research, and feasibility assessments. In contexts where multiple infrastructure development options are available, such as municipal own-build projects versus independent power producer (IPP) procurement, modelling enables a more rigorous comparison of their broader economic and financial implications.

One example is the assessment of the Atlantis solar PV plant. In this case, the central question was not only whether generation capacity could be developed, but how municipal ownership compared with alternative procurement approaches once wider costs and benefits were considered. Another application involved the evaluation of competing IPP procurement bids, where modelling informed recommendations by enabling comparison across different cost structures.

Energy systems modelling has also been applied in policy-oriented research on issues such as energy poverty alleviation, a complex area that requires consideration of a wide range of factors including broader electrification planning to assess long-term financial feasibility. In these contexts, modelling helps link policy objectives to operational and budgetary realities. Rather than producing a single definitive outcome, it provides a clearer basis for understanding trade-offs and prioritising action.

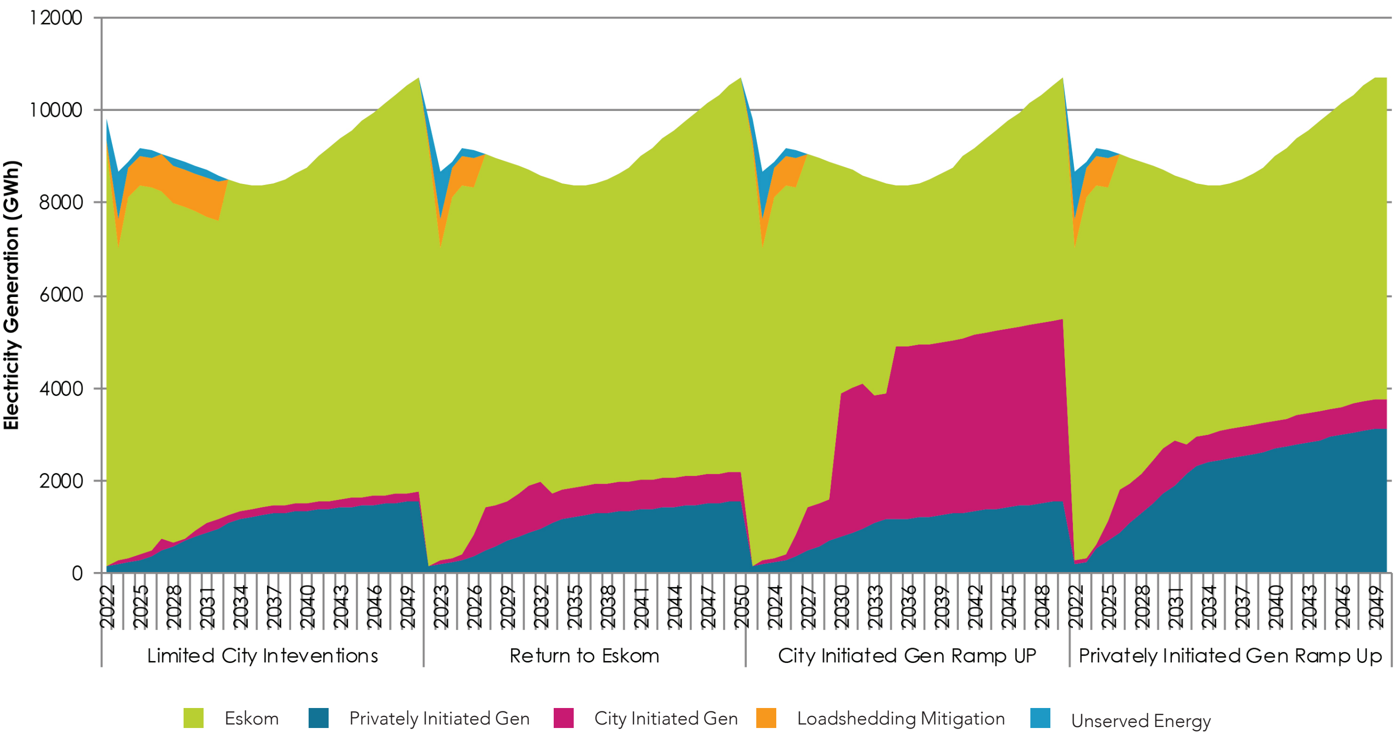

Figure 1: Example output from an electricity supply scenario modelling exercise, illustrating projected generation from different energy sources under alternative future scenarios.

❶ Start with the "build or buy" decision

One of the first questions in developing this kind of capability is whether energy systems modelling should be procured externally or developed internally. External procurement may be appropriate where the need is highly specialised, intermittent or too niche to sustain in-house. It can also provide access to scarce expertise. However, procurement brings its own challenges: supply chain processes are lengthy and time-consuming, specialist services can be expensive, specifications may be difficult to define in advance, and project management demands can be significant where the work is technically complex.

In-house capability becomes more compelling where there is an ongoing requirement to answer novel research questions, support iterative scenario development and retain institutional learning over time. In a metropolitan municipality context, the case for internal capability is strengthened where modelling is needed repeatedly to support strategic decision-making, network optimisation and service development.

Key reflection

Deciding whether energy systems modelling should be procured (almost exclusively) or developed as an in-house capability should not be treated as a purely financial consideration. Factors to consider include continuity of demand, strategic dependence on modelling outputs, and the value of retaining institutional knowledge over time.

❷ Resource in-house capability deliberately

Where the decision is made to invest internally, the business case extends beyond staffing. Tooling, hardware, software licensing and the broader operating model all require active management. Specialist modelling software can be expensive, and advanced tools often carry significant hardware requirements. If the underlying research and development capability is still immature, these costs can weaken the case for internalisation unless the function is closely aligned to high-value decision needs.

The maturity of the wider research and development environment is therefore important. Modelling software on its own does not create value. What strongly emerged for the Energy Systems Modelling business unit, is that value arises when the Directorate has the right questions to ask, the governance to prioritise them, and the internal capability to convert technical outputs into decisions that are understood and used.

Key reflection

First define priority use cases and then resource the modelling capability accordingly to reduce the risk of acquiring advanced tools before a sustainable use case and demand base exists.

❸ Continue to evolve the business case for organisational sustainability

Two important factors led the Energy Systems Modelling business unit to start investigating alternative modelling solutions, especially open-source options. Firstly, there is an ongoing effort to optimise value to the public by assessing lower-cost solution options, and a second, the need to plan for succession and knowledge sharing. A key learning from the exploration of different tools is that transitioning from one modelling tool to another is rarely straightforward. Specialist platforms have steep learning curves, and capability can become concentrated in too few individuals if succession planning is neglected. This raises an important organisational issue: resilience depends not only on the technical capability itself, but also on how well knowledge is distributed and retained.

Key reflections

- The need to reduce the burden of high licensing costs substantiates investigating into open-source tooling.
- Training, documentation and succession planning should be treated as core components of capability development.

❹ Good modelling depends on more than software

A central principle of energy systems modelling is that the quality of the outputs depends on the quality of the inputs. Good modelling requires access to credible datasets, adequate computing resources and disciplined treatment of assumptions. In practice, assumptions often matter as much as the modelling tool itself because they shape scenario boundaries, cost trajectories, demand expectations and system behaviour. Weak, untested or poorly documented assumptions reduce the efficacy of the model.

Key reflections

- Robust modelling is not simply a technical exercise; it is an institutional discipline that depends on transparency, documentation and careful interpretation.
- Major studies should include formal assumption records covering data sources, rationale, limitations and review responsibility. This strengthens transparency, repeatability and confidence in the results.

5 DSO data analytics and reporting capability

The second example addresses the development of data analytics and reporting capabilities to support DSO operations and comply with NERSA reporting requirements.

Rapid growth in DER (such as rooftop PV, batteries, electric vehicles (EVs) and virtual power plants (VPPs) has made traditional spreadsheet-based approaches insufficient. These methods cannot provide the speed, integration or consistency required in a more dynamic network environment where decisions may be required in real time or near-real-time.

The importance of advanced data analytics to the DSO's data-driven operating model has increased as the system itself has become more dynamic. Spreadsheet-based methods remain useful for some tasks, but they are not an adequate operating backbone for high-volume, high-frequency and auditable data environments. In these contexts, coding-centric and console-based workflows become increasingly necessary.

1 Purpose-built data products

Distributed assets such as EVs, controllable hot water loads, behind-the-meter batteries and VPPs are increasingly relevant as sources of network flexibility. While these assets add complexity to planning and operations, they also provide opportunities to alleviate congestion and manage operational constraints when they can be appropriately identified and utilised. For the DSO, it is therefore not sufficient to simply monitor the growth of DER; operational visibility must be timely and sufficiently granular to enable intervention when required.

Unlocking available capacity for grid management requires the ability to locate flexibility on the network, understand the conditions under which it can be relied upon, and assess its operational value at specific times and locations. To achieve this, specialised data products had to be developed that would convert asset, load and network data into actionable operational insight.

Key reflections

- Treat flexibility as an operational resource, not only as a policy concept. This requires capability to identify, value and coordinate distributed resources in relation to actual network conditions.
- Geographic information systems (GIS) are central to this capability as they provide the spatial context needed to link distributed assets to network constraints and operational actions.

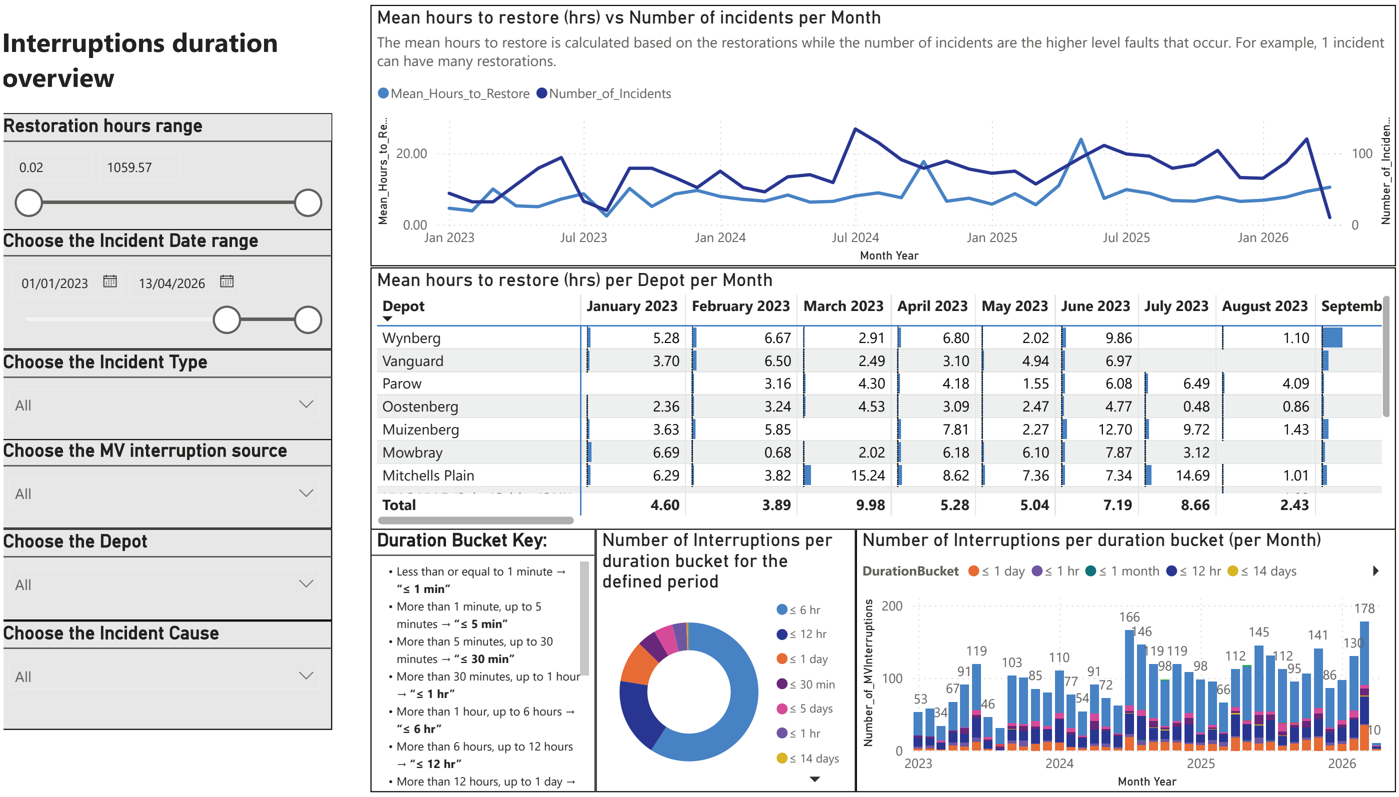

Figure 2: Example of a DSO operational monitoring dashboard that supports management decision-making by providing an overview of interruption-duration statistics for a specified period.

❷ Considering different data roles

The DSO's journey to bolster its data analytics capability began with a careful evaluation of operational needs and the recruitment of critical skills that were previously absent. For example, one of the early steps was the appointment of a data engineer to build complicated data pipelines from disparate source systems.

A clear distinction between data engineer, data scientist and data analyst roles is practically important. A data engineer is responsible for reliable pipelines and infrastructure; a data scientist is more likely to develop analytical or optimisation approaches for specific problems; and a data analyst translates data into interpretable outputs for decision support. Although these roles may overlap in smaller organisations, they should not be conflated in capability planning.

Key reflections

- Capability is a combination of people, processes and systems, and must be evolved alongside one another.
- Beginning with data engineering proved helpful, as it provided the organisational foundation.
- Be agile but define roles clearly in capability planning, even where one person temporarily covers more than one function.
- Advanced analytics capability is built on a reliable data foundation, rather than on visualisation or advanced modelling alone.

❸ Data sources and integration architecture

The DSO operational maturity depends on being able to draw data from a wide range of source systems, including SCADA, ADMS, MDUS, GIS (for infrastructure network components, such as protection relays), as well as weather feeds and variable energy data. Relative to these disparate data sources, new value is generated when operational, customer, asset and external datasets are combined and visualised.

The movement of data from protected operational networks into such an environment must be managed carefully. In a regulated utility context, the challenge is not simply technical integration; it is integration that preserves operational integrity, security and auditability. The breadth and quality of integration is therefore a useful indicator of maturity.

Key reflections

- Data access, protection, auditability and usability need to be designed together.
- Where pipeline reliability, data engineering and governance are weak, more advanced analytical ambitions are unlikely to be sustainable.

❹ Decision horizons and use cases

The DSO is faced with the challenge of developing data products that sufficiently meet the needs of different stakeholders, which requires an in-depth understanding of the business requirements and systems architecture. The DSO had to start by introducing usable dashboards to increase real-time and near-real-time situational awareness, day-ahead and intraday forecasting and re-optimisation, as well as monthly and annual regulatory and performance reporting to NERSA.

Looking forward, near-real-time data analytics is situated as the operational backbone for scheduling, dispatch and transacting in emerging energy markets, and this capability is being developed in anticipation of formal market participation. In this context, the ability to process large data volumes is essential for participation in the South African Wholesale Electricity Market (SAWEM). This highlights that metropolitan municipalities entering SAWEM compete not only on assets or scale, but also on the sophistication of their data analytics capabilities relative to private companies.

Key reflections

- Real-time or near-real-time readiness cannot be created at short notice.
- Monitoring dashboards and alerts have become a key enabler of effective operational decision making.
- Market-relevant data capability should be developed well before formal participation in SAWEM becomes imminent.

6 Conclusion and way forward

Although SEM and the DSO plan for different decision horizons, several lessons recur across both teams. In both SEM and the DSO, the experience of the City of Cape Town shows that advanced data analytics and energy systems modelling are not peripheral innovations; they are becoming essential components of how a modern municipal utility plans, operates and prepares for change.

The most important lesson is therefore organisational as much as technical. Central functions can and should provide shared capability, standards and good practice. At the same time, the operational dependency and subject-matter specificity of the energy environment justify dedicated specialist capability where the business case is clear. For other metropolitan municipalities, the implication is not to replicate structures mechanically, but to build capability deliberately: beginning with real business needs, investing in durable foundations, and evolving specialist capacity in step with the complexity of the system being managed.

Looking forward, as system complexity increases and market participation becomes more tangible, standardisation, data availability and the ability to process large volumes of information will become increasingly important.

The Transmission Systems Operator, for example, is making data public for market participation. This points to a future in which the data capabilities of municipalities participating in SAWEM will be judged not only by what data is collected internally, but also by how reliably it is structured, governed and shared.

This case study was made possible thanks to the support of the City of Cape Town.

GreenCape and the CCT would also like to thank all the stakeholders who contributed information and insights towards the production of this case study. Images in this document were taken during the construction phase of the project.

Images: Bruce Sutherland (City of Cape Town), Nicholas Fordyce and Freepik.

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