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REFERENCE GUIDE FOR MUNICIPAL ENERGY PLAN AND STRATEGY DEVELOPMENT

May 31, 2023

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FOREWORD

Following an amendment to the Electricity Regulation Act in 2020, allowing municipalities in good financial standing to develop their own power generation projects, municipalities must acquire the knowledge and skills to seize opportunities associated with utilizing renewable energy technologies. Since 2021, the USAID Southern Africa Energy Program (SAEP), a Power Africa initiative, in collaboration with the South African Local Government Association (SALGA), has been providing municipalities with capacity building on various topics such as Project Finance Principles for Renewable Energy Generation Projects, Electrification Project Management Office, Revenue Management, Public-Private Partnership (PPP) Approaches for Power Generation Development, and Energy Planning.

One of the key challenges municipalities face is knowing and understanding their energy needs. They must develop energy plans, to, among other things, determine their renewable energy potential and required generation mix.

Provinces find themselves in a similar situation enabled by the Electricity Regulation Act amendment. Some of them are starting to consider the possibility of procuring their own new generation capacity to mitigate load shedding impacts and to support economic growth objectives.

In 2022, SAEP supported municipalities and a provincial entity to undertake energy needs assessments and develop energy strategies and plans. Given the demand and need to continue this work, SAEP has developed this guide to capture the learnings from this phase and serve as a blueprint of how energy plans and strategies should be developed within a municipal context. This is important, considering that more municipalities and industrial development zones will require this type of support in the future.

The guide is not meant to be prescriptive. It provides the minimum requirements in terms of the methodology to be followed and the key outputs to be expected from an energy planning and strategy development study. SAEP hopes that municipalities, industrial development zones (IDZs) and special economic zones (SEZs) will find this guide useful in developing energy plans and strategies.

DOCUMENT REVISION CONTROL: RECORD OF CHANGES

Revision No.	Revision Date	Organization (and Custodian)	Record of Changes
1	May 31, 2023	SAEP	First Draft

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ACRONYMS

Acronym	Definition
AHP	Analytical Hierarchical Process
ANP	Analytical Network Process
CSP	Concentrated Solar Power
DFFE	Department of Forestry, Fisheries, and the Environment
DMRE	Department of Mineral Resource and Energy
DNI	Direct Normal Irradiance
DPE	Department of Public Enterprises
EE	Energy Efficiency
GCCA	Generation Connection Capacity Assessment
GHI	Global Horizontal Irradiance
GIS	Geographical Information System
GLPK	The GNU operating system's Linear Programming Kit
IDP	Integrated Development Plan
IRENA-SPLAT	International Renewable Energy Agency System Planning Test
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilo-Watt-hour
kWp	Kilo-Watt Peak
LCOE	Levelized Cost of Energy
MCDM	Multi-criteria Decision Making
MMSEZ	Musina-Makhado Special Economic Zone
MWh	MegaWatt-hour
NDM	Namakwa District Municipality
NDP	Network Development Plans
NERSA	National Electricity Regulator of South Africa
OSeMOSYS	Open-Source Energy Modelling System
PV	Photovoltaic
REDZs	Renewable Energy Development Zones
SDDP	Stochastic dual dynamic programming
SDF	Spatial Development Framework
SEA	Strategic Environmental Assessment
SOAR	Strengths, Opportunities, Aspirations, and Results
SSEG	Small-Scale Embedded Generation
SWOT	Strengths, Opportunities, Weakness, and Threats
TEMOA	Tools for Energy Model Optimization and Analysis
TIMES	The Integrated MARKAL-EFOM System
TDP	Transmission Development Plan
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
WAsP	Wind Atlas Analysis and Application Program

ENERGY ROADMAP FOR MUNICIPALITIES

An energy strategy provides a roadmap that highlights how governments, regions or organisations can efficiently and effectively manage their energy resources to meet strategic goals and objectives related to their energy needs. It involves identifying and implementing energy solutions that can help reduce energy costs, improve energy efficiency, increase the use of renewable energy sources and reduce carbon emissions. This guide was developed to support local, district and provincial government and their key stakeholders to cocreate energy strategies that will meet their short-, medium-, and long-term energy goals, such as reducing greenhouse gas emissions, increasing energy efficiency and increasing generation capacity with renewable energy sources. The process applied is based on a *road mapping methodology*[1] informed by data analysis and energy modelling. The development of the roadmap is conceived as a 'bottom-up' approach based on meaningful stakeholder engagement and buy-in and political commitment. Possible pathways to inform the energy strategy development are reviewed from an energy, environmental and economic perspective.

The process is governed by expert judgement and consensus forming, informed by data gathering, resource assessment, energy modelling, spatial demand forecast and analysis. Expert judgements, supported by sound data and analysis, are used to establish current baseline conditions so that milestones and performance targets can be set and energy pathways defined to achieve the roadmap goals. The development process ensures that a roadmap identifies shared goals and determines specific and achievable actions towards realizing a common vision.

Stakeholder engagement within the region is used to facilitate buy-in and political commitment, gather a cross-section of experts in technology, policy, economics, finance, social sciences and other disciplines to formulate goals and milestones, identify gaps, determine priorities and assign tasks. The engagement plan encourages the development of a community of practice to support implementation, monitoring and revision.

KEY DEFINITIONS

Energy Roadmap: An energy roadmap is a long-term strategic plan that sets a vision for the transition from the current energy system to a more sustainable, low-carbon energy system by providing pathways for achieving specific energy-related goals.

Setting a Vision: The process of analysing future scenarios and identifying objectives, typically over a long-term timeframe.

Energy Strategy: A strategy developed to effectively manage and utilize energy resources to meet future energy needs by setting goals and objectives related to energy conservation, efficiency and renewable energy use, and outlining specific actions and initiatives to achieve those goals.

Energy Plan: A comprehensive action plan that outlines how an energy strategy will be implemented based on baseline energy data, outlining energy conservation and efficiency measures, renewable energy development plans, energy infrastructure and distribution, financing and investment and monitoring and evaluation.

Stakeholders: Relevant individuals who have a vested interest in seeing the energy strategy developed and implemented, such as representatives from industry, government, academia and non-governmental organisations.

Resource Assessment: A systematic collection of site-specific meteorological data related to a particular energy resource (e.g., solar, wind) for the purpose of establishing resource availability and to accurately estimate the annual energy production.

Energy Modelling: This is a quantitative optimization modelling of a nexus of energy sources capable of satisfying a predefined demand over a period (e.g., 20 years) according to a predefined objective function.

Spatial Demand Forecast: This is also known as the geographic load forecast. In the context of this guide, it is a modelling approach where socio-economic and land use data are integrated into a set of geospatial data for the purpose of predicting long-term energy demand for a specific geographical area.

[1] http://www.energy.gov.za/files/SETRM/EnergyTechRoadmaps/Roadmap-guide.pdf

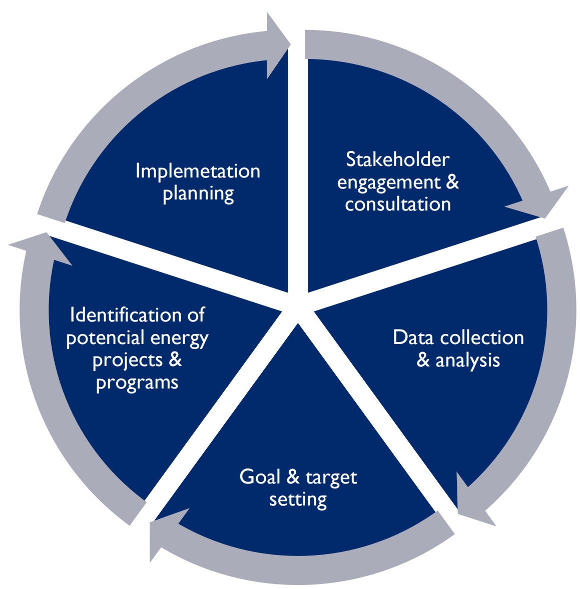
HOW TO USE THIS GUIDE

This guide provides an overview of the steps involved to successfully develop an energy strategy and plan that encourage energy efficiency and use of renewable energy in local communities. The method presented draws on leading practice and local experience based on stakeholder buy-in and political commitment. A step-by-step guide to inform energy strategy and planning aligned to national and provincial policy and plans is presented for district and municipal managers, community leaders and decision makers, government officials, technical staff and consultants. The development of an energy strategy typically involves several stages, including stakeholder engagement and consultation, data collection and analysis, goal and target setting, identification of potential energy projects and programs and development of an implementation plan.

Energy strategies typically take a long-term view and consider the energy needs and goals of a municipality over a period of 10 to 20 years or more. The exact timeframe for forecasting energy needs and goals may vary depending on the specific circumstances of the municipality and the energy sector. Municipalities are encouraged to use this guide to inform and manage energy planning in their local context by implementing long-term energy strategies and plans that respond to local needs. It is important to base energy strategies and plans on accurate data, clear assumptions and to regularly review and update the energy plan and strategy to ensure that it remains relevant and aligned with changing circumstances and priorities. By following this guide, local municipalities will have a clear sight of what data is needed to inform planning and the systems and processes needed to be put in place to maintain energy plans in the long-term.

Content and Interactivity

This guide provides details on how to prepare for each stage to inform energy strategies and implementation plans by defining the energy strategy development process, the tools and resources needed at every step and who to involve and engage in the process. The guide is divided into sections presenting details of what is expected by the project team. Each section provides examples that can be followed, though this is not prescriptive and could vary from one municipality to another. The content in each section also provides the activities to be carried out and helpful tips on how they can be efficiently carried out. Some infographics are included as a guide, which can be adopted.



Links

Helpful links are provided to resource materials using footnotes. These resource materials expressively give more information about the topic being discussed and how best such can be carried out at industrial standard.

Software Tools

Useful software tools are recommended at specific tasks in this guide. This list is not prescriptive, exhaustive and definite. Some of the software listed are open-source and can be leveraged by municipalities for strategic energy planning. Many programs and consultancies are available to assist in various parts of the planning process. It is, however, important that the skills to implement energy strategy development are developed in-house (if it does not already exist) to support implementation and long-term management of energy resources at municipalities.

Further Reading

The further reading section of this guide provides additional resources to support energy strategy development and implementation. These resources are credible materials developed within the space of strategic energy planning for use at no cost.

Templates

Specific templates are provided in the appendix for users to adapt to suit their needs. While this is not definite, it offers helpful content and specific information worth noting. For instance, the data collection template provides specific data types and categories to collect during the data collection phase.

External Support

Additional support in terms of human resources and local expertise for stakeholder engagement facilitation might be needed along the strategy development process. By implementing this step-by-step guide, local and district municipalities can identify where additional resources, support and expertise might be needed to inform their energy planning, who to involve at every level in the planning stages and how to implement and maintain energy plans at their local municipality. Many specific programs and consultancies are available to assist in various parts of the planning process. It is, however, important that the skills to implement energy strategy development are developed in-house (if it does not already exist) to support the implementation and long-term management of energy resources at local municipalities.

The time to develop an energy plan and strategy can vary depending on a variety of factors, including the size of the municipality, the complexity of the energy challenges and opportunities in the area, the level of stakeholder engagement and the availability of resources and funding. The timeline for each stage can also vary depending on the scope of the project and the level of stakeholder engagement. In general, it is important to strike a balance between moving quickly and ensuring that the energy strategy is comprehensive, inclusive and grounded in the needs and priorities of the community. Rushing the process can result in a less effective strategy, while taking too long can delay implementation and reduce momentum for change.

INTRODUCTION TO THE GUIDELINE

Developing an energy strategy and plan for a local municipality can be a complex and challenging process. To help guide municipalities through this process, this guide was developed as a framework to support strategy development, effective planning, implementation and maintenance. Local, district and provincial government plays a central role in energy planning, as it is responsible for setting policies, regulations and incentives that can promote sustainable energy use and support the transition to a low-carbon energy system. This guide is intended to support municipal government officials in strategic energy planning to develop more effective and inclusive energy plans aligned with the needs and priorities of the local community.

By following the steps and considerations outlined in this guide, municipalities can develop a comprehensive and effective energy strategy and implementation plans aligned with local priorities and support the transition to a more sustainable and resilient energy system.

Energy is a critical input for economic activities and essential for the functioning of many sectors, including service and manufacturing industries, transportation and buildings. Therefore, a stable and sustainable supply of energy is necessary to support economic growth and development. Developing and implementing a strategic energy plan enables local governments, district municipalities and provinces to supply reliable and least-cost energy that is sustainable and environmentally responsible. This can be achieved by setting a long-term energy vision and mission, goals and targets for increased energy capacity, grid-resilience and strengthening, energy efficiency and renewable energy, implementing policies and regulations to support these goals and promoting innovation and technology transfer.

In addition, strategic energy planning can have other benefits, such as reducing greenhouse gas emissions and improving air quality, enhancing energy security, creating jobs and economic opportunities in the renewable energy sector and enhancing the resilience of local communities to energy disruptions. Overall, strategic energy planning is an essential component of sustainable development and is critical for achieving long-term economic growth, environmental sustainability and social well-being. The topics presented in this guide are outlined below.

Photo credit: SAEP

SECTION A – THE STRATEGIC ENERGY PLANNING PROCESS

Strategic energy planning is essential for achieving long-term energy goals. Developing and implementing an energy strategy is an ongoing, dynamic process that requires continuous monitoring, evaluation, and adaptation to changing circumstances, emerging technologies, and new energy goals and objectives. This section introduces energy planning and the steps involved to successfully develop an energy strategy and implementation plan.

SECTION B – PLANNING FOR SUCCESS

Several key aspects are essential for ensuring a successful energy strategy, such as setting ambitious yet realistic goals, engaging stakeholders and building partnerships, identifying and prioritizing actions and establishing effective monitoring and evaluation mechanisms. However, effective leadership and governance is the most critical factor for the success of an energy strategy. Municipalities need strong leadership and effective governance structures to provide the necessary support and resources for the development and implementation of energy strategies. This section presents the key aspects required to make the development of an energy strategy successful.

SECTION C – SETTING A VISION

Setting a clear and compelling vision and mission is crucial for developing an effective and sustainable energy strategy and plan for a municipality. When developing the vision and mission, it is important to consider the unique characteristics and needs of the municipality, as well as the broader energy and sustainability context. The vision and mission should be aligned with local, national and international energy policies and regulations as well as other relevant sustainability goals and initiatives. The focus of this section is on developing and reviewing the vision and mission based on results and outputs of the studies done under section D.

SECTION D – A STEP-BY-STEP GUIDE FOR EXECUTION

This section focusses on a step-by-step guide for the development and execution of the various studies, understanding why it is important to have these studies, the tools required to conduct these studies, how-to guides and typical outputs. The key studies include:

- Determining status quo or energy baseline
- Needs assessment
- Resources assessment
- Energy planning and the associated projects (including generation capacity strengthening through least-cost optimization, energy plan and implementation plan)

SECTION E – ACTION PLANS TO ENSURE IMPLEMENTATION

Developing effective action plans is critical for implementing municipal energy strategies and achieving the desired outcomes. By setting specific goals, identifying concrete actions and establishing clear responsibilities and timelines, municipalities can ensure that their energy plans are implemented successfully and contribute to a sustainable and resilient energy future. This section focuses on the action plans to be put in place to implement the plan developed under section B. It is important that the action plan relates to other plans like the Integrated Development Plans and Electrification Plans, and that the action plan aligns to the District/Municipality's Spatial Development Frameworks, Provincial and National plans. Furthermore, this section will highlight how the action plans lead to the procurement phase and transaction advisory related work.

A. THE STRATEGIC ENERGY PLANNING PROCESS

Strategic energy planning is central to the long-term economic growth of any local government, province, or country. At the municipal level, an energy strategy strengthens socioeconomic activities and trade. Overall, strategic energy planning is an essential component of sustainable development and is critical for achieving long-term economic growth, environmental sustainability, and social well-being. Developing an energy strategy for a municipality involves multiple internal and external stakeholders, such as relevant departments within the municipality, provincial and national levels. The strategy development process investigates the short-, medium-, and long-term energy needs within a geographical boundary (national, provincial, district or local municipality) with clear goals and objectives towards satisfying the energy demand at least cost with a mix of environmental responsible energy resources, with the global drive to mitigate the effects of climate change in mind. A co-creation approach, which fosters the inclusiveness of the municipality, is mostly adopted for energy strategy development. This approach ensures co-ownership of the strategy with each stakeholder or represented department, whether core, involved or informed members. This, by experience, fosters the joint implementation of the final strategy with minimal challenges during the strategy approval phase.

The energy strategy development process is data-driven, and as such, it requires an in-depth data mining process from policy documents at all government levels. It also involves data from local utility suppliers and other related departments. The data input quality determines the strategy's quality and credibility. There is a need to investigate the national policies on energy through the Integrated Resource Plan (IRP), the approved energy technologies at the national level, the appropriate Spatial Development Frameworks (SDF), Integrated Development Plans (IDP) and the grid connection capacities for a municipality.

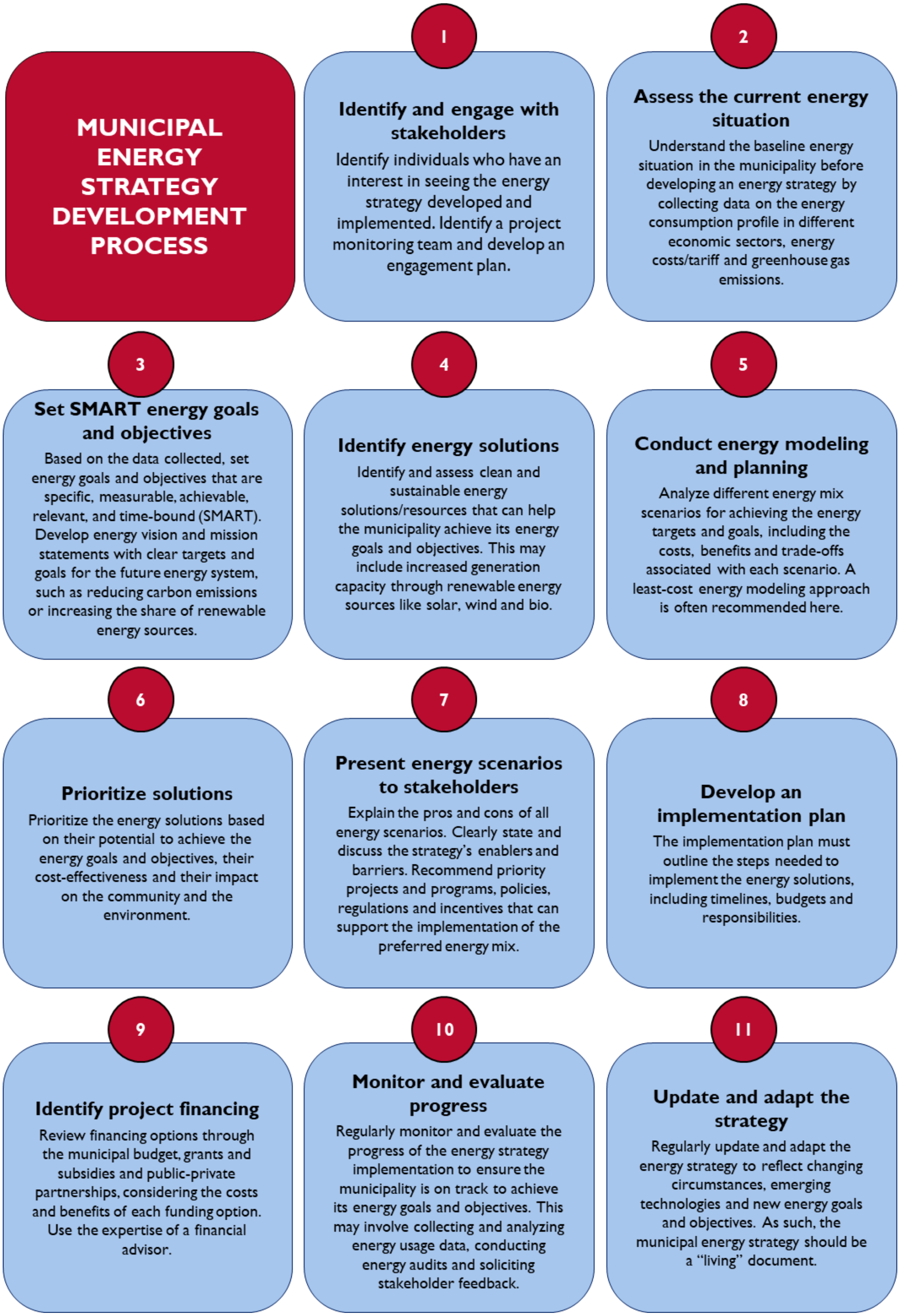
Several modeling techniques have been developed for energy strategy development The most common is the least-cost model. This presents a combination of investments that minimizes the present value capital, also known as a fixed cost, the operating, and the maintenance cost and simultaneously satisfies the short-, medium-, and long-term energy demand with adequate reliability.[2] While several commercial software options are available for this, the use of open-source software has increased among energy planners. However, the learning curve towards increasing their robustness is still gradual and a steep learning curve exists among their users. Some of these open-source software options have experienced significant user community development and funding towards making them accessible and available for public use, like the Open-Source Energy Modelling System (OSeMOSYS) and Tools for Energy Model Optimization and Analysis (TEMOA). The credibility of OSeMOSYS software has been verified through its use in several studies like that in Bangladesh[2] and in the US, Mexico, Costa Rica, Brazil, etc.[3] There is a continuous development of this tool towards improving its efficiency and effectiveness. This tool also has no updates or licensing fees, thus making it available for new users when the strategy must be updated.

The energy plan, based on the modeling outputs, should be a "living" document that requires updating at an agreed periodicity or when there is a significant policy or technical change which impacts the validity of the model outputs observed. In the same way, developing and implementing an energy strategy is an ongoing, dynamic process that requires continuous monitoring, evaluation, and adaptation to changing circumstances, emerging technologies, and new energy goals and objectives. An energy strategy should also be regularly reviewed and updated to ensure that it remains relevant and effective in achieving the desired outcomes. These skills must be developed at the municipal level to implement and maintain energy plans. This section presents a step-by-step guide to developing energy strategies and plans for local municipalities. Based on best practice and local experience, eleven steps to municipal energy strategy development are proposed. The following steps, detailed in this section, inform energy strategy development and implementation:

[2] Olsson, J. M. & Gardumi, F.Olsson, J. M. & Gardumi, F. (2021) "Modelling least cost electricity system scenarios for Bangladesh using OSeMOSYS." Energy Strategy Reviews 38, 100705

[3] https://www.i2am-paris.eu/detailed_model_doc/osemosys

Figure 1: Municipal energy strategy development steps



After the initial energy strategy is developed and implemented, it is important to regularly review and update it. This may involve regular monitoring and evaluation of progress towards achieving the energy targets and goals, including tracking energy usage, greenhouse gas emissions and other key performance indicators. A periodic review of the energy strategy to assess whether it still aligns with the latest international, national and local energy policy and regulatory frameworks, and whether there are new technologies or emerging trends that should be incorporated into the roadmap, is also required.

Engaging with stakeholders, including the local community, industry partners and other relevant stakeholders, to gather feedback and input on the energy strategy and to ensure that their perspectives and needs are considered should be included in the periodic evaluation. It is also important to incorporate new information and data as it becomes available, including new energy-related technologies, changing energy demand patterns and updated climate change projections.

Continuously seeking ways to improve the energy strategy, including identifying new opportunities to increase energy efficiency, reduce costs and accelerate the transition to a low-carbon energy system will enhance the effectiveness of the energy strategy over time. By treating the development and implementation of an energy strategy as an ongoing process, municipalities can ensure that their energy strategies remain relevant, effective and responsive to changing circumstances and emerging opportunities.


Photo credit: SAEP

B. PLANNING FOR SUCCESS

Several key aspects are essential for ensuring a successful energy strategy, such as setting ambitious yet realistic goals, engaging stakeholders and building partnerships, identifying and prioritizing actions and establishing effective monitoring and evaluation mechanisms. However, effective leadership and governance are the most important factors for the success of an energy strategy. In this section, we focus on the key aspects required to make the development of an energy strategy successful. These include, but are not limited to:

- Executive management and political leadership buy-in
- Stakeholder engagement from inception throughout the development of the plan and strategy and during implementation
- Technical analysis (Status quo/needs/resource assessment & planning studies) required to guide the strategic vision, mission and action plan.

Effective leadership and governance are the most important factors for the success of an energy strategy.

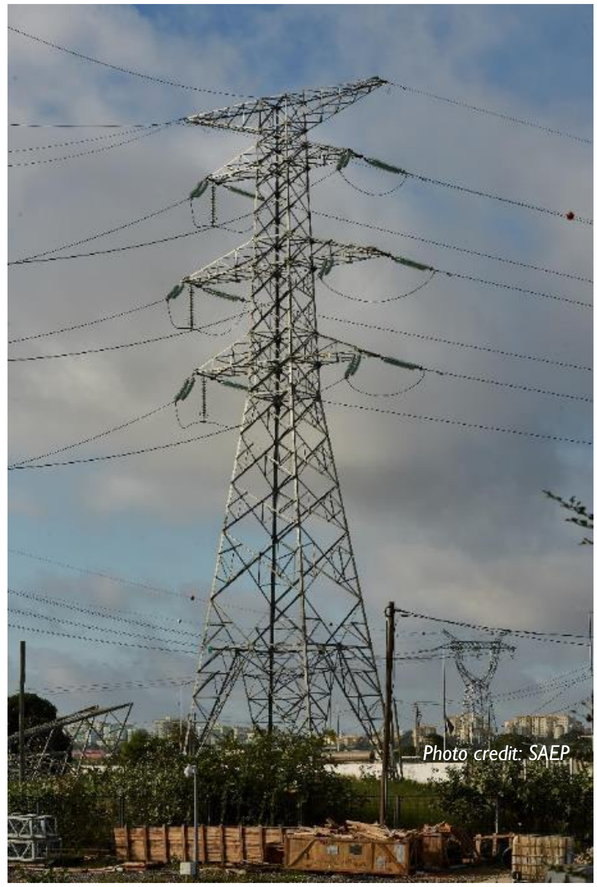


Photo credit: SAEP

A successful energy strategy should have a clear statement of the desired outcomes followed by specific pathways to achieve these goals. Setting clear, measurable goals and objectives is an important starting point for any energy strategy; however, executive management and buy-in from political leadership will determine whether a strategy will see the light of day and be successful in its implementation.

EXECUTIVE MANAGEMENT AND POLITICAL LEADERSHIP BUY-IN

Political commitment is critical for the success of an energy strategy. Municipal leaders need to provide the necessary support and resources for the development and implementation of the strategy and demonstrate their commitment to achieving the desired outcomes. This can help to build momentum and support for the strategy and ensure that it is integrated into broader municipal policies and plans. Without their support, energy planning initiatives may not receive the necessary resources, policy changes may not be achieved, stakeholder engagement can fail, unambitious targets could be set and the political support needed to be successful will be absent.

Executive management and political leadership buy-in are critical for the success of energy planning in municipalities for several reasons:

Providing resources and funding: Executive management and political leaders are responsible for allocating resources and funding to support energy planning initiatives. Without their support, energy planning may not receive the necessary resources and funding to be successful.

Ensuring stakeholder engagement: Executive management and political leaders can help facilitate stakeholder engagement and participation in the energy planning process. This can build support for energy initiatives and ensure the needs and perspectives of all stakeholders are considered.

Giving political support: Energy planning initiatives can sometimes face opposition or scepticism from some stakeholders. Executive management and political leaders can provide political support and build momentum and buy-in for energy initiatives.

Setting ambitious targets and goals: Executive management and political leaders are responsible for setting ambitious targets and goals for energy planning initiatives. This can help align the initiatives with broader municipal goals and priorities and have a meaningful impact on reducing greenhouse gas emissions and improving energy efficiency.

Driving policy and regulatory change: Energy planning often influences changes to policies and regulations, such as establishing building codes or incentives for renewable energy development and development of new frameworks. Executive management and political leaders are responsible for driving these changes and ensuring that they are implemented effectively.

Municipalities need strong leadership and effective governance structures to provide the necessary support and resources for the development and implementation of energy strategies. Effective leadership and governance can help to:

- Align the energy strategy with broader municipal goals and priorities.
- Provide political support and visibility to the energy strategy.
- Secure necessary resources and funding for the energy strategy.
- Encourage stakeholder engagement and participation in the energy planning process.
- Drive the implementation of the energy strategy through effective project management and decision-making.
- Establish clear roles and responsibilities for all stakeholders involved in the energy planning process.
- Develop the energy strategy through a transparent and participatory process that involves diverse perspectives and interests.
- Provide effective oversight and accountability for the implementation of the energy strategy.
- Establish effective monitoring and evaluation mechanisms to track progress and adjust course as needed.

Municipalities must have strong leadership and governance structures in place to support the development and implementation of energy strategies that can help them achieve their sustainability goals.

STAKEHOLDER IDENTIFICATION AND ENGAGEMENT

A successful energy strategy/roadmap is anchored in collaboration and stakeholder engagement to secure buy-in and political commitment. Engaging with a wide range of stakeholders, including local government, industry, community organizations and residents, can build support for energy initiatives and align energy policies and programs with the local communities' needs and priorities. Involving stakeholders in the energy planning process from the outset can help ground the strategy in local needs and priorities and have it benefit from diverse perspectives and expertise. There are several stakeholders involved in municipal energy planning, including:

Different spheres of government: The different spheres of government play a central role in energy planning, with varying levels of responsibility as it relates to setting policies, regulations and incentives that can promote sustainable energy use and support the transition to a low-carbon energy system. Government officials and staff may also be involved in conducting energy assessments, developing energy targets and goals and implementing energy efficiency and renewable energy projects.

Business and industry: Local businesses and industries can be important stakeholders in municipal energy planning, as they are major energy consumers and may have unique energy-related needs and concerns. Engaging with local businesses and industry associations can help align energy policies and programs with the needs of local businesses and industries.

Energy service providers: Energy service providers, including utilities and other energy companies, can be important stakeholders in municipal energy planning, as they may have expertise and resources that can be leveraged to support the transition to a low-carbon energy system. Engaging with energy service providers can help identify opportunities for collaboration and partnership in developing and implementing energy efficiency and renewable energy projects.

Community organizations: Community organizations, such as neighbourhood associations and environmental groups, can play an important role in municipal energy planning by advocating for sustainable energy policies and programs, raising awareness about energy-related issues and providing input on energy planning efforts.

Residents: Municipal energy planning can have a direct impact on residents, who are the end-users of energy. Engaging with residents can help align energy policies and programs with their needs and preferences and build support for sustainable energy initiatives.

By engaging with these and other stakeholders, municipalities can develop more effective and inclusive energy plans that are aligned with the needs and priorities of the local community. Triple helix collaboration involves collaboration between government, industry and academia to address complex societal challenges. In the context of energy strategy development, triple helix collaboration can bring together stakeholders from these three sectors to identify and address energy challenges and opportunities in a more effective and holistic manner.

There are several ways in which triple helix collaboration can improve energy strategy development:

Bringing diverse perspectives: Collaboration between government, industry and academia can bring a diversity of perspectives to the table, which can lead to more comprehensive and effective energy strategies. Each sector can bring unique expertise and knowledge, which can be leveraged to develop more robust energy plans.

Co-creating solutions: Triple helix collaboration can facilitate the co-creation of solutions that address the needs and priorities of all stakeholders. This can help to align the energy strategy with the needs and priorities of the community and that all stakeholders have a sense of ownership and investment in the strategy.

Enhancing innovation: Collaboration between industry and academia can enhance innovation in energy strategy development. Academia can bring cutting-edge research and technological developments to the table, while industry can bring expertise in commercialization and implementation. This can lead to more innovative and effective energy solutions.

Leveraging resources: Collaboration of this nature can also help to leverage resources for energy strategy development. For example, industry can provide funding or in-kind contributions, while academia can provide research and analysis and government can provide policy and regulatory support.

By working together, stakeholders can develop more comprehensive and effective energy strategies that address the needs and priorities of the community. The first step in municipal energy planning is the identification of stakeholders relevant to the project. This is vital to successfully co-creating the energy strategy and plan. The list of stakeholders is expected to cut across the national, provincial, district and municipal levels.

Shown below is a high-level list of stakeholders, each of which includes (but is not limited to) different relevant departments, often at each level:

Municipal Council executives (local and district levels)	Relevant power utility company(ies)	National, provincial, and local departments/sectors related to energy, regulation and governance	National, provincial, district and local Environmental departments	Project finance departments
	(E.g. Eskom)	(E.g. Department of Mineral Resource and Energy (DMRE), National Electricity Regulator of South Africa (NERSA), Department of Cooperative Governance and Traditional Affairs (COGTA) South African Local Government Association (SALGA))	(E.g. Department of Forestry, Fisheries, and the Environment (DFFE), Agriculture, Rural Development and Environment departments.)	(E.g. National Treasury, Department of Public Enterprises (DPE), Department of Trade, Industry and Competition (DTIC).)

Figure 2: High-level stakeholder list

For the purpose of engagement throughout the project duration, the list of stakeholders can be divided into three categories: the core team, the involved team and stakeholders that need to be informed. This is to create a common understanding of how each stakeholder can help the team, how involved they should be and who to contact when things arise. The stakeholder identification is expected to occur during the project inception meeting. It is advised that the inception meeting be a physical engagement.

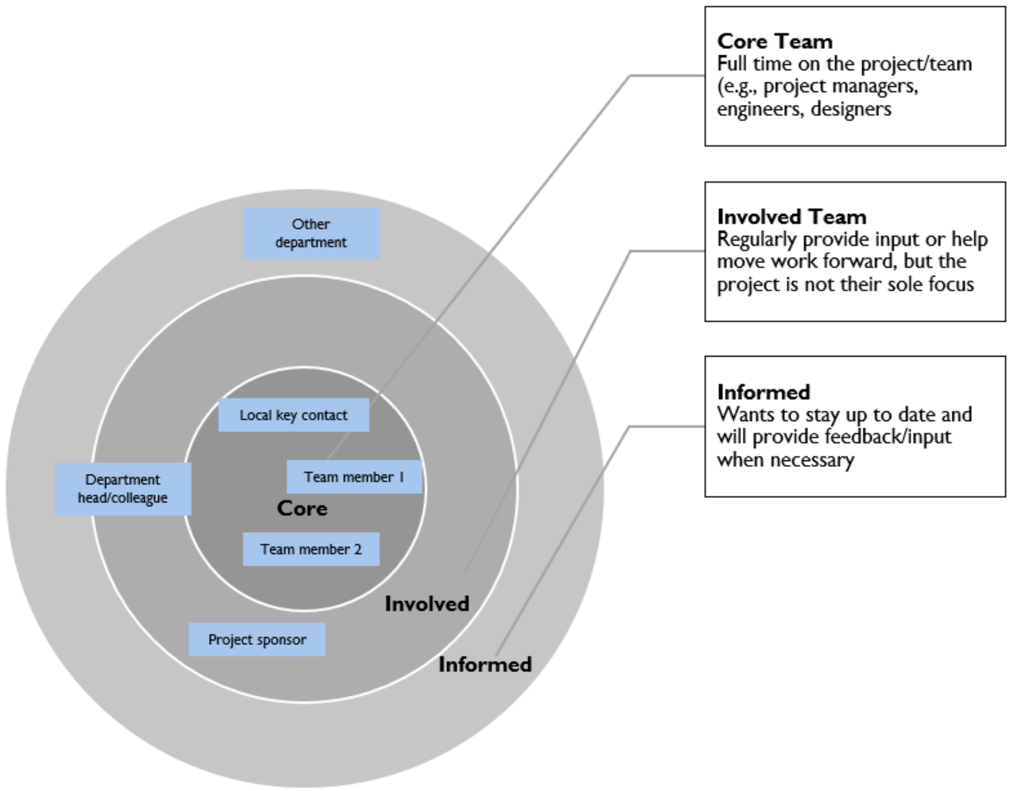


Figure 3: Stakeholder identification map

CONSTITUTING THE PROJECT MONITORING TEAM

The project monitoring team comprises stakeholders identified during the project inception meeting. A diverse project monitoring team is highly beneficial to the success of the project as diverse inputs can be harvested from the team. A periodic meeting (preferably a monthly engagement) is recommended. It is advised that the project monitoring team comprise stakeholders from the core and involved teams and include stakeholders that need to be informed on progress and decisions made.

PROJECT FINANCING

A good understanding of the concepts behind Independent Power Producers and Power Purchasing Agreements is essential for financing the municipal energy strategy and plan. The four financing structures commonly used for energy infrastructural financing are shown below and include host government financing, developer financing, resource-based infrastructural financing and project financing. Refer to the Understanding Power Project

A good understanding of the concepts behind Independent Power Producers and Power Purchasing Agreements is essential for financing the municipal energy strategy and plan.

Financing[4] resource material, a free e-book from Power Africa's Understanding Power Series, for detailed explanations of these key concepts.

Figure 4: Project financing approaches

The concerned municipality must have a good understanding of the expansive and often confusing terrain of power project financing and the associated risks to each financing route before any legally binding commitment is made. Another useful resource available for free download from the Understanding Power Series is the Understanding Power Purchase Agreement e-book.[5] It is recommended that the service of an expert transaction advisor be procured to provide necessary guidance for the municipality.

[4] https://cldp.doc.gov/sites/default/files/UnderstandingPowerProjectFinancing.pdf
[5] https://cldp.doc.gov/sites/default/files/PPA%20Second%20Edition%20Update.pdf

C. SETTING A VISION

Setting a clear and compelling vision and mission is crucial for developing an effective and sustainable energy strategy and plan for a municipality. When developing the vision and mission, it is important to consider the unique characteristics and needs of the municipality, as well as the broader energy and sustainability context. The vision and mission should be aligned with local, national and international energy policies and regulations and other relevant sustainability goals and initiatives. This section focuses on developing and ultimately reviewing the vision and mission based on results and outputs of the studies done under sections D and E.

ENERGY VISION AND ENERGY MISSION STATEMENT DEVELOPMENT

The energy vision and mission statements are critical drivers of the energy strategy and plan. Setting a vision and mission is an essential step in developing an energy strategy or plan for a municipality. The vision and mission provide the overarching framework for the energy strategy and guide the development of specific goals, targets and actions. The vision and mission statements are expected to be co-created during a stakeholder meeting at the project inception phase. To develop these, the opinions of stakeholders within the municipality should be collected and considered. The energy vision and mission statements must be aligned with the vision and mission statements of the municipality.

> A vision statement describes the desired future state of the municipality's energy system.
>
> A mission statement describes the purpose and approach of the energy strategy.

A vision statement describes the desired future state of the municipality's energy system. It should be a clear and inspiring statement of what the municipality wants to achieve in terms of energy sustainability and resilience. A good energy vision statement must be succinct. The vision statement could be less effective if it is too short or too long. However, the length of the vision statement must be sufficient for effective communication and easy commitment to memory by all. It is also expected to be a challenging goal with a high level of abstraction (e.g., "To create a …", "To build a …"). It is very critical that the vision statement be future-centric with a long-term goal in mind, which the energy sector drives towards satisfying.[6] Examples of energy visions include:

Sample Vision Statements:

"To build a reliable and sustainable energy system for local economic stimulation."

"To be a leading energy sustainable SEZ with diverse energy sources."

"Our municipality strives to become a leader in sustainable energy use, with a resilient and diverse energy system that supports economic growth, enhances environmental quality and improves social well-being."

A mission statement describes the purpose and approach of the energy strategy. It should be a clear statement of what the municipality will do to achieve the vision. Similarly, the mission statement should also be brief, memorable, realistic and compelling. It is characteristic of the mission statement to present the reason that the energy sector of the municipality exists. It is expected to communicate effectively and briefly who the audience of the strategy is, what needs it addresses and the duties to be carried out by the energy sector of the municipality.

[6] Kelly Burke (2011): Characteristics of a Good Vision Statement: integrated and paraphrased from various sources including the Academic Leadership Journal

Sample Mission Statements:

"To harness the district's abundant renewable energy resources for long-term socio-economic benefits."

"To develop an energy ecosystem that drives economic growth and development and environmental sustainability within the municipality."

"Our municipality will develop and implement a comprehensive energy strategy that promotes energy efficiency, renewable energy, low-carbon transportation and engages stakeholders in a collaborative and transparent manner."

When developing the vision and mission, it is important to consider the unique characteristics and needs of the municipality, as well as the broader energy and sustainability context. The vision and mission should be aligned with local, national, international energy policies and regulations and with other relevant sustainability goals and initiatives. Overall, setting a clear and compelling vision and mission is a crucial starting point for developing an effective and sustainable energy strategy or plan for a municipality.

D. A STEP-BY-STEP GUIDE FOR ENERGY PLAN EXECUTION

Developing an energy strategy is a data-driven process. Data is needed to identify energy challenges and opportunities, set goals and targets and develop effective strategies to address those challenges and opportunities. It is important for municipalities to collect and analyse relevant data as part of their energy planning process. This section focusses on a step-by-step guide for the development and execution of the various studies, understanding why it is important to have these studies, the tools required to conduct these studies, how-to guides and typical outputs. The key studies include:

- Determining status quo/energy baseline
- Energy needs assessment
- Resources assessment
- Energy planning and the associated projects (including technology type, capacity and timing)

STATUS QUO ASSESSMENT

A status quo assessment is an important step in developing an energy strategy. It involves evaluating the current state of energy consumption and production in a specific area and identifying existing energy challenges and opportunities. Understanding the current energy demand profile in each sector within the municipality is necessary to establish a baseline. Then, the municipality's long-term power and energy demand can be modelled considering the current energy need and the demand growth based on socio-economic factors. Finally, the energy resources, especially in terms of renewables, that are available to meet the projected demand need to be understood.

The status quo assessment typically involves the following steps:

1. **Data collection:** Data is collected on energy consumption, production and infrastructure in the area of interest. This can include data on electricity and fuel consumption, greenhouse gas emissions, renewable energy production and energy infrastructure. (See Appendix C for a data collection template and Appendix D for a sample data request letter to a utility company)

2. **Analysis of data:** The collected data is analysed to identify patterns, trends, energy challenges and opportunities. For example, data on energy consumption and greenhouse gas emissions can be used to identify areas where energy efficiency improvements and renewable energy projects can have the greatest impact.

3. **Stakeholder engagement:** Stakeholders, including community members, businesses and energy providers, are engaged to gather their input on the current state of energy consumption and production, as well as their ideas for addressing energy challenges and opportunities.

4. **SWOT analysis:** A SWOT (strengths, weaknesses, opportunities, threats) analysis is conducted to identify the strengths and weaknesses of the current energy system, as well as the opportunities and threats that may impact the development of an energy strategy.

5. **Identification of priority areas:** Based on the analysis of data and stakeholder input, priority areas are identified for further action. These may include areas where energy efficiency improvements can have the greatest impact, areas with high potential for renewable energy production or areas where energy infrastructure needs to be upgraded.

Status Quo Assessment

- Data Collection
- Analysis of Data
- Stakeholder Engagement
- SWOT Analysis
- Identification of Priority Areas

Overall, a status quo assessment provides a foundation for developing an energy strategy that is tailored to the specific needs and circumstances of the area of interest. By identifying existing energy challenges and opportunities, and engaging stakeholders in the process, municipalities can develop effective strategies for achieving their energy goals.

ENERGY NEEDS ASSESSMENT

To conduct a well-informed energy needs assessment, it is important that the IDP of the municipality be consulted to determine the municipality's projected socio-economic development plans. The SDF is another important document for understanding the expected demand growth for a municipality (either local or district). Other reports of vital importance are the IRP, Transmission Development Plan (TDP), Generation Connection Capacity Assessment (GCCA) and Network Development Plans (NDPs). A careful study of these documents provides the necessary context to begin forecasting the municipality's future energy demand.

DEMAND FORECAST METHODOLOGY

Demand forecasting is a process of estimating the future demand for energy in a particular area or region. It is an important step in energy planning because it helps to identify the amount of energy that will be required in the future and therefore, the capacity of energy infrastructure that will be needed to meet this demand. Several demand forecasting techniques have been developed over the years. For a municipal energy demand forecast, the conventional time series approach does not completely consider other geographical and socio-economic factors, hence, the spatial demand forecasting technique has often been adopted at this level.

A bulk of empirical literature suggests that geographical load forecasting, based on a hybrid of end-use and econometric methods, be used for spatial demand forecasting. This allows the integration of physical and behavioural factors into a common framework:

- The econometric relationships internalize the influence of price, income and policy effects
- The end-use (sub-class) approach provides an accounting plane for aggregating end-use and sectoral energy demands projected into the future

The accounting framework accommodates new end-uses, alternative fuel mixes (e.g., Gas, SSEG), penetration of appliances and technologies (EE), the growth pattern of physical output or its value, as well as population and its distribution amongst income class (socio-economic). This integrated approach provides a better grasp of many diverse influences that shape the demand for energy into the future.

A critical input to the geographical based demand forecast is the development perspective of the municipal area. The socio-economic development perspective provides the following insights:

- Determining present population and socio-economic characteristics, including affordability
- Providing estimates of possible future growth, based on historic trends and future growth scenarios (20-year period)
- Modelling population and economy to provide estimates of the future size and distribution of people and economic activities, and
- Providing take-up rates of individual developments and densification

The forecast should be interpreted as a future view of the energy demand based on the current understanding and interpretation of the variables shaping the future. In addition to demographic and economic municipal load growth, other factors including energy costs, climate change, extreme weather events, demand-side management (DSM) programs, load-shedding, small-scale embedded generation, renewables, smart meters, natural gas, should be considered. The impact of the abovementioned factors is then simulated in a load forecasting model to provide a more accurate projection of future demands.

One approach to demand forecasting involves using calibrated load class profiles and associated s-curves. Load class profiles are statistical representations of the energy consumption patterns of different types of consumers, such as residential, commercial or industrial users. S-curves are used to model the expected growth of energy demand over time, based on assumptions about factors such as population growth, economic development and technological change. The typical s-curves used to predict the growth patterns of the demand forecast is illustrated below.

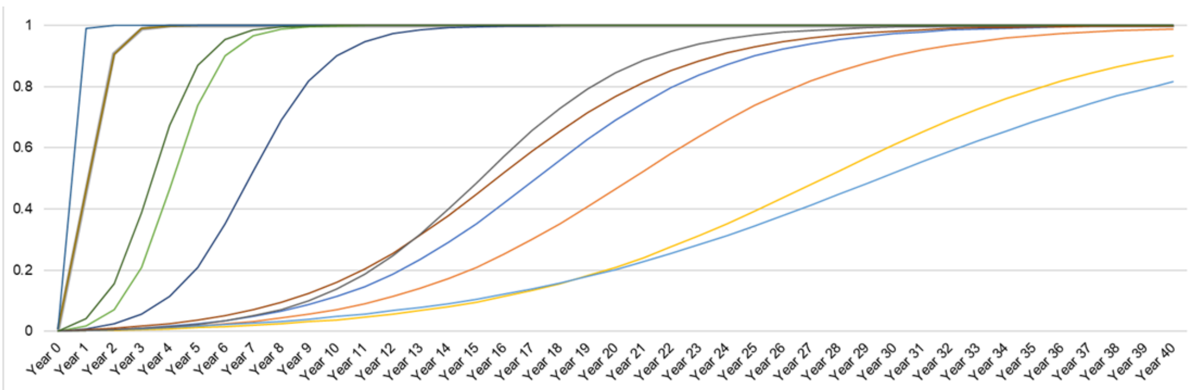


Figure 5: Typical S-Curves

To develop a demand forecast using this approach, the calibrated load class profiles are applied to identified future development areas. The associated s-curves are used to project the expected growth of energy demand in these areas over time. The resulting forecast can be used to estimate the total energy demand in a particular area or region and identify the infrastructure investments needed to meet this demand.

It is important to note that demand forecasting is subject to a range of uncertainties, including changes in consumer behaviour, technological developments and economic conditions. Therefore, demand forecasts should also be regularly reviewed and updated to reflect changes in these factors over time.

Developing a spatial demand forecast involves several steps. Here is a summarized overview of the typical process:

1. **Collect Data:** The first step is to collect relevant data, such as historical energy demand data, population data, economic data, land use data and any other relevant information. The data should cover a long period to capture the variability and seasonality of demand. These data types include geospatial and numeric data. It is expected that the collected data span at least 12 months. For municipal energy planning, it is necessary that all the collected data encompass primary, secondary and tertiary economic sectors detailed in the municipality's IDP. The data validation process is highly essential to ensure the credibility of the model output. It is recommended that data be collected from government repositories as opposed to third-party data repositories. Third-party data repositories with credible data sources could be used as an alternative where a paucity of data exist in government repositories.
2. **Data Cleaning and Pre-processing:** Once the data is collected, it needs to be validated, cleaned and pre-processed to remove any errors or inconsistencies. This step is crucial as the accuracy of the demand forecast depends on the quality of data.

Spatial Demand Forecast

- Data Collection
- Data Cleaning and Pre-processing
- Spatial Analysis
- Model Development
- Baseload Calibration
- Scenario Analysis
- Visualization and Reporting

3. **Spatial Analysis:** After cleaning the data, the next step is to conduct spatial zoning and analysis to identify spatial patterns and relationships between variables. This involves identifying variables that impact demand, such as population density, land use and economic activity.
4. **Model Development:** The next step is to develop a demand forecast model that incorporates the spatial variables identified in the previous step.
5. **Baseload Calibration (Validation):** Once the model is developed, it needs to be calibrated/validated using historical data. The model performance is then evaluated on a validation dataset to accurately calculate the current demand (kW) and energy (kWh).
6. **Scenario Analysis:** After the baseload calibration, scenario analysis can be conducted to estimate the impact of different factors, such as changes in population, land use or economic conditions on the demand forecast.
7. **Visualization and Reporting:** The final step is to visualize and report the demand forecast to stakeholders. This can be done using maps, charts and other visual aids to communicate the forecast and its potential impact on the municipality's infrastructure and services. It is expected that the forecast energy and power demand for all the sectors that comprise the municipality be reported, as this is also essential for sectoral energy plans.

It is essential to note that developing a spatial demand forecast is an iterative process that involves refining the model and incorporating new data over time. Additionally, spatial demand forecasting may require specialized software and expertise in geographic information systems (GIS) and spatial analysis techniques. In adopting a spatial demand forecast technique when taking an S-curve approach, it is essential that the saturation point parameters be carefully selected, as this influences the load growth in each load sub-class.

RENEWABLE ENERGY RESOURCE ASSESSMENT

It is necessary to understand the renewable energy resources available to meet the projected long-term energy demand. While other energy sources can be explored, the drive towards green energy solutions has discouraged the use of non-renewable energy sources for energy demand satisfaction.

It is often recommended to use the SWOT or the Strength, Opportunity, Results and Aspiration (SOAR) analysis to identify these resources and many other strategy enablers and barriers. This activity is best carried out during stakeholder engagements at the project inception meeting. Splitting the stakeholders into breakout groups is often helpful in facilitating interaction and inclusive discussion on these grey areas. Such a session facilitates information sharing between stakeholders towards the success of the project. During the breakout sessions, sticky notes could be handed over to each group, and a representative could be assigned in each breakout group to present the outcome of the brainstorming sessions. This exercise promises to provide good insights useful for the SWOT and SOAR analysis.

Figure 6: Sample SOAR Analysis

Energy strategies and plans towards a transition to renewable energy solutions place energy efficiency central to its development. South Africa possesses renewable energy in abundance as documented by the Department of Mineral Resources and Energy (DMREE).[7] An energy resource identification and capacity investigation relative to the study area in question, in tandem with the gazette national study, should be carried out to inform scenario. A baseline of existing renewable energy initiatives should be established during the SWOT and SOAR analysis to estimate future trends of renewable energy with reference to the recent gazette by the DMRE.[8] The renewable energy options should be prioritized based on their technical viability, savings/generation cost estimates, using the strategic corridors such as the Strategic Environmental Assessment (SEA) and the Renewable Energy Development Zones (REDZs) with reference to the nationwide site suitability analysis.[3] The nexus of expandable prosumers and prospects of small power plants should also be explored.

[7] Department of Energy, *State of Renewable Energy in South Africa*. 2015.
[8] CSIR, "Delineation of the first draft focus areas for Phase 2 of the Wind and Solar PV Strategic Environmental Assessment Prepared," 2017.

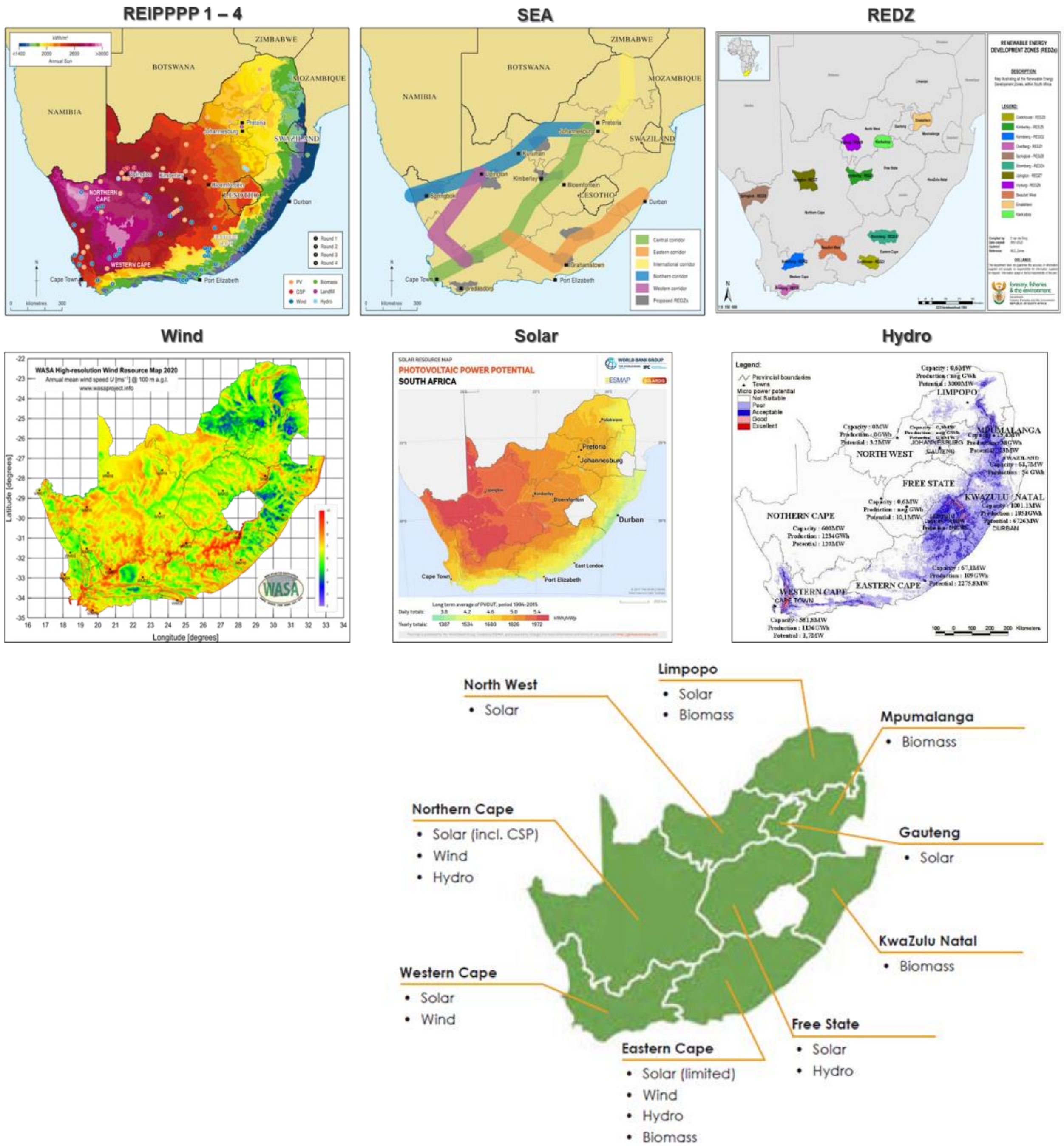


Figure 7: South African Renewable Energy Resource Potential, Strategic Corridors, and Provincial Energy Resource Map[9]

[9] SOURCES:

(a) C. McEwan, "Spatial processes and politics of renewable energy transition: Land, zones and frictions in South Africa," Polit. Geogr., vol. 56, pp. 1–12, 2017.

(b) SANEDI: Wind Atlas for South Africa: https://www.wasaproject.info/

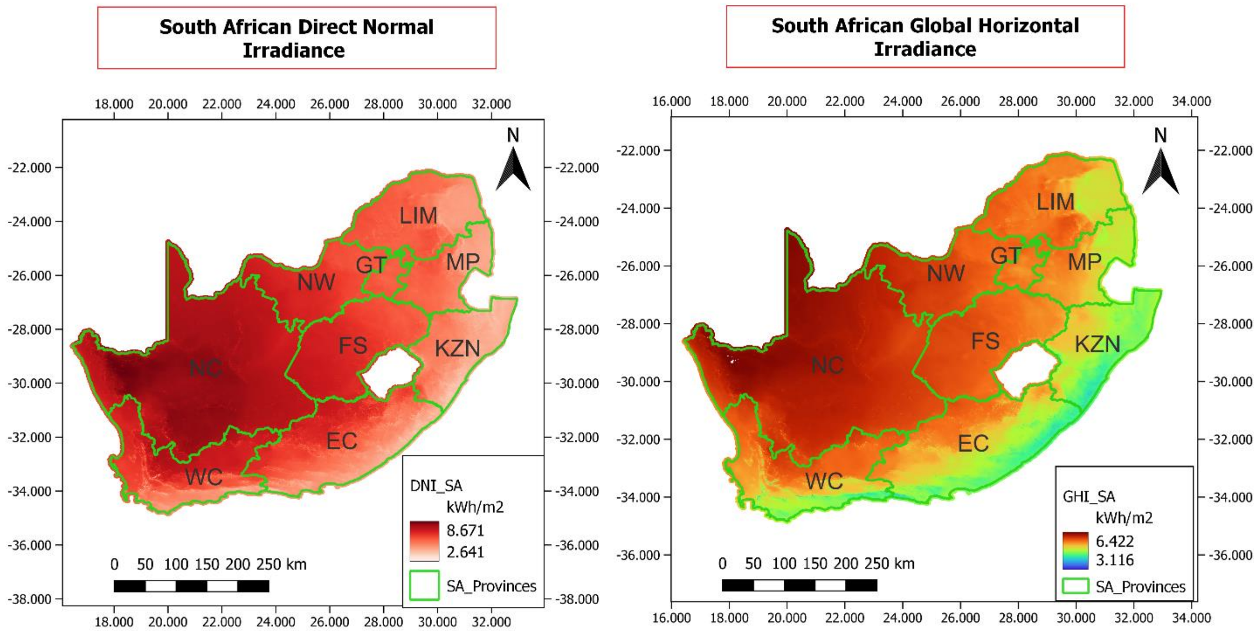


Figure 8: South African DNI and GHI by provinces[10]

Mitigating the global climate risk at national level has increased the drive towards power generation from renewable energy sources and energy efficiency initiatives. Since the country's economy is coal-driven, the need for a just energy transition that enhances the NDP, supported by the Integrated Energy Plan (IEP) and IRP, is considered essential to guide energy strategies and planning.

Preliminary renewable energy resource assessment is vital during the energy dispatch modelling for understanding the renewable energy mix available within the geographical boundary as an on-site solution and those that could be procured through wheeling as an off-site solution. Several online platforms can be used to determine the renewable energy resource potential for the geographical location (specifically wind, solar and bio-resources). Some of these include:

1. Global Solar Atlas[11]
2. Global Wind Atlas[12]
3. Wind Atlas for South Africa (WASA)
4. RE Ninja[13]
5. BioEnergy Atlas[14] (this was developed for South Africa)

It is essential that the resource map be compared with commercial viability at the utility scale. For solar energy, a global horizontal irradiance (GHI) ≥ 1300 kWh/m^2/year is considered economically viable for utility-scale resource

(c) DFFE: https://egis.environment.gov.za/redz
(d) SOLARGIS: https://solargis.com/maps-and-gis-data/download/south-africa
(e) DMRE: https://www.energy.gov.za/files/media/pub/state-of-renewable-energy-in-south-africa.pdf
(f) K. Kusakana and H. Vermaak, "Hydrokinetic power generation for rural electricity supply : Case of South Africa," no. November 2017, 2013.

[10] Process Energy and Environmental Technology Station (UJ-PEETS)
[11] https://globalsolaratlas.info/map?c=11.523088,8.4375,3
[12] https://globalwindatlas.info/en
[13] https://www.renewables.ninja/
[14] https://bea.saeon.ac.za/

harvesting.[15] For wind energy, a wind speed of ≥ 6.5 m/s is considered economically viable for utility-scale resource harvesting.[16] On the other hand, there is no established benchmark for bioenergy resources as the nitrogen content of each feedstock differs. Table 1 presents the list of sample resource assessment tools, their benchmarks and an inquiry form for determining resource availability in the municipality at a utility-scale level.

Table 1. Renewable energy resource assessment inquiry guide

Resource		Sample resource assessment tool	Minimum benchmark for utility-scale exploration	Estimated peak capacity (kWp)	Estimated annual energy production (MWh)
Wind		a. WindPro *(Commercial)* b. Global Wind Atlas *(Open Source)* c. RE Ninja (*Open Source)* d. Wind Atlas Analysis and Application Program (WAsP) *(Commercial)*	Average Wind Speed > 6.5 m/s		
Solar	Photovoltaic (PV) *(Global Horizontal Irradiance- GHI)*	a. Global Solar Atlas *(Open Source)* b. RE Ninja *(Open Source)* c. Solar GIS *(Commercial)* d. PVsyst *(Commercial)*	Average GHI ≥ 1300 kWh/m²/year		
	Concentrated Solar Power (CSP)- *Direct Normal Irradiance (DNI)*	a. Global Solar Atlas *(Open Source)* b. RE Ninja *(Open Source)*	Average DNI > 1800 kWh/m²/year[17]		
Bioresources		BioEnergy Atlas for South Africa *(Open Source)*	Greater than 1000 m³/hr of biogas *		
Others					

* - Large centralized biodigesters with large number of sources and siting close to landfills offer high prospects. However, variable heating values of different feedstock exist. [18]

[15] Adedeji, P. A., Akinlabi, S. A., Madushele, N., & Olatunji, O. O. (2021). Beyond site suitability: Investigating temporal variability for utility-scale solar-PV using soft computing techniques. *Renewable Energy Focus*, *39*, 72-89

[16] Adedeji, P. A., Akinlabi, S. A., Madushele, N., & Olatunji, O. O. (2021). Hybrid neurofuzzy investigation of short-term variability of wind resource in site suitability analysis: a case study in South Africa. Neural Computing and Applications, 33, 13049-13074.

[17] Levosada, A.T.A., Ogena, R.P.T., Santos, J.R. V., Danao, L.A.M., 2022. Mapping of Suitable Sites for Concentrated Solar Power Plants in the Philippines Using Geographic Information System and Analytic Hierarchy Process. Sustain. 14. https://doi.org/10.3390/su141912260

[18] https://iea.blob.core.windows.net/assets/03aeb10c-c38c-4d10-bcec-de92e9ab815f/Outlook_for_biogas_and_biomethane.pdf

ENERGY MODELLING/PLANNING

Energy modelling or planning is the process of using computer simulations and analytical tools to evaluate different energy scenarios and identify the most effective strategies for meeting energy goals. Energy modelling can be used to:

Identify energy efficiency measures: Energy models can be used to identify energy efficiency measures, such as building retrofits, which can reduce energy consumption and costs while increasing system productivity and profitability.

Forecast energy demand: Energy models can be used to forecast future energy demand by analysing historical data and using predictive algorithms.

Planning assumptions: Making assumptions are important to help frame the analysis and decision-making process and enable planners to develop a coherent and robust strategy. Assumptions relating to input technology, energy supply and demand and infrastructure need to be made. Modeling assumptions may cover areas such as policy, economics and environmental factors. Please refer to Appendix E on possible model assumptions. The Lazard website[19] is also a helpful tool for the model assumptions.

Evaluate energy supply options: Energy models can be used to evaluate different energy supply options, such as renewable energy, fossil fuels and nuclear energy, based on factors such as cost, reliability and environmental impact.

Define future scenarios for modelling: Scenario planning can be used to develop a set of plausible and internally consistent descriptions of the future state of the energy system.

Optimize energy system design: Energy models can be used to optimize the design of energy systems by analysing different configurations and identifying the most efficient and cost-effective options.

Energy Modelling Process

- Identify Energy Efficiency Measures
- Forecast Energy Demand
- State Planning Assumptions
- Evaluate Energy Supply Options
- Define Future Model Scenarios
- Energy System Optimization

Energy modelling can help municipalities to develop energy strategies that are based on data-driven analysis and take into account a range of factors, such as energy demand, supply and cost. Energy modelling can also help municipalities to identify opportunities for reducing energy consumption and costs, while improving energy security and reducing greenhouse gas emissions. The energy modelling phase involves a long-term energy planning process. Here, the municipal energy targets are realized through a quantitative analysis of different energy scenarios capable of satisfying the projected energy demand under a set of clearly defined objectives.[20] This phase is mostly achieved through a quantitative modelling approach. A plan built on quantitative models of different scenarios offers a platform for stakeholders to explore future energy system evolutions and provides a roadmap for definite energy investments. For instance, the South African IRP is a product of such a quantitative process.

[19] https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/
[20] IRENA, "Energy Planning and Modelling Support in Africa," 2020.

Scenario analysis is one of the key phases of energy planning.

The model is solved to choose the best energy mix that satisfies all the defined constraints and simultaneously achieves the predefined objective over a typical 20-year horizon.

Scenario analysis is one of the key phases of energy planning. Several feasible energy mixes are considered to see how they can satisfy the long-term energy demand of the municipality according to specific constraints and a defined objective function, all subsumed in an optimization model. The model is solved to choose the best energy mix that satisfies all the defined constraints and simultaneously achieves the predefined objective. As a common practice, minimizing the cost of energy is often adopted as the objective of scenario modelling. Hence, in technical terms, the objective function of the optimization model becomes a cost minimization function over the entire planning period. This cost function for least-cost of energy could be the lowest levelized cost of energy (LCOE), for example, an estimate of the cost of production of energy from the investor's perspective. Some of the constraints often considered in scenario development include the energy balance, technical limits and system security requirements, etc. A model horizon of 20 years and above is often considered for each of the scenarios, according to the agreed length of the plan.

The energy plan provides a schedule of when the model builds what technology at the least cost. It gives the level of emission, water use and total cost expected over the planning horizon. Appendix F shows a sample energy plan for a district municipality comprising six local municipalities.

A number of energy modelling tools are widely used for power system planning. These modelling tools determine the optimal long-term expansion plan for a power generating/supply system. Constraints may include limited fuel availability, emission targets, system reliability requirements and other factors. Optimal expansion is determined by minimizing discounted total costs. Table 2 presents a list of some of the available energy modelling tools and their license status.

Table 2. Examples of energy modelling tools

S/N	Software	License
1	Plexos[21]	Commercial
2	Open-Source Energy Modelling System (OSeMOSYS)[22]	Open Source
3	International Renewable Energy Agency System Planning Test (IRENA-SPLAT)[23]	Open Source
4	PROMOD[24]	Commercial
5	The Integrated MARKAL-EFOM System (TIMES)[25]	Open Source
6	PROPHET[26]	Commercial
7	Stochastic dual dynamic programming (SDDP)[27] for Hydrothermal	Commercial
8	ORDENA[28]	Commercial
9	Tools for Energy Model Optimization and Analysis (TEMOA)	Open Source

[21] https://www.energyexemplar.com/plexos
[22] http://www.osemosys.org/
[23] https://www.irena.org/Energy-Transition/Planning/SPLAT-Models-for-Africa#:~:text=System%20Planning%20Test%20(SPLAT)%20capacity,the%20five%20African%20power%20pools.
[24] https://www.hitachienergy.com/products-and-solutions/energy-portfolio-management/enterprise/promod
[25] https://iea-etsap.org/index.php/etsap-tools/model-generators/times#:~:text=TIMES%20is%20a%20technology%20rich,to%20long%2Dterm%20time%20horizons.
[26] https://www.iesys.com/Prophet/Index
[27] https://www.psr-inc.com/softwares-en/?current=p4028
[28] https://www.mercadosaries.com/ordena/

Though commercial tools exist for the energy planning phase, some open-source tools have also gained traction due to their increasing user community, funding for continuous improvement and the credibility of collaborating developers. Below is a short discussion of the OSeMOSYS tool, which is one of these open-source tools.

THE OSeMOSYS TOOL

OSeMOSYS is an open-source energy-modelling software that allows for the modelling of energy flow between sources and end users over a predetermined period. See Appendix A for more detail on the tool. The modelling tool uses a predefined energy demand of the case study geography to determine the set of energy resources capable of meeting these long-term demands and the associated cost and feasible potential under several constraints. It consists of equations written in the GNU MathProg language and utilizes the GNU's Linear Programming Kit (GLPK) to solve a system of linear equations to minimize total cost over the predefined period while meeting all energy demands. There are several objectives for the dispatch model development. However, the most common one is the least-cost model. This maximizes electricity availability at the least cost and is thus often the focus for the users of the tool.

The open-source OSeMOSYS software was designed to assist in the development of local, national and multi-regional energy strategies. The significant investment involved in human resources, training and purchase of commercial software for long-term energy planning and the requirement for continual renewal of licenses for some of this software has given rise to collaborative efforts to develop credible open-source software for the same purpose.

The OSeMOSYS software was developed as a collaborative effort of several institutions, which include the International Atomic Energy Agency (IAEA), Stanford University, University College London (UCL), KTH Royal Institute of Technology, the United Nations Industrial Development Organization (UNIDO), Stockholm Environment Institute (SEI), University of Cape Town (UCT), Paul Scherrer Institute (PSI) and North Carolina State University.[4] Being an open-source software, it gives the technical personnel in the municipality the ability to download and use it at no cost. Free resource materials have been developed for the software, including the 2015 OSeMOSYS User Manual.[29]

Photo credit: SAEP

[29] http://www.osemosys.org/uploads/1/8/5/0/18504136/new-website_osemosys_manual_-_working_with_text_files_-_2015-11-05.pdf

E. ACTION PLANS TO ENSURE IMPLEMENTATION

Developing effective action plans is critical for implementing municipal energy strategies and achieving the desired outcomes. By setting specific goals, identifying concrete actions and establishing clear responsibilities and timelines, municipalities can implement their energy plans successfully and contribute to a sustainable and resilient energy future. This section focuses on the required actions to implement the plan developed under section B. The action plan must relate to other plans like the IDPs and electrification plans and align to the district plan, provincial and national plans. Furthermore, this section will highlight how the action plans lead to the procurement phase and transaction advisory-related work.

Action plans are critical for implementing municipal energy plans and achieving the goals and targets set out in the plan. Action plans provide a detailed roadmap of specific activities, projects and initiatives to undertake and achieve the desired outcomes of the energy plan.

Key steps for developing effective action plans for municipal energy plans include:

Identify priority areas

Review the energy plan and identify the priority areas where action is needed. This could include energy efficiency in buildings, the promotion of renewable energy, adoption of low-carbon transportation and others. The project monitoring team and the municipal stakeholders must agree on the feasible energy mix proposed. This further creates ownership of the model results and the drive toward implementation of the energy plan. The plan for meeting the projected energy demand and the baseload satisfaction in the municipality must also be reviewed with stakeholders.

With the model results and informed by the stakeholder discussion, there is a need for the municipality to determine priority projects and phases of implementation. It is necessary to establish where and when each energy project is carried out. A ranking system can be used to determine the order of priority for project execution. Some multi-criteria decision-making (MCDM) tools that could be useful include the analytical hierarchical process (AHP), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), the Analytical Network Process (ANP), etc. More of these tools and their strengths and weaknesses can be found in the literature.[30]

Set specific goals and targets

For each priority area, set specific goals and targets consistent with the overall goals of the energy plan. The energy plan with stakeholder inputs is compiled along with an implementation plan. Project champions must be identified to ensure successful project implementation. A final implementation plan can be presented to the municipality upon aggregation of inputs from stakeholders on the first draft.

Identify actions and priority initiatives

Identify the specific actions and initiatives that will be undertaken to achieve the goals and targets. This could include measures such as retrofitting municipal buildings to improve energy efficiency, installing solar panels on municipal buildings, promoting public transit and active transportation and many others.

[30] Adedeji et al. (2020), Neuro-fuzzy resource forecast in site suitability assessment for wind and solar energy: A mini review, Journal of Cleaner Production, 269, 122104, https://doi.org/10.1016/j.jclepro.2020.122104

It is essential to distribute the draft of the energy strategy and plans among the stakeholders within the municipality and district for input and comments. This should be circulated among the three project teams: the core, involved and informed team members. Input from the municipality executive committee is essential at this stage to create ownership of the plan.

Assign responsibilities

Identify the stakeholders responsible for implementing each action and initiative. This could include municipal departments, community organizations, private sector partners and others.

Establish timelines and performance indicators

Establish timelines for each action and initiative and develop performance indicators to monitor progress and measure success.

Develop a budget

Develop a budget for the action plan, including estimated costs for each action and initiative.

Monitor and evaluate progress

Regularly monitor and evaluate progress against the action plan, adjust course as needed and communicate progress to stakeholders. It is necessary to measure the success of the energy plan as the projects progress and periodically verify projects against set targets. The energy plan is expected to be a "living" document, which requires updates at an agreed periodicity and whenever there is a relevant significant technical or policy change. It is necessary to conduct a capacity development workshop to equip the municipality on the plan update process. It is important that the frequency of energy strategy and plan updates be agreed upon by stakeholders, but socio-economic and policy dynamics could necessitate an unscheduled update of the plan in later years. Such an update is often influenced by socio-economic growth in the region, policy change, shift in demand and supply, major national energy reform and demographic change.

Establishing a framework for monitoring and evaluating progress towards achieving energy goals and objectives and adapting the energy strategy as necessary in response to changing circumstances or emerging opportunities is critical

Establish transaction advisory services

to ensuring ongoing success. Overall, a successful energy strategy/roadmap requires a combination of technical expertise, stakeholder engagement and effective policy and regulatory frameworks, all working together towards a shared vision for a sustainable energy future. This guide will provide a framework for implementation towards developing and implementing this vision. Developing effective action plans is critical for implementing municipal energy plans and achieving the desired outcomes. By setting specific goals, identifying concrete actions and establishing clear responsibilities and timelines, municipalities can implement their energy plans successfully and contribute to a sustainable and resilient energy future.

One key agreement between an IPP and the off-taker is the power purchase agreement (PPA). The PPA is probably the most important document for sign-off to achieve financial close. Partnering with the private sector allows governments the opportunity to access greater financial resources and technical expertise. Accessing private finance needs to be balanced by the fact that, despite increasing private participation, power is a public good that requires active government engagement. Therefore, PPP arrangements are usually employed. Project sponsors most often employ the services of a transaction advisor to assist with various transaction-related services because this is a specialized field. In Appendix B, some of the key transactional advisory services worth considering are listed for further reference.


Photo credit: SAEP

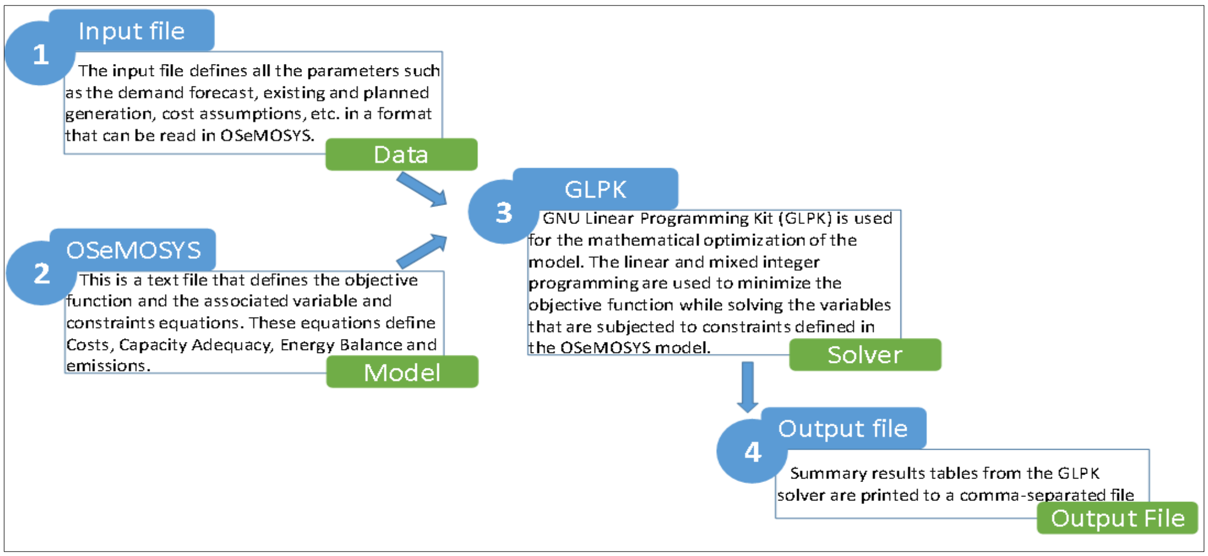
F. FURTHER READING

1. T. Niet, A. Shivakumar, F. Gardumi, W. Usher, E. Williams, M. Howells, Developing a community of practice around an open-source energy modelling tool, Energy Strategy Reviews, Volume 35, 2021, https://doi.org/10.1016/j.esr.2021.100650.
2. F. Gardumi, A. Shivakumar, R. Morrison, C. Taliotis, O. Broad, A. Beltramo, V. Sridharan, M. Howells, J. Hörsch, T. Niet, Y. Almulla, E. Ramos, T. Burandt, G. Peña Balderrama, G. Pinto de Moura, E. Zepeda, T. Alfstad, From the development of an open-source energy modelling tool to its application and the creation of communities of practice: The example of OSeMOSYS, Energy Strategy Reviews, Volume 20, 2018, Pages 209-228, ISSN 2211-467X, https://doi.org/10.1016/j.esr.2018.03.005
3. M. Howells, H. Rogner, N. Strachan, C. Heaps, H. Huntington, S. Kypreos, A. Hughes, S. Silveira, J. DeCarolis, and M. Bazillian, "OSeMOSYS: the open-source energy modelling system: an introduction to its ethos, structure and development", Energy Policy, vol. 39, no. 10, pp. 5850–5870, 2011.
4. Moksnes, N. et al.Moksnes, N. et al. (2015) "2015 OSeMOSYS User Manual." http://www.osemosys.org/uploads/1/8/5/0/18504136/new-website_osemosys_manual_-_working_with_text_files_-_2015-11-05.pdf
5. USAID-Understanding Power Purchase Agreements: https://cldp.doc.gov/sites/default/files/PPA%20Second%20Edition%20Update.pdf
6. USAID-Understanding Power Project Financing: https://cldp.doc.gov/sites/default/files/UnderstandingPowerProjectFinancing.pdf
7. World Energy Outlook Special Report (2020): An Introduction to Biogas and Biomethane; https://iea.blob.core.windows.net/assets/03aeb10c-c38c-4d10-bcec-de92e9ab815f/Outlook_for_biogas_and_biomethane.pdf

Photo credit: SAEP

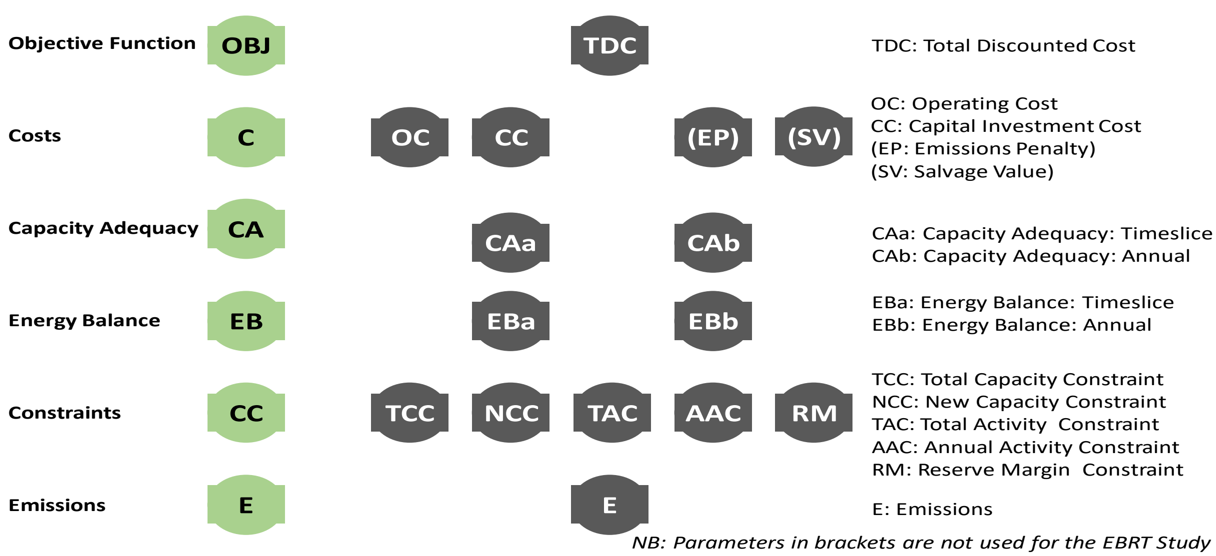
APPENDIX A OSEMOSYS STRUCTURE

The OSeMOSYS model defines the objective function and formulas that need to be solved, based on the sets, parameters and variables defined by the analyst in the input file. GNU Linear Programming Kit (GLPK) is then uses these equations and associated input data to derive the optimal solution. OSeMOSYS prints out the results into a comma-separated text file (.csv file) or another format as defined by the analyst. Figure 5 shows a high-level structure of the OSeMOSYS model.



OSeMOSYS high-level structure

Figure 6 below shows the main equations that are deemed to be important in understanding the operation of the OSeMOSYS model. The relationship between these equations is discussed in the provided OSeMOSYS User Manual.



OSeMOSYS block equations

APPENDIX B TRANSACTION ADVISORY SERVICES

Important aspects to study and understand in the PPA:

- Contracted Capacity (MW)
- Contracted Energy (GWh/a)
- Term of PPA (Years)
- Connection/metering point: Wheeling:(If required)
- PPATariffs (Capacity and/or energy)
- Tariffe scalations: % per annum (CPI linked)
- PPA Penalties
- Default by Seller: Items that can lead to default by Seller and termination by Buyer
- Default by Buyer: Items that can lead to default by Buyer and termination by Seller
- Consequences of termination
- Consequences of termination due to default by Seller
- Consequences of termination due to default by Buyer
- Change in Law
- Step-in rights (Lenders;Buyer)

APPENDIX C DATA COLLECTION TEMPLATES

Template 1

S/N	Baseload Definition	YES	NO	COMMENTS
Technical Data				
1	Substation maximum demand readings (MVA)			
2	Last 5 years of electricity meter data at hourly resolution (kW, kVA, kVAr)			
3	Daily energy consumption data of the municipality			
4	Energy demand data for municipality from Eskom			
5	Sectoral Energy Demand and Consumption			
6	Energy mix records			
7	Load shedding history			
8	Electricity applications			
9	Electrical Network Diagram and the substation SLD's			
10	NERSA D-Forms			
Socio-economic data of the SLMs				
1	Spatial Development Framework (SDF)			
2	Integrated Development Plan (IDP)			
3	Housing Projects			
4	Projected 5 years Population Growth Forecast			
5	List of Sectors in the Municipality			
6	Socio-economic distribution			
Environmental & economic data of the SLMs				
1	Environmental Impact Assessment Previous Projects (for power generation plants, If available)			
2	Other environmental requirements			
Geospatial Forecast Definition				
1	Area of supply (shapefile)			
2	Sub-transmission and distribution network shapefiles			
3	Geospatial locations of existing power microgrids			
4	Municipal Owned Land spaces			
5	Electrification Plans and backlog			
6	Planned new developments/settlements			
7	Spatial Development Framework			
8	Existing Electricity/Energy Masterplans			
Policy Documents				
1	Integrated Development Plans for Municipality/ South Africa			
2	Integrated Energy Planning Policies for Northern Cape			

3	Generation, Transmission and Distribution Policy documents			
4	Local DSM & EE Strategies			
Techno-Economic Data				
1	Energy resource data			
2	Current Tariff structure			
3	Sub-transmission capacity			
Additional Status Quo Data				
1	Substations built after 2012 and supply areas			
2	40MVA and 20MVA new substations and supply areas			
4	Current status of SSEG in the municipality			
5	Current status of IPPs in the municipality			
6	Current status of Wheeling in the municipality			
7	Details of developers turned away by municipality because of unavailable capacity			
8	LPU expansion plans for top 5 high energy users in the area			
9	Local Economic Development Strategy			
10	Municipal future plans for Embedded Generation, IPPs and Wheeling			

APPENDIX D SAMPLE LETTER TO UTILITY COMPANY

Template 2

Eskom

Megawatt Park, Maxwell Drive

Sunninghill, Sandton

Johannesburg

23 September 2022

To whom it may concern,

The University of Johannesburg Process, Energy and Environmental Technology Station (UJ-PEETS) is supporting **#Name of Municipality/District** on the development of an energy needs assessment and energy strategy / plan.

Data requested

Sector demand: Eskom volume sales (GWh) to their direct Prepaid Power Users (PPU), Small Power Users (SPU), Large Power Users (LPU) and Top Customers (amalgamated across these customer types), within the **#Name of Municipality/District** Boundaries across the Eskom supply areas and amalgamated by broad sector (residential, commercial and institutional, industrial, agricultural and transport) from **2017 to 2021** financial year in daily timeseries format. The amalgamated data format requested is provided in Table 1.

Table 1: Sector demand data requested

Sector	Data description
Residential	Total amalgamated sales (GWh) to customers on Residential and Prepayment tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if it's a district***) amalgamated across customer types (PPU, SPU, LPU, Top Customers).
Commercial	Total amalgamated sales (GWh) to customers on Commercial tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if it's a district***) amalgamated across customer types (PPU, SPU, LPU, Top Customers).
Public lighting	Total amalgamated sales (GWh) to customers on Public Lighting tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if it's a district***) amalgamated across customer types (PPU, SPU, LPU, Top Customers).
Industrial	Total amalgamated sales (GWh) to customers on Industrial and Mining tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if it's a district***) amalgamated across customer types (PPU, SPU, LPU, Top Customers).
Agricultural	Total amalgamated sales (GWh) to customers on Agriculture tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if***

	it's a district) amalgamated across customer types (PPU, SPU, LPU, Top Customers).
Transport	Total amalgamated sales (GWh) to customers on Traction tariffs, amalgamated across the local municipalities in the municipality/district (***List all municipalities if it's a district***) amalgamated across customer types (PPU, SPU, LPU, Top Customers).

Energy and demand forecast: Demand and energy forecast of the Namakwa District Municipality area, split into the individual local municipality supply areas. The granularity of the forecast can be at transmission level if distribution level data is unavailable. This data is needed to understand the projected energy consumption growth of the Namakwa District Municipality in the future. The nature of the required data will be timeseries of the demand growth curve for the local municipalities under the district municipality and the aggregated district municipality growth data also.

Energy Mix Record: A list of power generation plants in the Municipality and their associated capacities (Renewable and Non-renewable power generation plants) including identified microgrids and minigrids feeding into the Eskom Transmission lines in the district municipality. The regions within the municipality which they supply will be of high interest.

Load Shedding History: Time series data of the load shedding history within the District Municipality from **2017-2021.**

Electrical Network: Substation maximum demand readings (MVA) from **2017 to 2021** for the **#Name of Municipality/District**. This is important to determine the maximum transmission capacity relative to any proposed micro-grid in the municipality.

The data will be presented within the energy needs assessment and energy strategy report for **#Name of Municipality/District** in an amalgamated form, in order to avoid exposing any one customer or industrial sub-sector.

Please revert any queries with regards to the data requested and proposed data presentation to #

Regards,

____

Technical Deputy Director, **#Name of Municipality/District**

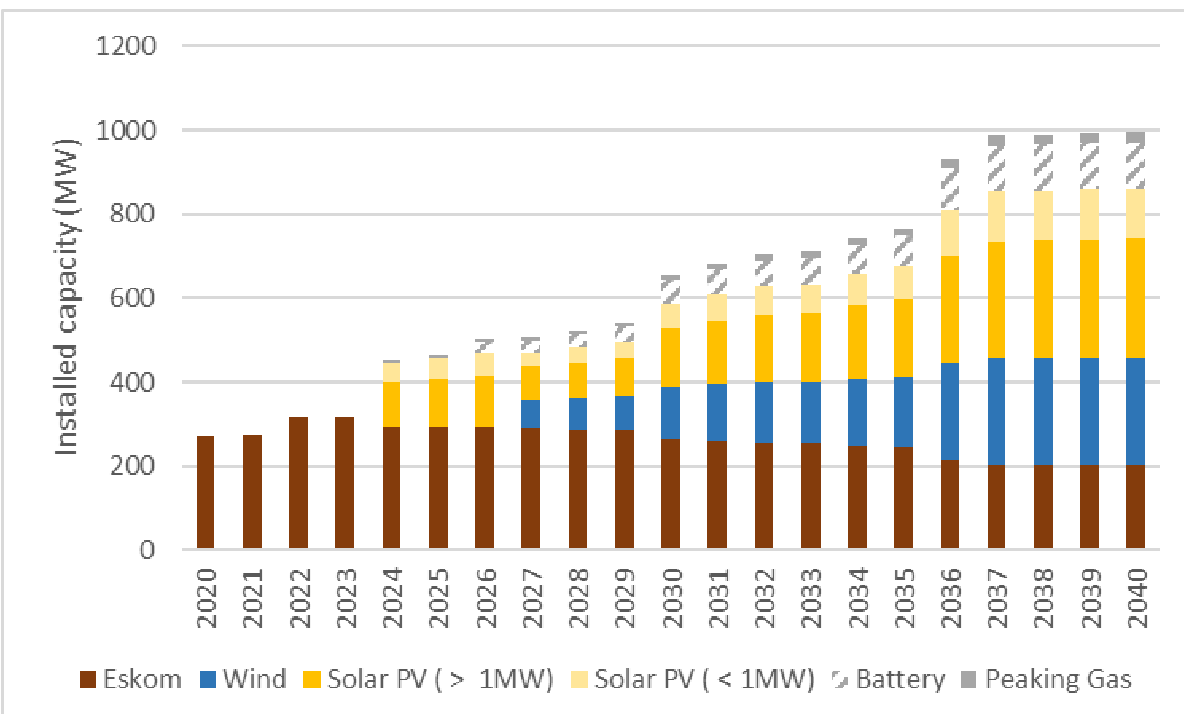
APPENDIX E TECHNOLOGY COST ASSUMPTIONS AND PROJECTIONS

Technology	Capital Cost	Fixed O&M	Variable O&M	
	R/kW	R/kW	R/kWh	Fuel
Solar PV (Utility Scale)	17 204.50	235.43	0.00	Sun
Solar PV (Small Scale)	1 9921.00	271.65	0.00	Sun
Onshore Wind (Utility Scale)	24 448.50	398.42	0.00	Wind
Combined Cycle Gas Turbine	18 110.00	325.98	0.50	Natural Gas
Coal-Fired Power plant	54 330.00	1448.80	0.35	Coal
Waste Heat Power Plant	57 952.00	0.00	0.25	Recovered Heat
Aquarius Engine	39 842.00	5161.35	42.56	Ammonia
Fuel Cells	59 400.80	9 199.88	22.00	Hydrogen
Biodiesel	39 842.00	5 433.00	9.06	Biodiesel
Battery Energy Storage System (BESS)	7 244.00 (R/kWh)	83.31		
Concentrated Solar Power (CSP)	135 825.00	1 448.80	0.00	Sun

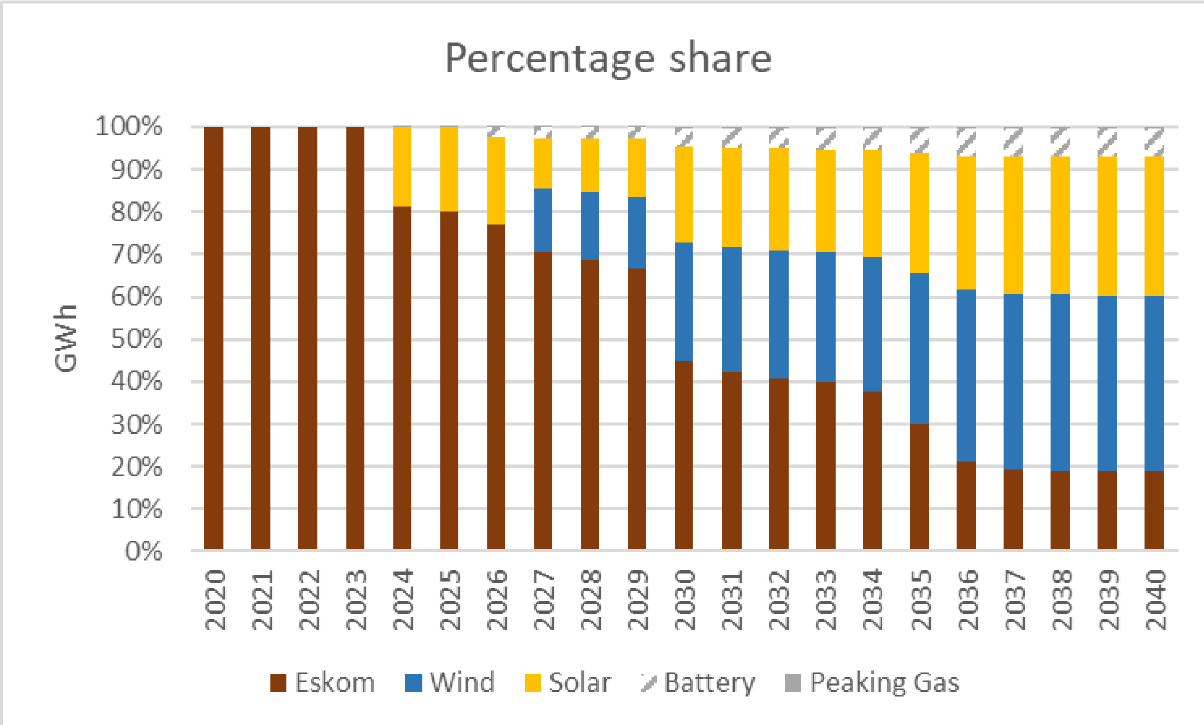
APPENDIX F SAMPLE ENERGY PLAN

Sample Energy Plan

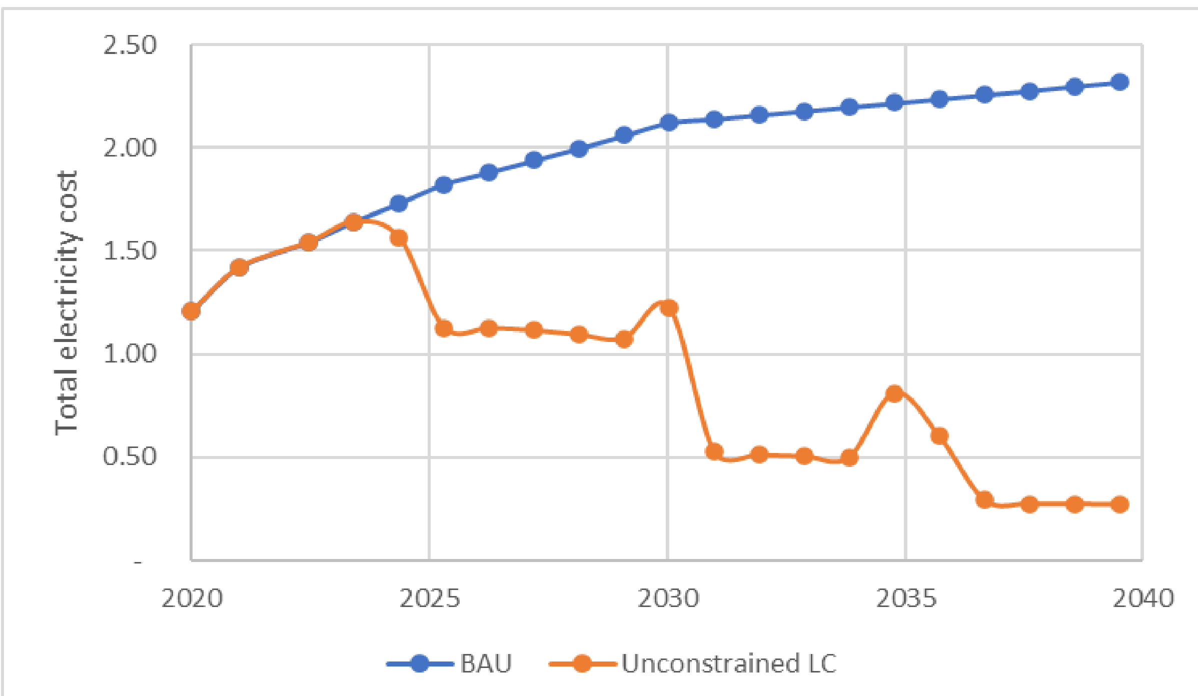
	Local Municipality							
Year	A	B	C	D	E	F	Centralized PV	Centralized Wind
2026	5.0	0.3	1.8	2.0	15.0	2.0		
2027			0.1					
2028			0.1					
2031							100.0	100.0
2032		0.1						
2037		0.1						
2038								
2039								
2040								
Total generation capacity by local municipality (MW)	**5.0**	**0.5**	**2.1**	**2.0**	**15.0**	**2.0**	**100.0**	**100.0**
% Contribution to generation capacity	**2.2**	**0.2**	**0.9**	**0.9**	**6.6**	**0.9**	**44.1**	**44.1**



Installed capacity and energy mix for the Least-cost scenario



Installed capacity and energy mix for the Least-cost scenario

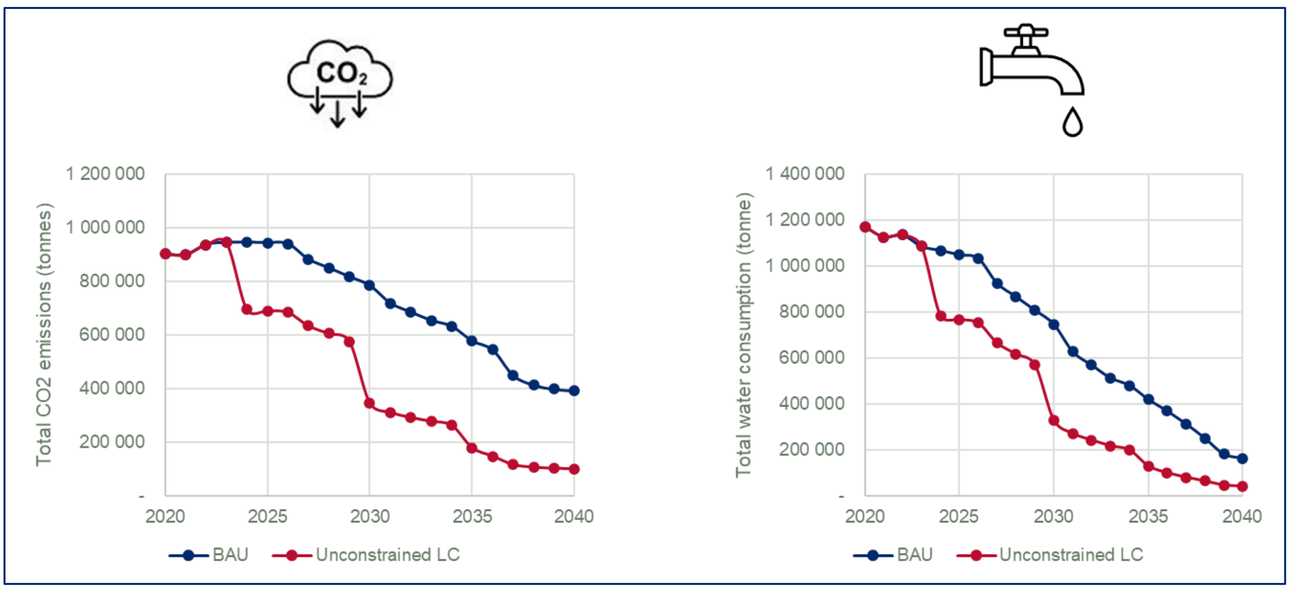


Total system cost: Business as Usual (BAU) and Least-cost

Full-time equivalent permanent jobs from the Least-cost investment path

Technology	**MW installed capacity**	**Jobs per MW *[31]**	**Total jobs**
Solar PV small scale embedded generation SSEG (<1MW)	120	39	4 680
Embedded Gen >1MW	281	17	4 777
Onshore Wind	256	8,2	2 099
Total indicative jobs			**11 556**

* *Solar PV figures SAPVIA (2021), for onshore Wind (Hanto et. al, 2021[32])*



A sample of CO_2 emissions and water impact assessment

[31] SAPVIA (2021) Solar PV Industry Job Report; https://www.sapvia.org.za/wp-content/uploads/2021/05/SAPVIA-PV-Industry-Jobs-Study-Report-COMBINED.pdf

[32] https://doi.org/10.1016/j.envsci.2021.06.001