Integrated Resource Planning Development Manual

Acknowledgments

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Abbreviations and acronyms

AfDB	African Development Bank
BESS	Battery energy storage system
DSM	Demand side measures
ECA	Economic Consulting Associates
ESI	Environmental and social impact
ESMF	Environmental and Social Management Framework
EV	Electric Vehicle
GDP	Gross domestic product
IPP	Independent power producers
IRP	Integrated Resource Planning
LCOE	Levelised cost of energy
NDC	Nationally determined contributions
NPV	Net present value
OCGT	Open cycle gas turbine
PPA	Power purchase agreement
RES	Renewable energy sources
SACREEE	The Southern African Development Community's Centre for Renewable Energy and Energy Efficiency
SADC	Southern African Development Community
SAPP	Southern Africa Power Pool
TOR	Terms of Reference
VRE	Variable Renewable Energy
WASP	Wien Automatic System Planning

1 Introduction

This manual is intended as a guide for SADC member countries who want to develop an Integrated Resource Plan (IRP) or update a previous IRP. It provides an overview of the key steps and processes in initiating, developing, and implementing an IRP, as well as providing an insight into some of the key topics and issues relevant in the IRP process.

The target audience for this manual is decision makers and those responsible for organising and steering the development of the IRP. It therefore focuses on providing a high-level overview of the process. The IRP planning process will vary across countries and as a result the steps and processes set out in the manual should be seen as a guide and adopted and adapted to local circumstances.

The manual is structured as follows:

- The remainder of **Section 1** provides an overview of the role of decision makers in power sector planning and provides a high-level overview of what an IRP is.
- **Section 2** discusses the steps to initiate an IRP.
- **Section 3** outlines the steps in developing an IRP.
- **Section 4** offers an overview of specific issues relevant to the IRP process, such as renewable energy, energy efficiency, and distributed generation.
- **Section 5** concludes by discussing the challenges in implementing the IRP.

1.1 Power system planning

Power system planning is the process which aims to set out the development of a region's or country's power sector over a given time frame into the future. The overarching objective of power system planning is to develop a long-term generation and transmission plan which meets the forecast electricity demand at the lowest economic cost, subject to policy targets and constraints. The main output of this planning process is the sequence of investment projects in the electricity sector and, where trade is possible, the import / export contracts which need to be secured, over the next 3-5 years.

The planning process starts with the demand forecast. Both aspects of demand – the demand for energy (measured for example in MWh) and capacity (measured in MW) – need to be accommodated. Although consumers primary requirement is energy, it is the system-wide peak capacity which defines the most expensive component of power sector development. The shape of the demand (demand by hour) is also important. Demand fluctuates at very short intervals and power sector least cost plans needs to ensure that demand can be met at all times.

Power system planning is challenging because of the scale of investments that are involved, the long lead times that are often involved and the risks of over- or under-investment. Over-investment would lead to the crowding out of investments in the productive sectors of the economy, leading to lower economic growth. This can also be the consequence of under-investment which would lead to electricity shortages and load shedding which curtail production and dampen productive sector investments particularly in electricity intensive industries which is where comparative advantage lies for many SADC states.

Being integrated into the **SAPP regional interconnected grid** and having access to the SAPP competitive power markets[1] provides a planning 'safety valve'. If domestic demand turns out to be higher than expected when the power plants are built ('under-investment') the deficit can be made up by importing from the region, and similarly for a situation where demand is lower than expected ('over-investment') where the surplus capacity can be used to export electricity to the region. Generating foreign currency exports from the power sector is attractive, but it is important to stress that investment in excess of projected domestic demand should only be planned for if bilateral export contracts have already been secured and/or a careful analysis of SAPP's competitive markets has revealed secure prospects for future exports.

The significant implications of planning in the power sector on the entire economy underline why it is crucial for decision makers to properly engage with the planning process. Power planning is not just a technocratic process, but one in which trade-offs are to be explored and policy decisions made. Consequently, there is a need for decision makers to engage with power system planning and establish the right environment for a comprehensive and holistic planning process.

1.2 Integrated Resource Planning

What is Integrated Resource Planning?

Integrated Resource Planning is an approach to national power system development planning which incorporates a holistic assessment of available energy resources and opportunities for demand management into deriving a least cost combination of supply and demand side measures to meet long-term requirements for electricity services during a specified period, while furthering broad national objectives such as social equity and environmental sustainability.

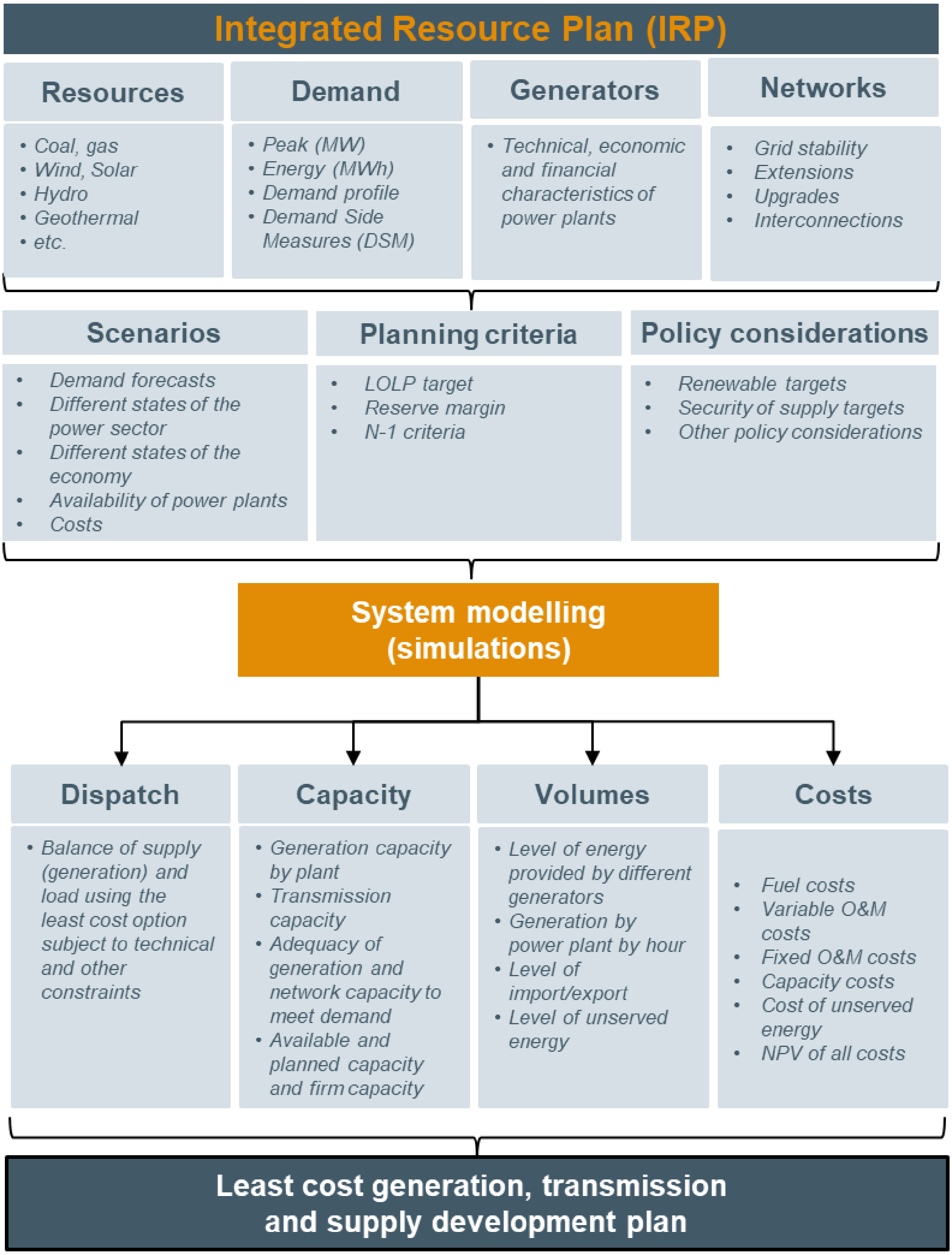
The key distinction of an IRP from more traditional power system planning approaches is that an IRP analyses and shapes demand as well as supply, whereas traditional planning takes demand as a given. This opens avenues to explore whether it may be more economic to investment in energy efficiency measures which reduce demand or provide incentives to reduce peak demand by shifting load demand to off-peak hours, instead of expanding generation capacity.

Figure 1 provides an overview of the IRP process. In the top panel are the key inputs into the planning process. These include information on the available resources and potential generation options, as well as the forecast demand, and information on the network. The core of the IRP is the least cost simulation which models the demand-supply balance of the system and assesses which generation options can provide electricity at the lowest cost, subject to the policy constraints and planning criteria specified in the model. The result of this simulation is a least cost generation development plan, which includes a sequence of investments that

[1] See http://www.sapp.co.zw/market-overview and http://www.sappmarket.com/

need to be made over the next say 3-5 years, set in the context of the much longer time frame (typically 20 years) covered by the model.

Figure 1 Overview of IRP process



A further feature of the IRP is that it incorporates broad electricity policy objectives and national development goals. This is particularly relevant against the backdrop of national climate and decarbonisation policies, with the IRP offering a route to incorporate these goals into power system planning.

Transmission and distribution planning are optional components of an IRP. Although the impact of new generation capacity on transmission will need to be considered, a more detailed transmission or distribution plan may be included where no recent plan exists or for relatively small systems.

Why develop or update an IRP?

Developing an IRP can be a key step to advancing a country's electricity sector. An IRP can support the establishment of a framework which is needed to attract investment into the country's electricity sector. It also acts as a way to incorporate measures such as energy efficiency and demand side management into sector planning. Furthermore, it can allow a country to align its power sector planning with broader planning and policies.

An IRP can act as a useful document which provides answers to questions such as what technologies the utility should invest in, the cost of doing so, how to best meet peak demand, or how to meet renewable energy targets. It can also provide useful insights for policymakers, for example by providing an indication of the cost of meeting different policy targets such as national climate commitments.

An IRP defines the long-term vision for the power sector. The emergence of new technologies and risks means that this strategy needs to be frequently updated to provide an accurate representation of current and future market conditions. Key reasons why an IRP may need to be updated include:

- **Changes to the regulatory framework –** Changes to the regulatory landscape, which could affect the development of an IRP. An example of this is the introduction of a Modified Single Buyer framework in Namibia.

- **Changes in demand –** The need to update an existing plan if demand for electricity has changed significantly since the last plan, for example due to rapid economic growth, step loads, electrification, or the uptake of electric vehicles.

- **National climate commitments and NDCs –** There is increasing pressure to align IRPs with a country's national climate commitments and NDCs agreed on in the Paris Climate Agreement. The electricity sector is considered a prime candidate for decarbonisation because the marginal cost of reducing electricity sector emissions is often less than in other sectors. IRPs need to outline options how decarbonisation can be achieved. Amidst this backdrop, an IRP may also need to be updated or developed to avoid locking in fossil-fuelled generation assets.

- **Integration of renewable energy sources into the power system** – Increasing the share of renewable energy in the power sector brings about considerable benefits for the environment and can lower energy costs, but it poses implementation challenges such as reserve planning and network stability issues. An IRP should recognise and address those risks.

- **Emergence of new technologies –** Capture technology developments such as net metering, distributed photovoltaic generation, energy efficiency, and storage solutions. While the short- and medium-term investments are likely to be based on existing solutions, the long-term strategy should promote innovation in the energy sector.

- **Evolution of fuel prices –** Changes in domestic and/or international fuel prices require the review of the existing plan.

- **Discovery of new resources –** Resources that have been discovered and have an impact on the country's electricity sector should be considered in an IRP.

2 Initiating the IRP process

This section outlines the considerations and steps that need to be taken to initiate an IRP. It focuses on the institutional structure and scope of the IRP, the resources needed to develop an IRP, and how to best manage the development of an IRP.

2.1 Institutional structure to manage the IRP process

The institution responsible for national power system planning will typically be spelt out in legislation. It is often the energy ministry, but may be the energy regulator or the national utility, or, in an unbundled system, the entity responsible for transmission system operation.

The IRP development process should be collaborative and involve various relevant stakeholders from the electricity sector. The institution with the legislated responsibility can delegate different aspects of the process to other entities, but in any event would be well advised to form an **IRP Consultative Committee**, or one with decision making powers which might be called an **IRP Steering Committee.** In either form, the committee should involve the various interested parties to ensure their involvement and ultimately their ownership and commitment to the final IRP. Key stakeholders who might be directly involved in the IRP development process include:

- **Utility –** The vertically integrated utility may have expertise in least cost planning, including access to relevant software. It should also be able to provide some of the detailed data needed for the IRP. However, the utility is likely to have vested interests in elements of the IRP.

- **Regulator –** Depending on the institutional arrangement of the country, the regulator may have a fundamental role in the governance and long-term planning of the sector. This can include stipulating development scenarios, reliability criteria, and other constraints that need to be considered.

- **Ministry of Energy –** May have a legally-defined role for sector development or a keen interest in stipulating the direction in which the sector is developing (eg higher renewable energy targets).

- **Ministry of Economy or Finance –** As above, but may also have an interest in the implications of different development plans on electricity prices and sectoral employment.

Once the entities responsible for the IRP and those who have an interest in it have been identified, it is important to develop a clear governance or steering structure for the IRP process. The exact nature of this structure will depend on the legislated responsibilities. However, at a minimum, the roles and responsibilities of the different entities should be clearly defined from the onset. This includes outlining who has the ultimate responsibility over decisions which need to be made as part of the IRP, such as which development scenarios to use. Clearly defined, regular meetings should be set up by the structure. In addition to a high-level governance structure, it may be beneficial to nominate mid-level representatives from the relevant entities who can discuss technical aspects of the IRP on a day-to-day basis. Annex A1 includes examples of the governance or steering structure for the IRP process of several countries. The governance or steering structure or the IRP process will be different in each country due to the heterogeneity in national legislation and these examples should not be seen as a best practice to adopt in each country.

2.2 The scope and objectives of the IRP

The first step in the developing an IRP is to consider and outline the scope and objectives of the IRP. This is a crucial step, as **an IRP is not an off-the-shelf product but should be tailored to the specific needs and circumstances of the country**. By giving attention to this stage, the IRP is likely to be a useful document which is implementable and can guide the country's power sector development.

Assess the context

As a precursory activity, an analysis should be carried out which assesses the current context which will be relevant for the IRP. Contextual factors which need to be considered include the following:

Socio-economic context – Gaining an understanding of the wider context is crucial to help understand the impact of these broader factors on the electricity sector. These factors will also be key to developing the demand forecast and scenarios. Factors to consider include:

- Population and population growth
- Urbanisation
- GDP, GDP growth and other economic indicators
- Economic development plans and policies
- Sectoral composition of the economy

Current power sector context – Understanding the context of the electricity sector will help ensure that the IRP is tailored to the specific requirements of the country and that it considers unique characteristics and relevant future developments of the sector. Factors which should be assessed include:

- Key stakeholders in the power sector (eg utility, independent power producers, independent transmission and distribution companies, regulators)
    - Financial viability and (if applicable) subsidisation of the utility
- Main regulatory acts governing the sector
    - Should include regulations pertaining to aspects relevant to the IRP which are beyond the direct control of the utility, such as distributed generation, electric vehicles, demand side measures and net metering

- Key policies currently governing the sector
    - This should include current policies related to energy efficiency, demand side management, tariff structures, as well as peripheral policies such as electrification and EVs
- Participation in regional organisations
- Endowment with energy resources
- Regional energy trade
- Electrification rate and how it varies with urban/rural areas
- Generation mix
- Network losses
- Market structure
    - Is the power market competitive or a monopoly? What is the position of the national utility in supplying the national demand?
- Current tariff structure
- Any serious constraints
    - Are transmission systems within the country interconnected?

Future power sector context – The future context will be shaped by the policy positions that are relevant to the time horizon covered by the IRP:

- Development in fuel supply (eg expected gas discovery)
- Policies in fuel supply, such as import policies or policies targeting specific resources (eg no coal policies)
- Policy developments related to energy efficiency and demand side management
- Changes to the policy on tariffs (in particular whether average level is set to recover costs and whether there are or will be incentive-based tariffs such as time of use)
- Changes to the policy on and regulatory framework for distributed generation and net metering
- Electrification targets in urban and rural areas
- NDC commitments and associated policies that will have a bearing on the load forecast (eg phasing out of conventional vehicles in favour of electric vehicles) or on the required generation mix (eg minimum contributions to meeting energy demand from hydropower and/or new renewables)

    - Policy on market structure – if the market is to be opened, an indication of the time frame for this

- Policy on regional trade in electricity and energy

- Policies on the diversity of energy resources

Define scope of IRP

It is important to consider the scope of the IRP that is to be developed. Key considerations include:

- Will the IRP only consider grid-connected customers, or off-grid customers and access as well?

- Will the IRP consider transmission and distribution in addition to generation, or focus on generation? In larger countries transmission planning is frequently done separately, but smaller states may find it useful to combine both. Distribution planning analyses different elements in comparison to generation and transmission planning and is typically conducted separately. However, smaller countries, as indicated above, may consider including distribution planning in the IRP. The time frame that should be covered by the IRP. Typically IRPs cover 20-25 years, with the generation and investment plan for the first five years being elaborated in detail.

Interaction with other policies and previous plans

Consideration should be given to where the IRP slots into a country's other planning documents and policies. If the IRP is being updated, the previous IRP should be evaluated to determine what improvements can be made this time to improve the usefulness of the document and overcome weaknesses and shortcomings of the previous IRP. If it is the first IRP to be developed, existing power sector planning documents should be considered. These may come under different names such as power system plan or electricity master plan.

Planning documents in related sectors, such as distribution and transmission or universal electrification if they do not form part of the IRP, should also be considered to ensure that the IRP aligns with them. In some countries, the electricity IRP forms part of a broader resource planning effort which may consider energy more broadly as well as other resources such as water.

Focus also needs to be paid to national, regional and international policies which have an impact on power system planning. For example, the IRP should take into account stated policies on renewable energy uptake, nationally determined contributions (NDCs) formed as part of the Paris Climate Agreement, or developments such as increased electric vehicle (EV) penetration.

Set out the objectives of the IRP

Careful consideration of IRP's objectives is central to a successful planning process. With power system planning moving away from a minimalist least cost supply path to a broader and more holistic analysis, there are potentially conflicting objectives that need to be evaluated. The effects on the wider economy, environment, and society are not easily measured, but some prioritisation of objectives is necessary to come up with concrete recommendations. The assessment of the context should held inform the objectives of the IRP. These may include:

- Ensuring a reliant and diversified supply of electricity to existing and new customers
- Sustainable use of national resources with careful consideration of the environment, climate resilience, and future generations
- Meeting policy targets, for example those relating to the affordability of electricity or wider integration of renewables
- Meeting a country's climate commitments (eg decarbonisation targets or 'net zero' ambitions) or NDCs
- Decreasing electricity tariffs by considering regional trade options while ensuring supply security criteria are met.
- Minimising the effect on the environment and the society
- Taking account of climate change mitigation options to limit the impact of the power sector expanding
- Wider deployment of demand side measures (DSM) to closer match electricity supply and demand patterns
- Providing local employment benefits and driving innovation in the power sector
- Improving the reliability of supply
- Maximise economic benefits, which will also include aspects such as reducing the level of unserved energy to the optimum level

To ensure that the IRP is focussed and its implementation can help meet the agreed objectives it is important that the objectives are realistic and achievable. To do so it is helpful to think of a framework that helps identify the relevant characteristics of each objective. An example could be the **SMART guideline** which states that goals should be:

- **S**pecific **–** the goal should be clear and precise, eg minimise the cost of an electricity expansion plan subject to constraints.
- **M**easurable **–** explains what performance indicators will be used to quantify the outcome, eg net present value (NPV) of costs.
- **A**chievable**/A**ssignable **–** defines what entity is responsible for achieving a particular objective, eg the Ministry of Energy, the national utility of the national regulatory authority.
- **R**ealistic **–** objectives should be tailored to the realities of a particular country. As an example, stating the objective as minimising the cost subject to constraints is

fine. An example of an unrealistic objective would be specifying a concrete number for NPV prior to any analysis.

- **T**imely **–** objectives should have a time frame associated with them, eg minimise the NPV over the period of 2020 to 2040, with 2020 being the base year for calculations.

Other examples of using the SMART framework (no significance should be attached to the numbers or performance indicators quoted as these should be agreed on a case-by-case basis) are detailed in Table 1 below.

Table 1 Examples of using the SMART framework

Specific	Measurable	Achievable/ Assignable	Realistic	Timely
Increase the proportion with access to electricity to 50% by 2030	Define how access to electricity is measured, eg the proportion of population that is connected to an electricity outlet with certain minimum technical requirements	Ministry of Energy	Consider the starting point of the analysis. A 50% objective may be well within the reach of some countries within a 9 year period, while for others it will be too ambitious or too low	Specify the time frame- by 2030
Increase deployment of DSM to decrease and/or shift electricity demand by 5% by 2025	Specify how much of electricity demand reduction would be expected as a result of increased utilisation of DSM (eg 5%)	The national utility	The percentage reduction should take into account the current state of DSM in the country and ensure the goal is within reach	Specify the time frame, eg by 2025
Increase the share of renewable energy sources in the energy mix to 25% by 2030	Specify which resources will be considered in evaluation. Specify the objective (eg 25%)	Ministry of Energy, the national utility, IPPs	Consider the current share of RES in the market. Is a 25% share to high/low?	Eg by 2030

Source: ECA

2.3 Requirements for developing the IRP

The process of developing an IRP can require significant resources and expertise. This section outlines the requirements for developing an IRP, and how these can best be provided.

Technical requirements

The development of the least cost plan requires both data and appropriate software. These are important considerations which should be made in advance of commencing on the development process.

Data

Producing accurate load forecasts and generation plans requires a breadth of data. Initially an assessment should be carried out on the type of data that is already available, which will identify areas where additional effort will be required to source and develop the data.

As the aim is to continuously update the IRP, consideration should be given to developing appropriate databases which can then be continuously updated and will reduce the level of effort required for future iterations.

Software

At the heart of the IRP lies the least cost generation development plan. A choice exists between simple Excel-based models or more advanced software such as PLEXOS, SDDP, WASP or others. Thought should be given to see whether any of the stakeholders in the IRP development process (eg the utility) have access to such software and would thus be able to provide access to the software and associated expertise. More advanced planning software packages are generally expensive, and attention needs to be paid on how issues surrounding licensing will be resolved if the least cost planning is to be done by an entity (eg a Consultant) separate to that responsible for developing the IRP.

Using Consultants

Many countries opt to employ Consultants to assist in the development of an IRP. Consultants can bring valuable expertise, including experience from other jurisdictions, in developing an IRP. They are also able to provide extra resources to aid the IRP's development. However, focus should be given to **avoid completely outsourcing the development of the entire IRP to Consultants**. The IRP should be 'owned' by the local stakeholders responsible for its development. This will develop local stakeholders' understanding of the process and allow the IRP to be best aligned with the country's IRP objectives and the local circumstances. This can also help establish the IRP as a dynamic document which is continuously updated.

The extent of Consultant involvement will depend on various factors, including the resources available and the expertise of a country in developing key aspects of IRP. The annex to this manual contains two 'model' Terms of Reference which act as a template for the procurement of Consultants:

- **A 'comprehensive' or 'full' TOR –** The scope of work here covers most of the IRP process. It is aimed at countries which do not have experience or expertise in developing an IRP. Although the Consultant will do most of the development, it would be expected that local actors still play a role in working with the Consultant to define and develop the IRP.

- **A 'limited' TOR –** The scope of work is limited to the more technically complex and computationally heavy tasks such as the load forecast and least cost generation plan. The country will lead on other aspects, while the Consultant will provide support and run the models in these more narrowly specified areas.

The model TOR in Annex A1 provide an overview of the information to include in a TOR to allow Consultants to prepare and submit relevant and feasible proposals, an illustrative scope of work, and an indicative table outlining the team requirements that should be sought. It also provides a guide to budgeting for Consultants.

Capacity building

Capacity building is an important objective of an IRP and should be initiated early in the planning process. This is particularly true when Consultants are being contracted due to insufficient capacity to develop the IRP in-house. As a result, a key objective should be for the Consultant to transfer knowledge and skills and build internal capacity for the Client so that future IRPs can be developed in-house.

Capacity building should respond to a gap analysis / needs assessment with a variety of approached - on-the-job training, coaching and mentoring (eg is a member of the Client to be embedded into the consultancy team), and structured training activities (eg training workshops at certain points in the study, the length and content of these workshops, in particular what software training should be provided).

Depending on the existing capacity of the stakeholders and the scope of the IRP, capacity building could cover all aspects of the IRP or focus on some specific aspects. Different methods of capacity building can be selected depending on the size of the system. As an example, general principles of IRP planning could be explained in small group sessions while software usage could be part of one-to-one tutorials.

While it is difficult to design an ideal training component that would fit all, the Consultant should propose a capacity building plan that clearly specifies how the capacity building component is going to be delivered. This involves an indication of time commitment and objectives that the capacity building component will achieve. At minimum, this should include the ability to understand the planning process, interpret IRP's results and appreciate the constraints of the models deployed. Where models are handed over, the Consultant should provide sufficient capacity building to ensure the stakeholders are able to become proficient users of the model at a later stage.

Budget

Developing an IRP can require a significant budget, especially when Consultants need to be used to assist the development process. Based on experience in developing IRPs, the estimated level of effort for a generation and network IRP varies between 200 to 300 days, although this is highly dependent on factors such as the size of the system and depth of analysis. For example, if the IRP also includes transmission and distribution planning, a higher level of effort and budget will be required. Similarly, additional scenarios may also lead to higher levels of effort.

As a result, it is crucial to give careful consideration to the scope of the IRP and the depth of analysis which is required. This underlines the importance of ensuring stakeholders are included from the beginning to help ensure the scope is tailored to the needs of the country and sector.

The responsible entities will need to ensure the availability of relevant staff, and if work is be contracted to Consultants that the necessary funding is available. The responsible entity may need to source funding for the development of an IRP from the relevant government ministry or seek support from a regional organisation or international donor.

2.4 Managing the IRP process

As discussed in Section 2.1, it is desirable for the institution legally responsible for developing the IRP to form a committee that brings together all important stakeholders. This committee could be an IRP Consultative Committee or could have decision making powers, which may be captured by the term Steering Committee. To avoid potential misunderstanding and delays, the governance structure for the process needs to be specified clearly at the outset. This should include time periods for intermediate deliverables being specified and enforced. Care needs to be taken in deciding on the level of representation of the different entities in the IRP Committee – too high a level will make it difficult to convene meetings, while too low a level will make it difficult for binding decisions to be reached.

A clear governance structure is needed even if all or most of the key tasks are to be performed by the entities that belong to the committee, but becomes essential when external Consultants are being contracted. It would be best for Consultants to have to report to a single IRP lead, even if that person is working in the context of an advisory or a directive committee. The general approach the Consultant should take to executing the scope of work needs to specified. Similarly, how the national organisations involved in the IRP will interact with the Consultants also needs to be spelt out. This will often be via a **counterpart group** of mid-level officials, who will be the primary focus of the capacity building.

2.5 Stakeholder engagement

The consultation process undertaken as part of the IRP should not be limited to the entities represented on the IRP Committee, but should include electricity sector players like independent power producers, transmission system operators, industrial and commercial energy consumers from the private sector (particularly representatives of large users, such as the chamber of mines, confederation of industries. etc) and, if possible, representatives of domestic electricity consumers and of households which are yet to have access to any form of electricity.

These stakeholders could be encouraged to be members of the IRP Consultative Committee or, in countries with an IRP Steering Committee structure, there could also be an IRP Consultative Committee with a broader membership. Other ways to achieve stakeholder engagement is to make sure there are consultation windows when stakeholders are invited to comment on drafts (eg to discuss the load forecast before it is finalised and when the draft results of the base case are available). These consultation windows can be opened to the wider public, with all residents, public institutions, firms, and organisations being invited to provide comments. A further approach is to offer workshops in which the IRP is presented to interested stakeholders and discussions can be held. This can be useful in helping create a wider sense of understanding of the IRP process.

Whichever approach is selected, it is important to ensure that sufficient time is dedicated to stakeholder consultations and that the engagement process spans across the entire IRP development process, including pre- and post- development. This is essential to ensure the document is well socialised within the sector. Furthermore, it is important to be transparent about the IRP development and stakeholder engagement process. Failure to do so would run the risk of undermining the credibility of the IRP process. For example, the final IRP should make clear (eg in an annex) how the various responses gathered in the stakeholder engagement process have been considered and acted upon.

3 Producing an IRP

This section provides an overview of the key steps that need to be taken to develop an IRP. It provides details of the different steps and aspects that should be considered in them.

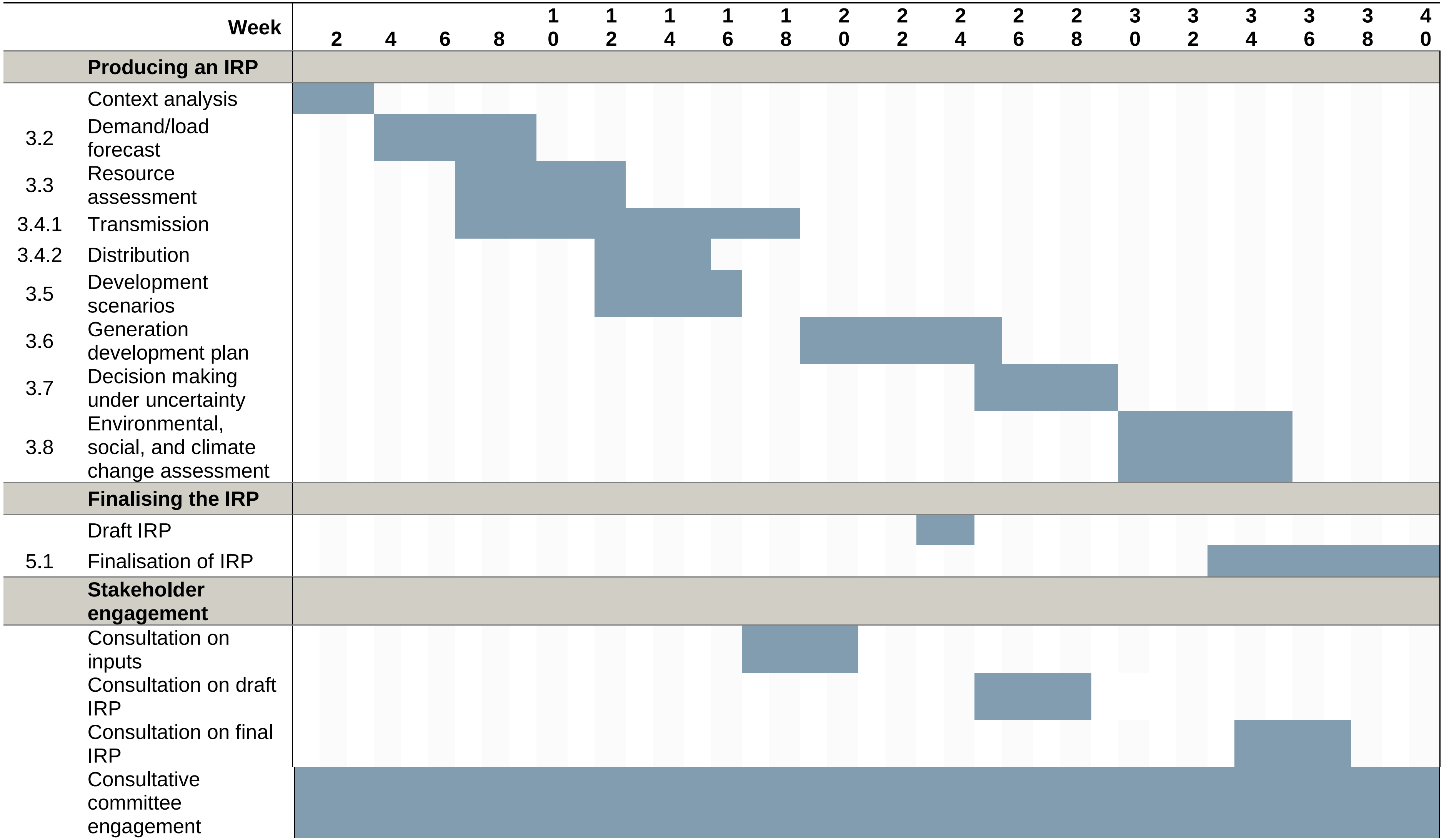
3.1 Overall approach

Developing an IRP is a complex resource which can require significant resources and time. Figure 2 provides an overview of the steps taken to produce an IRP and an indicative timeline. The steps correspond to the sections of this manual. The time required for the different steps will depend on the size of the country, and the scope of the IRP.

The initial steps include an analysis of the context, outlined in Section 2.2. Following this the demand forecast is developed, and resource and generation options are assessed. From this development scenarios are established which then feed into the modelling and development of the generation development plan. After this, uncertainty is considered, for example through additional scenarios, and the chosen options are assessed with regards to their social and environmental impacts.

As discussed in Section 2.5, stakeholder engagement should span the entire IRP development process. This could include consultation on the demand forecast, resource assessment, and development scenarios, the publication of a draft IRP, and a consultation period on the final IRP.

Figure 2 Indicative IRP development timeline



3.2 Demand/load forecast

The key input to the IRP is the demand or load forecast. This assesses what the electricity demand is likely to be over the period covered by the IRP. The demand forecast is typically developed at the national level and considers customers who are served by the national utility and the private sector (eg IPPs). The forecast needs to cover several aspects, which are illustrated in:

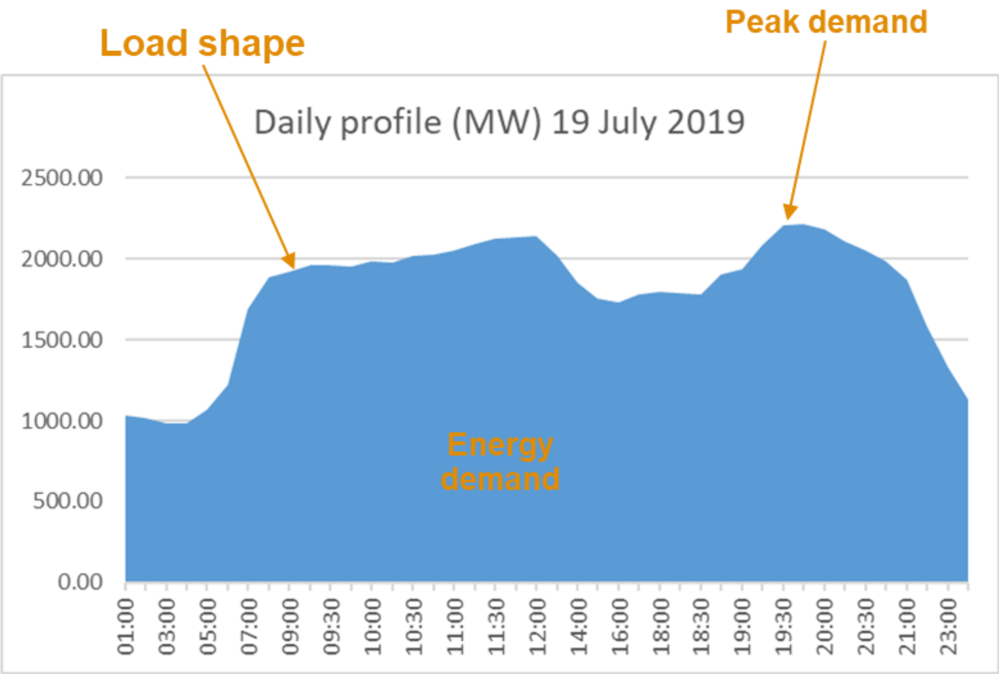
- **Energy demand forecast –** the total amount of energy that needs to be supplied. Usually expressed in GWh.

- **Peak demand forecast –** the total amount of energy that needs to be developed for generation, transmission, and distribution. Usually measured in MW.

- **Load shape –** the amount of energy that has to be provided in any given hour. This will determine how much power plants operate during a day. A question arises whether the hourly load profile should be constructed on an annual basis (ie for each of the 365 days in a year) or on a daily basis. The former increases the accuracy, particularly where there are significant seasonal variations, but is more complex and requires long modelling and computation times.

- **Demand side measures –** consideration needs to be given to how demand may be influenced by DSM such as energy efficiency, distributed generation, or time of use tariffs. Ahead of conducting the demand forecast it may be necessary to assess DSM and energy efficiency measures which are already in place, and those which may become effective during the IRP's horizon.

Figure 3 Illustrative forecast load profile



Source: ECA

Demand is influenced by various factors. For example, commercial and residential customers tend to have different load profiles, with residential customers often seeing a peak in the evenings when households turn on heating/cooling technologies and cooking appliances. Seasonal variations also impact the demand profile, with significant electricity being consumed by heating or cooling.

There are different methodologies which can be used to develop the demand forecast. The most common approaches are:

- **Trend:** Historical growth trends are extrapolated into the future. This approach tends to be relatively easy to implement but fails to account for factors such as changes in the sectoral composition of the economy or changes in technology. It fails to explain the reasons for the growth in load and is contingent on the historical trend continuing in future years.

- **Bottom-up:** This involves a detailed assessment of electricity by different types of consumers and how these consumers' consumption habits will change in the future. This can lead to relatively accurate forecasts but requires large amounts of data and assumptions. For example, assumptions need to be made about the average number of lightbulbs a household is likely to use and the energy consumption of these lightbulbs. A benefit of the bottom-up approach is that it can account for expected changes to electricity consumption, such as the increased uptake of EVs.

- **Econometric (also referred to as top-down):** This uses a mathematical relationship to describe the relationship between the primary driver of electricity growth (often GDP, GDP per capita, and/or population) and electricity consumption. Conducting a successful econometric forecast is contingent on having a long historical dataset which can be used in the model.

In reality, most forecasts use a combination of the above methodologies.

Regardless of the methodology selected for demand forecasting, it is important to understand its limitations. While trend and bottom-up frameworks provide a structured approach, both need adjustment to attempt to include uncertain shifts in demand. Understanding the relationship between growth in electricity demand and future developments in electricity demand (large industry step loads, mass housing programmes, EV and energy efficiency measures) is important in refining the demand forecast. Risks could also be managed by utilising probabilities for uncertain outcomes or developing additional scenarios.

The forecasts and different scenarios would need to take account of:

- DSM, energy efficiency (EE) and national electrification plans
- Tariff policies, and in particular changes in tariff policies such as moving from generalised subsidies to electricity consumers to cost recovery tariffs
- Policies affecting network losses, such as revenue protection plans (for commercial losses) or major refurbishment plans that are envisaged to decrease technical losses
- Further impact on demand if a carbon tax is added to tariffs
- Developments in customer-installed distributed generation and net metering
- Electrification policies which have a direct bearing on demand for grid-supplied electricity (eg electric vehicles, electrification of the railways, switch from traditional iron and steel to electrical smelting of scrap steel etc)
- Possible other country-specific factors

If an existing demand forecast has been developed it may suffice to simply update this with more recent data. However, if previous demand forecasts are limited it may be useful to dedicate resources to developing a comprehensive demand forecast, as this will help ensure the IRP accurately reflects and meets future demand.

The output of the demand forecast should be the final expected demand at the customer level as well as forecasts at the sent-out level of both maximum demand (MW) and energy (GWh). For transmission planning, the load forecast will need to be spatially disaggregated. Data permitting, load shape curves should also be provided.

A key issue with demand forecasts is that they are often optimistic, due to being based on upbeat projections of GDP growth and large new customers. There is often a national context in which such optimism is politically driven, and it may be invidious for the power planners to argue for more ‘realistic’ forecasts. As a result, focus should be given to assessing the uncertainty surrounding the demand forecasts. Where uncertainty is expected to play a significant role, additional scenarios could be provided to account for the uncertainty and avoid issues arising from optimism bias.

Particular focus should be paid to the uncertainty surrounding demand arising from increased electrification and EE measures. For example, if a country has a stated policy to significantly increase EV uptake, a scenario should reflect the impact of this on forecast electricity demand. Such policies may also impact the load profile, in addition to the forecast levels of energy demand. This underlines the importance of also considering scenarios for factors beyond different levels of economic growth. For example, a scenario to model higher rates of electric cooling or EV penetration may result in a change of the load profile and peak demand, in addition to leading to higher electricity demand.

The demand forecast is often the most contentious component of an IRP process. All stakeholders should keep in mind that demand forecasts are never 'accurate' and that the objective is to have a view of the growth in demand which enables a sequence of generation and transmission investments to be chosen.

Uncertainties identified during the demand forecast stage are not lost, but are considered later through sensitivity tests. Under and over estimation of demand could entail investment decisions which are (directly or indirectly) costly for the economy, but there are many steps in the IRP process which mitigate against these risks.

There is thus a need to agree at an early stage on the base demand forecasts to be used for the next stages of the IRP process.

3.3 Resource assessment

An IRP takes a broad perspective at power system planning by considering all available feasible options. This includes all available resources on the supply side as well as technologies and policies available on the demand side. This step should focus on identifying and existing resources and options and specificity what role they could play in the satisfying the customer demand.

In considering the resources available, both domestic and imported capacity of fuels should be considered. As part of this, consideration also needs to be given to transportation and infrastructure costs (eg natural gas pipelines). For renewable energy sources, separate assessments may need to be conducted to evaluate the potential of solar or wind energy.

To make the analysis more structured and comparable, it is helpful to establish assessment criteria that will be applied to determine feasibility of different options. Such criteria can range from economic (eg cost) to social (eg employment opportunities), environmental (eg emissions) and technical (eg the available technology, climate resilience and reliability objectives). The assessment can be supported by more thorough analysis of a particular resource (eg a wind atlas).

The output of this analysis should be a selection of feasible options that will be treated as candidate projects for the least cost generation phase of the IRP study.

3.3.1 Fuel price forecast

To be able to conduct a holistic assessment of different resources and generation options, a fuel price forecast needs to be developed. This should assess the likely price of different fuels over the horizon covered by the IRP, consider whether the fuel will be sourced domestically or imported, and any assumptions that may have an impact on the final price.

3.3.2 Existing, committed and candidate power generation units

Gather information on existing and proposed power generation units (conventional plants as well as large scale renewable generation facilities). This information should cover:

- Technology
- Fuel
- Commissioning year
- Expected decommissioning year
- Installed and available capacity
- Capex
- Grid costs
- Variable operational and maintenance (O&M) costs (excluding fuel cost)
- Fuel costs
- Annual fixed costs
- Forced and maintenance outage rates
- Heat and ramp rates
- Operation regime
- Greenhouse gas emissions
- Storage capacity, including battery energy storage systems (BESS) (if applicable)

Where applicable, consider power purchase agreements (PPA) with domestic independent power producers (IPPs) connected to the national grid and, where applicable, agreements with neighbouring countries, utilities and producers on electricity imports and exports.

3.4 Transmission and distribution

The basic costs of the transmission lines needed to evacuate power from new generation plants should be included in the generation development plan but more a detailed transmission and distribution plan is not always included in an IRP. Countries have the option to include this depending on whether a recent transmission and distribution plan has been prepared that has taken into account the likely generation investments. Other factors, such as the size of the system, should also be considered when determining the scope of the study.

3.4.1 Transmission

If the scope of the IRP includes transmission planning, the first step is to map the existing transmission system and note committed and candidate transmission projects which have already been identified. The aim of the transmission development plan is to develop a least cost transmission development plan which ensures that the grid can operate reliably and meet demand, integrate new power generation facilities, and, if applicable, facilitate trade with neighbouring countries. The transmission plan should be based on the demand forecast and linked to the generation expansion plan.

The following aspects may be important to consider in the development of the transmission plan:

- Create a strong linkage to generation planning and associated operational simulations. Employ the scenarios studied as part of generation planning for transmission system planning to assess the flexibility of the transmission system plan and evaluate augmentation options for the plan to accommodate a range of generation development possibilities.

- The location of generation as well as major constraints in the system are to be analysed to consider high VRE (variable renewable energy) regions and identify other potential transmission system bottlenecks emerging in the system.

- Incorporate contingencies around VRE in addition to the standard (n-1) contingency.

- Establish a reasonable generator dynamic database to perform a critical dynamic analysis of the system which is essential to assess the system inertia with high renewables.

- Consider the stability induced transfer capability limits as part of generation planning since stability studies are essential for the power system.

- Recommend adjustments in the generation expansion plan looking at different solutions such as battery storage, priority transmission lines, smart grid investments, etc.

3.4.2 Distribution

Distribution planning is not commonly included in IRPs and is typically outside the scope of an IRP. This is because distribution investment decisions tend to be taken on a more decentralised basis, using local knowledge and distribution engineers who consider local developments, feeders, and substations alongside the availability of local funding. It is less common to see distribution plans being developed on a centralised basis.

In some contexts, the scope of an IRP could include high-level, indicative electrification plans. These could help develop an understanding of the potential load on the grid.

3.5 Development scenarios

A key element of an IRP is deciding the scenarios which are to be developed. The number of scenarios to be developed will depend on the scope and objectives of the IRP. Examples of scenarios include:

- **Base case** – the assumptions on which this is based need to be precisely specified.
- **High/Low demand case** – least cost expansion option subject to the high/low scenario of the demand forecast (these should be developed as part of Section 3.2)
- **High renewables / NDC case –** required a higher proportion of renewables and/or energy efficiency and demand side management measures to meet the country's NDC commitments.
- **Emissions reduction case –** a more extreme variant of the previous scenario which significantly reduces or even eliminates emissions (eg net zero) from the electricity sector. This might include assumptions on emissions caps, carbon prices, and national climate commitments (NDCs).
- **Self-sufficiency case** – require local generation to supplant imported energy or reliance on imported capacity (or some reduced proportion of imports). For the avoidance of doubt, self-sufficiency does not imply that a country should not import any energy. Instead, it focuses on ensuring that a country had sufficient domestic capacity but still participates in the intra-regional market to reduce marginal costs. For example, if a country has sufficient generation capacity to meet its demand it may still import cheap hydropower from a neighbouring country when water levels are high.
- **Wholesale market case** – analysis of the changes to the national utility's generation investment sequence if there is increasing opening up of the national electricity market to wholesale competition.
- **Other scenarios** would be country and situation specific.

3.5.1 Reliability criteria

In addition to defining scenarios, reliability criteria need to be defined ahead of running the least cost simulation. Reliability criteria indicate the level of reliability that needs to be provided by the generation and transmission plan.

The typical generation planning reliability criteria are either:

- **Reserves margin** – This indicates how much spare capacity is needed to ensure the reliable operation of the system. It is typically expressed as a % of peak capacity.

- **Loss of load probability (LOLP) –** Provides the probability that the system load will exceed available supply. This can be expressed as the maximum days per year in which this can occur.

- **Expected energy not served (EENS) –** Indicates the amount of demand that is expected not be met by supply in a given year.

The network planning criteria include:

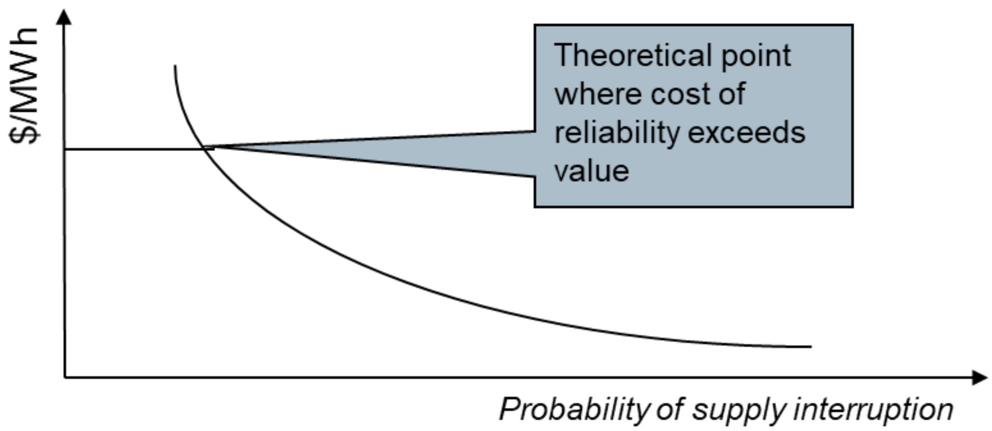
- **N-1 reliability level –** stipulates that the system is able to meet peak demand even with one transmission line, main power transformer or unit for reactive power compensation out of service.

- **Voltage levels –** Minimum and maximum voltage levels during normal and contingency operation.

- **Capacity –** indicates the maximum thermal loading of equipment.

Defining the reliability criteria is ultimately a trade-off between cost and the probability of supply interruption. As illustrated in Figure 4 reliability criteria levels which lead to a lower probability of supply interruption come at a higher cost. In choosing the value of the criteria, some countries differentiate between thermal-based power plants and hydropower plants. Power pools may also have common reliability criteria which need to be incorporated into domestic IRPs. For example, the Southern African Power Pool stipulate a reserve margin of 10.6% for thermal-based power and 7.6% for hydropower plants.

Figure 4 Trade-off between reliability and cost



3.6 Generation development plan

The core of the IRP is the least cost generation development plan. The aim of this is to conduct simulations of the power system to assess the set of generation options with the lowest NPV of economic costs.

Traditionally, the cost of power generation options has been compared through the Levelised Cost of Energy (LCOE). The LCOE is an indicator of the cost of producing one MWh of energy from a power plant and is calculated at the ratio of the sum of costs incurred by the power plant over its lifetime and the energy generated over its lifetime. However, the LCOE only provides limited information. For example, it does not capture the technical constraints of different generation options, fails to consider the intermittent natures of RES, and does not reflect that the value of electricity varies throughout the day.

A key distinction needs to be made between plants that provide the base load vs those that provide the peak load. Base load plants such as coal plants are capable of continuous operation and typically have lower operating costs but higher capital costs. Peak load plants such as OCGT or battery storage are only required for a few hours in a year to meet peak demand. They need to be able to be dispatched quickly and as a result typically have higher operating costs but lower capital costs. Screening curves can provide some additional insights into the costs of different generation options. A screening curve shows the LCOE for different load factors. This provides information as to whether a certain technology is viable as a base or peak load plants.

To overcome the limitations posed by LCOE, an IRP relies on a least cost dispatch simulation. These simulations typically involve large datasets, various generation candidates, and dynamic analysis to account for hydro, RES, and storage. The key of the modelling is economic dispatch, which simulates how supply and demand (load) is balanced using the least cost generation options, subject to technical constraints. Conducting dispatch simulations allows for hourly fluctuations in demand to be captured as well as the different characteristics of technologies. It can also assess the ancillary services provided by generation plants.

The result of the least cost simulation will be a generation development plan. This will provide a list (often referred to an investment sequence or investment schedule) of the candidate options which are to be developed over the horizon covered by the IRP.

3.6.1 Network expansion plan

Where transmission planning is included in the IRP, a network expansion plan should accompany the generation development plan. Network expansion plans are more time-consuming than generation plans, so output should be restricted to one main plan, potentially with one or two variants. It is also important to note that there is an iterative process between generation and transmission planning. If transmission planning using the indicative generation plan suggests very high transmission investment costs, generation plans will need to be revisited. Some generation planning software (eg PLEXOS) include simple network planning components which can reduce potential iterations, although transmission planning software (eg PSS/E or DigiSilent) will need to be conducted to verify the results.

3.7 Decision making under uncertainty

The uncertainty surrounding some of the underlying assumptions is a key challenge in developing an IRP. Factors such as demand, pricing, and resource availability can all vary and only be estimated accurately with a certain degree of certainty. Policy decisions which may not yet be made at the time of developing the IRP, such as renewable energy targets or carbon pricing, can also impact the IRP. Furthermore, it is difficult to predict consumer behaviour and how policy directives, such as those relating to energy efficiency, demand side responses, or

EVs, translate into market outcomes. In addition, the technically and economically feasible technology options may change over the course of the IRP, particularly due to the continued rapid developments in the renewable energy space.

As the IRP forms the basis for large, multi-year investment decisions, this uncertainty raises questions on how to make these decisions. To inform decision making several tools can be used:

- **Scenarios:** Different scenarios can be used to model uncertainty. They may show how the least cost plan varies under different market outcomes (eg different level of demand or different costs) as well as the impact of different policy decision (eg different renewable targets or changes to regional trade). If a power plant is selected as the least cost option in several scenarios, then it is more likely to be a good investment option. For example, if a given wind plant is selected as the least cost option in the low, base, and high demand scenarios it is a good investment regardless of how demand actually evolves. Scenarios should be carefully chosen to extract key insights, but the number of scenarios should not be unlimited. Too many scenarios (potentially more than 10) might introduce complexity and key insight may be lost.

- **Sensitivities:** These can be used to identify the robustness of the least cost plan under different market conditions. For example, it can highlight if a given power plant would still be selected if fuel prices increased, or if the cost of capital were to increase.

- **Stress tests:** These tests can held reveal the impact of decisions. For example, a stress test may be conducted to estimate the impact of what happens if one invests for the high demand scenario, but demand actually turns out to be low.

- **Probabilistic assessment:** An assessment can be conducted in which possible market outcomes are weighted by the probability of occurring. Monte Carlo simulations are a form of probabilistic assessment which can be used to generate multiple outcomes under uncertain events such as VRE generation. Other probabilistic analysis techniques that can be used to model uncertainty include real options, the assignment of probabilities to market outcomes and others.

- **Real options:** Real options analysis is an attempt to value flexibility to respond to new information. It is defined as the right, but not the obligation, to take a predefined action, at a predetermined cost, for a predetermined period in time to react to changing market conditions. For example, an IRP may include the option to double the capacity of a generation plant if demand exceeds a predefined threshold in a predefined time period. These real options can be assessed through the probability weighted NPV including options.

The above list is not exhaustive but focussed on the most common tools used to deal with uncertainty. However, countries may wish to use alternative qualitative and/or quantitative risk management frameworks which have the same overarching aim of assessing the impact of uncertain developments on the IRP and incorporating this risk into the final outputs.

3.8 Environmental, social, and climate change considerations

As discussed in the introduction, a key characteristic of an IRP is that it is a more holistic planning document which also considers broader national policy objectives. Such objectives may include those relating to climate change impacts and emissions or social equity. As a result, focus also needs to be given to environmental, social, and climate change aspects of the electricity sector and its development.

Although these factors should be kept in mind throughout the entire IRP development process, for example in the development of the scenarios, it is useful to have an impact assessment section dedicated to these factors. In many cases, such assessments will be stipulated by the donor providing the funds for the IRP.

3.8.1 Climate change implications of the development scenarios

An IRP should consider the climate change implications of the different generation development scenarios. Supply options which favour low carbon technologies and generation sources, as well as energy efficiency measures can help mitigate emissions. This can be assessed through a scenario analysis under which the greenhouse gas emissions under different scenarios are evaluated and compared against the country's national NDC.

With respect to climate resilience, attention should be given to how resilient different investments and generation options are to climate change. For example, significant investments in hydro capacity may expose to the country's electricity sector to variations in rainfall and droughts.

3.8.2 Environmental and social considerations

An IRP should also consider other environmental and social impacts. Environmental impacts may include local air pollution, the flooding of sensitive areas (eg when a hydro dam is developed), or the threat to flora and fauna from the development of new plants or transmission lines. Social impacts may include the impact of different generation options and jobs and the value chain, the displacement of populations, the impact of sensitive land (eg indigenous land), or the impact of tariff changes on households and the economy.

These impacts should be assessed through environmental and social impact (ESI) assessments conducted for the key development options. Where committed projects are to be financed by development partners, this should include an overview of the social and environmental assessments required by the donor. For SAPP countries, this should include compliance with the Environmental and Social Management Framework (ESMF). The ESMF is a tool which helps ensure alignment and compliance with safeguarding guidelines, including those of the World Bank and AfDB. Consideration should also be given to the socio-economic impacts and costs of the early retirement of generation assets (eg early exit from coal).

In addition to assessing the impact of various development options, focus should also be given to providing viable mitigation options. It is good practice to make these assessments available in the public domain and to apply some common standards that specify the minimum requirements for an ESI assessment. These could be developed by the national regulatory authority.

4 Key IRP topics

This section provides an overview of some of the key issues which need to be considered when developing an IRP.

4.1 Renewable energy

Renewable energy sources play an increasingly large and important role in many country's generation mix and electricity policies. This is because RES are seen as a key tool to meeting a country's climate and emissions reductions targets. In addition, many RES technologies have matured in recent years and become competitive with traditional generation options.

However, RES pose some unique challenges. The key issue is that RES generation is intermittent. For example, solar PV is contingent on sunshine, wind energy is dependent on wind levels, and hydro is constrained by the amount of water that is available. Electricity can only be produced when these resources are available. However, this may not coincide with the system load profile. For example, solar PV is predominately produced during the daylight hours, and may not be able to contribute to the capacity needed to meet peak demand in the evening.

As a result, additional fast response reserves or storage capacity may be necessary. For example, BESS may be considered alongside solar PV plants to ensure that the system load profile can be met. This, including the costs associated with additional reserves or storage, needs to be factored in when assessing renewable energy sources in the context of the IRP.

4.2 Energy efficiency

Energy efficiency has been a key component of IRPs since they emerged following the 1970s oil crises. Energy efficiency should be considered as a resource in its own right and is considered as one of the cheapest and cleanest energy resources available. We say that energy efficiency improves when a given level of service can be provided with reduced energy input, or if the service is enhanced with the fixed energy input. Energy intensity – the quantity of energy required per unit output – is often used as a proxy for energy efficiency.

The first challenge when incorporating EE into an IRP is to define the counterfactual. The counterfactual scenarios could be:

- **Baseline scenario – '**business-as-usual' includes underlying degree of efficiency improvements as technology improves and equipment is replaced (ie some improvement in energy intensity). This provides a realistic assumption of improvements in the technology; however, it adds complexity as assumptions need to be made about the underlying level of technology improvements.

- **Frozen scenario (static) –** assumes no efficiency improvements. Based on expected growth of energy-services (ie energy intensity per end-use sector is maintained). Although this is simpler to develop than the baseline scenario, it does not provide a realistic picture.

- **Dynamic frozen scenario –** Allows for replacement of retired equipment with new more efficient models, but does not allow for new technology.

In developing the IRP the energy efficiency potential needs to be established. This is derived from a list of potential EE measures and the savings offered, and the potential demand for these measures. These measures can be shown in an energy efficiency cost curve which highlights the marginal cost of energy savings from different options.

There are two ways in which these EE measures can be incorporated into the least cost generation plan. The first sees energy efficiency considered as a candidate resource, similar to other generation options. The least cost generation planning software determine the optimal level of EE measures, including considering the impact of how they impact the load shape. An alternative, simpler process is to develop a set of demand side scenarios with different levels of EE measures included in them.

4.3 Demand side management

Providing capacity to meet peak demand is often the most expensive component in providing electricity. Traditionally, power system planning has focussed on developing sufficient generation capacity to meet peak demand. However, in an IRP focus is also given to the demand side, and it may in many cases be more economic to reduce peak demand. One approach to this is through tariff policies and developing efficient tariffs which ensure the efficient use of electricity.

The development of Smart Grids and associated technologies such as advanced metering infrastructure provide the option for advanced tariff structures which offer time-dependent tariffs. Such time of use tariffs can see electricity be priced higher at times of peak demand. It can also allow for demand charges to be incorporated into the tariff structure, which involves a payment for the capacity provided to meet the customer’s peak demand. These measures create economic incentives for the consumer to reduce their peak demand and shift load to other periods of the day. For example, large consumer may invest in storage facilities, whereas households may decide to use appliances such as washing machines outside of the peak period.

4.4 Distributed generation

Distributed generation refers to small-scale generation across the distribution network, for example through rooftop solar PV. This distributed generation may or may not be connected to the grid. In either instance the impact of distributed generation tends to be to reduce demand. This is because consumers will use electricity generated by the distributed technology before relying on generation from the grid. Where distributers sell electricity to the grid this reduces the demand needed from traditional generation options.

A significant share of distributed generation comes from solar PV. This causes issues in the network as it leads to higher levels of supply and low demand during the day.

4.5 Regional power system integration

As described in Section 1.1, if a country is part of the SAPP interconnected grid and can import and export electricity, the costly risks of over- or under-investment in the power sector are significantly diminished:

- Exports: overestimating demand and installing more capacity than is needed domestically provides a surplus which can be exported into the region.

- Imports: underestimation of demand and installing less capacity than is needed does not lead to costly unserved demand if the country can import to cover the shortfall.

The latest SAPP Pool Plan will provide guidance on what is economic within the region, including the development of generation projects that are very large in relation to national demand, but which are economic for the region as a whole. The SAPP market should not be taken for granted, however, especially on the export side, so countries cannot assume that an export market will exist and therefore autonomously plan to be an exporter. Export demand that is included in the IRP load forecast must be based on secure contracts or well-founded export prospects in the growing competitive markets offered on the SAPP Coordination Centre market platform.

5 Finalising and implementing the IRP

At the end of the processes described in Sections 3 and 4, the scenario that best meets the policy and planning criteria while minimising costs needs to be agreed as the one defining the IRP for the upcoming period. The next phase is often the most challenging – the actual implementation of the plan.

5.1 Finalising the IRP

The measure used to compare different scenarios that incorporate policy constraints and planning criteria, and to explore the risks and how these can be mitigated, is the NPV of costs. That is not, however, the final output of the process but the metric that provides insight into the trade-offs that are involved between competing objectives.

The final step is for one scenario to be selected that represents the best compromise and for a consensus to be forged amongst the stakeholders that this should be treated as the IRP for the upcoming period. For this final IRP, the key outputs will include the following:

- The sequence of investment projects and overall investment requirements
- Associated imports/exports from/to neighbouring countries to inform PPA contracts
- An approximate operating schedule of power plants and associated costs
- A forecast of the overall operating costs of the business
    - This should also include a summary of the implications for tariffs
- Total quantities of fossil fuels and associated greenhouse gas emissions

The investment projects and trade contracts are the main elements to be implemented and for which specific implementation measures are necessary.

5.2 Overcoming challenges in implementing an IRP

One of the challenges in implementing an IRP is that it is often not clear how the proposed investments can actually be carried out. To overcome this, it is important to consider the policy instruments and environments which need to be put into place to execute the various investments. Ideally, these considerations should be kept in mind throughout the development of the IRP. This underlines the importance of establishing the institutional structures and responsibilities for IRP implementation, in addition to those for IRP planning, from the onset. A useful approach to aid the implementation of the IRP is to have an 'Action Plan' included in the IRP. This sets out the actions that need to be taken in the short-term horizon to deliver on the investments suggested by the IRP.

The implementation stage is likely to be more successful if the capacity building and stakeholder engagement components are taken seriously. As implementation is driven by people, training and communication between key stakeholders should not be undervalued. A well-managed transparent consultation process also plays a key role in the implementation stage due to the large scope of the exercise.

While the preparation of an IRP is clearly on the planning side of power system development, there are several benefits to establishing a well-managed link between planning and implementation. Power assets are typically very capital intensive, and implementation is often stalled due to the lack of financing. A well socialised IRP can boost confidence amongst investors and reduce financing costs. The Action Plan moves planning into concrete measures that need undertaking to realise an IRP’s objectives.

5.3 Updating an IRP

An IRP should not be considered a one-off planning document. Instead, it should be considered a ‘living’ and dynamic document, which is continuously updated as the sector develops. To increase confidence and predictability in the planning process it is useful to stipulate a period in which the IRP is reviewed. In many countries, IRPs are reviewed every 3-5 years. However, it may be necessary to update the IRP before this if there are major changes to the sector and policy landscape (eg regional trade commences or new renewable targets are implemented).

Annexes

A1 Examples of institutional structures

This annex provides brief examples of IRP steering and governance structures in selected SADC countries. These have been provided to offer insights into the different ways in which countries organise and manage their IRP process. However, it is important to reiterate that these are not 'off-the-shelf' solutions, nor do they necessarily reflect best practice for each country, Instead the governance and steering structure should be tailored to each country to reflect national legislation, structures, and other requirements.

A1.1.1 South Africa

In South Africa, the Department of Mineral Resources and Energy holds the responsibility for publishing an IRP. This is governed by the Electricity Regulation Act of 2006. However, the Department devolves the responsibility for managing and developing the IRP to the national utility, Eskom. This allows to make use of Eskom's existing expertise and capabilities in least cost generation planning. In turn the independent regulation, the National Energy Regulator of South Africa (NERSA) is responsible for the development of regulation which implement the IRP.

A1.1.2 Mozambique

In Mozambique, the Ministry is responsible for national sector planning, although the utility, EDM, assumed lead responsibility for formulating the Integrated Master Plan. EDM established a 'Joint Coordination Committee' (JCC) which consisted of representatives of public sector institutions. The purpose of the JCC is to ensure that the Master Plan reflects national power development policies.

In addition to the JCC, a Joint Study Team (JST) was established as a subsidiary body to the JCC which acts in a more operational manner and provides support in the day-to-day development of the Master Plan.

A1.1.3 Namibia

In Namibia, the Ministry of Mines and Energy is legally responsible for sector planning. The development of the 2016 IRP plan was managed by the regulator, the Electricity Control Board. However, the 2020 IRP plan is being directly managed by the Ministry.

In both cases, during the development of the IRP, a project management unit was set up to help coordinate the key stakeholders responsible in the IRP process:

- Ministry of Mines and Energy
- Electricity Control Board
- NamPower (national utility)
- Regional Electricity Distributors

A2 Model Terms of Reference

These model Terms of Reference (TOR) are illustrative of TOR which a country may issue when procuring Consultants to support them in developing their Integrated Resource Plan (IRP). As discussed in the main body of the IRP Manual, the level of Consultant involvement will vary depending on a country's experience in developing an IRP and available resources. We present two model TOR. The first provides a more comprehensive set of services in assisting a country to develop an IRP, whereas in the second the role of the Consultant is limited to providing support in the computationally heavy least cost generation planning stage.

A2.1 Comprehensive Terms of Reference

A2.1.1 Client

This section should outline who is commissioning the IRP and which entity is contracting the Consultant (the Client). It should also state the relationship of the Client with the key IRP stakeholders. For example, is the Client a member of the IRP Steering Committee, or part of the IRP Consultative Committee? It should be clear to who the Consultant will report to throughout the project.

A2.1.2 Introduction and objectives

The purpose of this section is to set up the scene for study, define the planning responsibility, scope and objectives that are meant to be achieved through the development of the IRP. For more information, please refer to the main body of the IRP Manual.

A2.1.3 Context and rationale

This section provides a high-level summary of the prevailing conditions in the power market. The Client can use this section to highlight any significant new developments that could affect the IRP study. The current state of power planning practices should be summarised here by mentioning if and when previous power system plans were developed.

A2.1.4 Scope of work

Overall approach

The overall approach section specifies whether the Consultant is expected to develop their own methodology or adopt the approach that was utilised in the previous IRP.

Inception report

The inception report serves as a starting point of the IRP study and should include the following sections:

- Consultant’s understanding of the IRP objectives;
- A high-level overview of the electricity sector and analysis of existing sector planning documents;
- Elaboration of the methodology previously described in the technical proposal;
- Confirmation of the time frame for the study

The Consultants should also conduct a preliminary assessment of available data, submit data requests and identify potential data issues. If the desired data is not available, the Consultant should provide a proposal of what data they will use and explain the impact of using the second-best data.

The inception report should clarify the data collection process and responsibilities of both parties. While the data collection process is led by the Consultant, the Client can improve the quality of inputs by facilitating interactions between the Consultant and relevant stakeholders.

Demand side management (DSM) and energy efficiency (EE)

As a pre-cursor to the demand forecast task, analyse DSM and EE measures already in place and those that are expected to become effective during the plan period. Some EE programmes may be able to be packaged as a candidate resource for evaluation in the least cost planning software alongside generation candidates.

National Electrification plans

This task involves an analysis of the national electrification plan. The output of analysis should include the number of future grid-connected electricity customers and analyse the impact of distributed power generation on electricity demand. The spatial distribution of demand is also required if the scope of the IRP includes a network expansion plan.

If no electrification plan exists yet, consideration should be given to procuring a separate study to develop a national electrification plan prior to the development of the IRP. While it is possible to conduct both studies in parallel, there is the risk of potential delays and lack of coordination between institutions which has to be managed.

Electricity demand forecast

This task comprises a review and development of the demand forecast. As a first step, the Consultant should review the demand forecast which is currently in use, the methodology on which it is based and the availability and granularity of available data (eg time intervals, disaggregation by different customer types). The IRP is typically developed from a national perspective and should therefore include customer demand satisfied by the national utility and private sector (eg independent power producers (IPPs)).

Data collection stage requires active involvement from the Consultant as well as the Client. While the Consultant should develop a data request sheet and lead on the data collection and analysis tasks, the role of the Client is to facilitate the interaction between the Consultant and various institutions. The Client will often have a good perception of data availability and could help navigate the Consultant through the process, leading to better study outcomes.

As a second step, the Consultant should either update the existing demand forecast or prepare a new one. The decision should be based on the assessment of the accuracy of the previous demand forecast and its suitability to existing and future conditions in the power sector. The demand forecast should examine the impact of EE, DSM strategies, and distributed generation on demand.

Regardless of the selected approach, the methodology and data assumptions should be clearly explained. There should be a forecast of final expected demand at the customer level (energy exiting the network) as well as forecasts at generators sent-out level (energy entering the network) of both maximum demand (MW) and energy (GWh). For transmission planning, the load forecast will need to be spatially disaggregated.

The Consultant should also analyse the load shape. For example, hourly load shapes should be provided for different days of the week, public holidays, and different seasons. This data may need to be provided from national control centres or system operators. The Client could use their legal mandate to streamline the data collection process.

Due to the uncertainty surrounding future electricity demand, the Consultant should suggest risk management measures that will be utilised to improve the versatility of the demand forecast.

Resource assessment

Under this task, the Consultant should provide an assessment of available supply options. The output of this analysis should be a selection of feasible options that will be treated as candidate projects for the least cost generation phase of the IRP study.

In some cases, it may be necessary to commission sub-studies to explore the availability and viability of resources. For example, a sub-study may examine the potential of solar energy in a given country.

Fuel price forecast

Under this section, the Consultant should develop the fuel price forecast over the planning horizon. The forecast should state whether the fuel will be sourced domestically or imported and any assumptions that are used to derive the final price.

Existing, committed and candidate power generation units

Under this task, the national utility and any IPPs will supply information on all existing and proposed power generation units (conventional plants as well as large scale renewable generation facilities). The Consultant should support this by preparing a template which specifies the information required, which should cover:

- Technology;
- Fuel;

- Commissioning year;
- Expected decommissioning year;
- Installed and available capacity;
- Capex;
- Grid connection costs;
- Variable operational and maintenance (O&M) costs (excluding fuel cost);
- Fuel costs (a factor of heat rates/efficiency and fuel prices);
- Annual fixed costs;
- Forced and maintenance outage rates;
- Heat and ramp rates;
- Greenhouse gas emissions;
- Storage capacity (if applicable)

If applicable, the Consultant should also consider PPAs and export and import contracts.

Transmission

Transmission planning can either be considered as part of the IRP or be procured as a separate study. If it is included, the task should involve a thorough analysis of the existing transmission system, as well as an assessment of committed and candidate transmission projects.

Distribution

Distribution planning is typically not included in the scope of the IRP; however, it can be considered to the extent of high-level, indicative electrification plan. Under this task, the Consultant should analyse existing, committed and candidate distribution projects.

Planning criteria and policy-defined constraints

This task involves an identification and assessment of planning and policy criteria that will define modelling constraints.

Development scenarios

The TOR should provide an indicative number of scenarios that the Consultant is expected to analyse. Proposed scenarios should be aligned with the objectives of the IRP and can serve as a risk management tool to address the uncertainties inherent in the plan. Certain scenarios could already be specified at the TOR stage, whereas others could be agreed with the Client during the course of the study. The TOR could request the Consultant to provide a quote for any additional scenarios that were not initially considered but could be requested at a later stage,

Generation development plan

Under this task, the Consultant should develop a generation expansion plan including the following outputs:

- A base case plan. This should be a least cost plan subject to policy constraints based on the base case load forecast and policy constraints.
- An analysis of the implications of alternative policies.
- Sensitivity analyses to show how the development plan would change under alternative future scenarios.

The Client should carefully consider the level of assistance required with least cost generation modelling. The decision will depend on whether there is existing least cost modelling capability amongst Client's staff and whether the Client intends to develop that capability in the future. The next step involves **software selection** - the Client should specify whether there is preference for particular least cost generation planning software (which may have been used before) or whether the Consultant is allowed to make a case to use their in-house software. If the Client decides to develop future least cost modelling capability, training and licence requirements need to be additionally considered. Alternatively, the Client may decide to specify software requirements under a separate sub-heading (see Section A2.1.5).

Network expansion plan

Provided transmission and distribution planning is included in the scope of work, the Consultant should develop a transmission and distribution development plan (if both are included in the scope of the study). The Consultant should present the methodology that will be used to assess the power flows, any relevant assumptions and reliability criteria that will be used in the study.

In line with the previous task on generation planning, similar considerations related to modelling capability should be given in determining the scope of this activity. The task description should specify whether it is expected that at the end of the project, the Client will have internal capability to develop a network expansion plan. If this is the case, training and licence requirements need to be considered. This section should additionally specify whether the Client has any software preference or if the Consultant can present the case for the software they consider suitable for the task. Alternatively, the Client may decide to specify software requirements under a separate sub-heading (see Section A2.1.5).

Climate change implications

Under this task, the Consultant is requested to provide an assessment of climate change implications associated with the main generation and network development options. The technical proposal should include proposed methodology providing more detail on the proposed approach.

Environmental and social considerations

The TOR should specify the extent to which the Consultant is expected to cover the environmental and social considerations. Environmental Social Impact (ESI) assessment studies are typically conducted at a high-level in an IRP considering the overall impacts of the system. ESI can either be requested as part of the IRP or as separate sub-studies. More detailed ESI studies by power plant or for network projects are typically conducted in feasibility studies.

If an ESI component is envisaged, the TOR should request the Consultant to propose an ESI methodology that would be compliant with the necessary frameworks (eg Southern African Power Pool's (SAPP's) Environmental and Social Management Framework). The Consultant should also be requested to provide mitigation options to address the adverse impact on the environment and communities.

Sensitivity tests and risk analysis

Under this task, the Consultant is requested to suggest risk management tools that address the uncertainties embedded in long-term planning and to propose mitigation measures.

Finalisation

As a final step, the Consultant should, together with the Client and relevant stakeholders, select one preferred scenario. The selected scenario should specify a clear investment sequence, and outline the investment costs, imports/exports, an approximate operating schedule of power plants and the associated costs, the forecast operating costs of the utility, and total fossil fuel consumption and greenhouse gas (GHG) emissions.

An **Action Plan**, developed together with the Client, can assist in facilitating the transition from planning to implementation stage. A list of key recommendations can further aid the dissemination of the IRP and its implementation.

A2.1.5 Project management and deliverables

Under this task, the Consultant is requested to provide their proposed approach to project management. This section should include the following:

Reporting

This subsection should define the deliverable schedule and how the project is going to be managed by the Consultant. It should state the language requirements for the Consultant, whereby the language requirements for the day-to-day work of the Consultant may differ from the language in which the report is to be produced. Deliverables should at minimum include:

- Inception report confirming the methodology and work plan.

- Monthly progress reports.
- Sub-study reports – where some tasks are to involve significant sub-studies then these should be treated as separate deliverables (eg DSM and EE Sub-study, National Electrification Strategy Sub-study, Resource Assessment Sub-study).
- Load forecast report (can additionally specify the report format, eg draft as a PowerPoint (ppt) presentation, final in ppt and a written report). This should also include the models (and if applicable the relevant licences) and data files used.
- Generation development plan (can additionally specify the format, eg draft as ppt presentation, final in ppt and a written report).
- Network expansion plan (can additionally specify the format, eg draft as ppt presentation, final in ppt and a written report).
- Data files and models used in the generation and network expansion plans.
- Final workshop presentation that covers all tasks and a final, comprehensive written report that includes feedback from the workshop.

Software

Unless software requirements have already been specified under Section A2.1.4, this paragraph should outline the requirements of the software the Consultant is to use for the least cost generation plan, and where applicable the network expansion plan. If a country has existing least cost generation planning capabilities, or intends to develop them in the near future, it should state if there is a preference for a specific commercially available software package. Otherwise, this section could allow for the Consultant to recommend a software package. More advanced software packages would come with higher costs.

If the country wishes to develop its planning capabilities, this section should clarify how licensing issues are going to be dealt with and stipulate the need for training and capacity building in using the software.

Capacity building

The TOR should state the type and extent of capacity building sought by the country. It should specify whether a gap analysis needs assessment is to be conducted, and the types of activities which should be provided by the Consultant. These may include, but are not limited to:

- On-the-job training;
- Coaching;
- Mentoring;
- Structured training workshops

This section should provide details on these activities, for example how many representatives from the Client or other stakeholders are to be embedded into the Consultant's team for coaching and mentoring, or the scope and length of the training workshops.

The Consultant should provide a detailed capacity building plan which illustrates the delivery of the capacity building component and the objectives that the capacity building component will achieve. At minimum, this should include the ability to understand the planning process, interpret IRP's results and appreciate the constraints of the models deployed. Where models are handed over, the Consultant should provide sufficient capacity building to ensure the stakeholders are able to become proficient users of the model at a later stage.

Stakeholder engagement

This should provide an overview of the nature of stakeholder engagement, and the role of the Consultant in supporting these efforts. For example, if the IRP development process is to be accompanied by stakeholder workshops, the TOR should specify the role of the Consultant in designing and delivering these workshops. If there is to be a formal consultation period, it needs to be made clear if the Consultant is responsible for analysing the submissions and incorporating them into the final IRP.

The responsibility for a successful execution of the stakeholder engagement process rests jointly on the Client and the Consultant. The Consultant should factor in stakeholder engagement as a crucial component of the IRP and ensure successful dissemination of the IRP through workshops and consultation windows. However, the Client is expected to take an equally active role due to their knowledge of the sector and key market participants.

Workplan and level of effort

This section can provide an indication of the level of effort envisaged for the study and delivery timeframes.

The level of effort that is required will depend on the scope of the IRP and the size of the electricity system being considered. Table 2 provides an indicative overview of the relative level of effort required for the different tasks outlined above. These numbers should be interpreted with caution and carry more meaning in relative terms (eg the portion of time that should be spent on developing the demand forecast). The most time-consuming tasks relate to the development of actual expansion plans and sufficient time should be allocated to those tasks. As noted previously, an IRP can be kept short in scope and exclude the network component of the plan (which should be then procured separately).

Table 2 Indicative level of effort required for IRP components

Component	Suggested deliverable schedule	Level of effort (days)	Comments
Inception	Deliverable 1	5-20 days	If an inception meeting with the whole team is planned in-country, then considerably more time will have to be allowed.
Analysis of existing plans		5-15 days	
Demand forecast	Deliverable 2	20-45 days	More time to be allowed if detailed electrification, DSM or EE sub-studies are required.

Component	Suggested deliverable schedule	Level of effort (days)	Comments
DSM and EE			
Resource and generation assessment	Deliverable 3	45-90 days	More time to be allowed if detailed resource assessment sub-studies are required
Fuel price forecast			
Scenario development			
Generation development plan			
Transmission	Deliverable 4 (optional)	0-80 days	Analysis of the transmission networks can be considered in a separate network development plan if the scope of the IRP is to be kept short
Distribution		0-20 days	Simple distribution planning without detailed modelling. If distribution is to be based on a GIS electrification planning sub-study, then more time would be needed for this.
Impact assessment	Deliverable 5	15-25 days	Depending on donor funding arrangements, an analysis of the climate change, environmental and social implications of the development plan is likely a mandatory component
Capacity building	Continuous + specific courses	15-25 days	To save on travel expenses, formal training courses can be scheduled to be back-to-back with stakeholder workshops
Stakeholder engagement	Continuous + workshops	20-35 days	
Project management	~15%-20% of project time	20-70 days	
Total		145-425 days	The total could be lower if the study is a limited updating exercise but could equally be much more if detailed sub-studies are included.

A2.1.6 Budget

Quoting a concrete number that should be spent on developing an IRP is challenging as it will depend on many factors, including the size of the system and the expected depth of analysis. The TOR should give an indicative budget to provide Consultants with an insight into the envisaged scope of work prior to putting together the financial and technical proposals. Based on experience of power development studies, the estimated level of effort for a generation and network IRP should vary between about 145 and 425 professional days.

This translates to the budget of the order of US$180-US$600 thousand, with professional fees accounting for approximately 80% to 90% of the total. This estimate includes the cost of flights and per diems and organising workshops. If training workshops are to be residential, additional resources would be needed. Other add-on costs may include software licences. The TOR should make clear what assumptions the bidders should use to arrive at their financial proposals. This will ensure Consultants bid for a similar scope of work that is required to be delivered.

A2.1.7 Team composition

The size of the team will depend on the scope of work and size of the system. The Consultant could be requested to suggest their own team, which at minimum should include the team leader, a generation planning expert, a transmission planning expert (if transmission planning is included in the scope of the IRP) and an economist.

Table 3 Minimum qualifications of key experts

Position	Role	Minimum qualifications
Team leader	• Overall coordination of the project team; • Main contact person for the Client and other stakeholders; • Leads stakeholder engagement process; • Responsible for quality of all deliverables produced by the Client	• University degree in engineering or economics; • 10 years of experience in electricity sector planning; • Experience in developing IRPs; • Experience of working in the country/region; • Proven ability to take on team leader positions
Generation planning expert	• Leads the demand forecast and generation development plan; • Supports capacity building and model hand over	• University degree in engineering or a relevant sub-discipline; • Experience in generation planning; • Knowledge and expertise in generation planning software
Transmission planning expert	• Leads the transmission and distribution analysis; • Leads the network expansion work	• University degree in engineering or a relevant sub-discipline; • Experience in transmission planning; • Knowledge and expertise in transmission planning software
Economist	• Works closely with other team members to bring economic analysis into electricity sector planning	• University degree in economics or a relevant sub-discipline; • Experience in power sector planning

A2.2 Limited Terms of Reference

The second version of the TOR envisages that the scope of work is limited to the more technically complex and computationally heavy load forecast and least cost generation plan. Under this arrangement, the Client is expected to lead on most aspects of the study. Preparation of the demand forecast and least cost generation plan is outsourced to Consultants who provide support and run the models.

A2.2.1 Client

This section should outline who is commissioning the IRP and which entity is contracting the Consultant (the Client). It should also state the relationship of the Client with the key IRP stakeholders. For example, is the Client a member of the IRP Steering Committee, or part of the IRP Consultative Committee? It should be clear to who the Consultant will report to throughout the project.

A2.2.2 Introduction and objectives

The purpose of this section is to set up the scene for study, define the planning responsibility, scope and objectives that are meant to be achieved through the development of the IRP. For more information, please refer to the main body of the manual. The introduction section should specify that the Consultant is expected to provide assistance at specific stages of IRP development only. This will prevent Consultants from bidding on different scopes of work.

A2.2.3 Context and rationale

This section provides a high-level summary of the prevailing conditions in the power market. The Client can use this section to highlight any significant new developments that could affect the IRP study. The current state of power planning practices should be summarised here by mentioning if and when previous power system plans were developed.

A2.2.4 Scope of work

Overall approach

The overall approach section should specify that the Consultant is required to provide assistance limited to preparing a demand forecast and a generation expansion plan. This section should additionally specify whether the Consultant is expected to develop their own methodology or adopt the approach that was utilised in the previous IRP.

Inception report

The inception report serves as a starting point of the IRP study and should include the following sections:

- Consultant’s understanding of the scope of work;

- Elaboration of the methodology previously described in the technical proposal;
- Confirmation of the time frame for the study

The Consultant should also conduct a preliminary assessment of available data, submit data requests and identify potential data issues. If the desired data is not available, the Consultant should provide a proposal of what data they will use and explain the impact of using the second-best data.

The inception report should clarify the data collection process and responsibilities of both parties. While the data collection process is led by the Consultant, the Client can improve the quality of inputs by facilitating interactions between the Consultant and relevant stakeholders.

Electricity demand forecast

This task comprises a review and development of the demand forecast. As a first step, the Consultant should review the demand forecast which is currently in use, the methodology on which it is based and the availability and granularity of available data (eg time intervals, disaggregation by different customer types). The IRP is typically developed from a national perspective and should therefore include customer demand satisfied by the national utility and private sector (eg IPPs).

Data collection stage requires active involvement from the Consultant as well as the Client. While the Consultant should develop a data request sheet and lead on the data collection and analysis tasks, the role of the Client is to facilitate the interaction between the Consultant and various institutions. The Client will often have a good perception of data availability and could help navigate the Consultant through the process, leading to better study outcomes.

As a second step, the Consultant should either update the existing demand forecast or prepare a new one. The decision should be based on the assessment of the accuracy of the previous demand forecast and its suitability to existing and future conditions in the power sector.

Regardless of the selected approach, the methodology and data assumptions should be clearly explained. There should be a forecast of final expected demand at the customer level (energy exiting the network) as well as forecasts at generators sent-out level (energy entering the network) of both maximum demand (MW) and energy (GWh). If transmission planning is procured separately, the load forecast will need to be spatially disaggregated.

Under the limited scope of work, it is assumed that the results of national electrification and DSM programmes can be readily made available to the Consultant. The demand forecast should examine the impact of electrification programmes, EE measures, DSM strategies, and distributed generation on demand.

The Consultant should also analyse the load shape. For example, hourly load shapes should be provided for different days of the week, public holidays, and different seasons. This data may need to be provided from national control centres or system operators. The Client could use their legal mandate to streamline the data collection process.

Due to the uncertainty surrounding future electricity demand, the Consultant should suggest risk management measures that will be utilised to improve the versatility of the demand forecast.

Existing, committed and candidate power generation units

Under this limited TOR, it is assumed that the Client can provide the Consultant with a list of candidate generation options resulting from a previously completed resource assessment study, information on existing and committed projects should also be made available together with a fuel price forecast. The Consultant should support this by preparing a template which specifies the information required, which should cover:

- Technology;
- Fuel;
- Commissioning year;
- Expected decommissioning year;
- Installed and available capacity;
- Capex;
- Grid connection costs;
- Variable O&M costs (excluding fuel cost);
- Fuel costs (a factor of heat rates/efficiency and fuel prices);
- Annual fixed costs;
- Forced and maintenance outage rates;
- Heat and ramp rates;
- Greenhouse gas emissions;
- Storage capacity (if applicable)

If applicable, the Consultant should also consider PPA and export and import contracts.

Planning criteria and policy-defined constraints

This task involves an identification and assessment of planning and policy criteria that will define modelling constraints.

Development scenarios

The TOR should provide an indicative number of scenarios that the Consultant is expected to analyse. Proposed scenarios should be aligned with the objectives of the IRP and can serve as a risk management tool to address the uncertainties inherent in the plan. Certain scenarios could already be specified at the TOR stage, whereas others could be agreed with the Client during the course of the study. The TOR could request the Consultant to provide a quote for any additional scenarios that were not initially considered but could be requested at a later stage,

Generation development plan

Under this task, the Consultant should develop a generation expansion plan including the following outputs:

- A base case plan. This should be a least cost plan subject to policy constraints based on the base case load forecast and policy constraints.
- An analysis of the implications of alternative policies.
- Sensitivity analyses to show how the development plan would change under alternative future scenarios.

The Client should carefully consider the level of assistance required with least cost generation modelling. The decision will depend on whether there is existing least cost modelling capability amongst Client's staff and whether the Client intends to develop that capability in the future. The next step involves software selection- the Client should specify whether there is preference for a preferred least cost generation planning software (which may have been used before) or whether the Consultant is allowed to make a pitch on their in-house software. If the Client decides to develop future least cost modelling capability, training and licence requirements need to be additionally considered. Please refer to "software" and "capacity building" subsections of the manual for more information. Alternatively, the Client may decide to specify software requirements under a separate sub-heading (see Section A2.2.5).

Sensitivity tests and risk analysis

Under this task, the Consultant is requested to suggest risk management tools that address the uncertainties embedded in long-term planning and to propose mitigation measures.

A2.2.5 Project management and deliverables

Under this task, the Consultant is requested to provide their proposed approach to project management. This section should include the following:

Reporting

This section should define the deliverable schedule and how the project is going to be managed by the Consultant. It should state the language requirements for the Consultant, whereby the language requirements for the day-to-day work of the Consultant may differ from the language in which the report is to be produced. Deliverables should at minimum include:

- Inception report confirming the methodology and work plan.
- Progress updates. Given the limited scope of work, these do not have to be in a report form but should serve the purpose of keeping the Client updated on work progress.

- Load forecast report (can additionally specify the report format, eg draft as a PowerPoint presentation, final in ppt and a written report). This should also include the models (and if applicable the relevant licences) and data files used.
- Generation development plan (can additionally specify the format, eg draft as ppt presentation, final in ppt and a written report).
- Data files and models used in the generation expansion plan.
- Final workshop presentation that covers the above tasks and a final, comprehensive written report that includes feedback from the workshop.

Software

Unless software requirements have already been specified under Section A2.2.4, this paragraph should outline the requirements of the software the Consultant is to use for the least cost generation plan. If a country has existing least cost generation planning capabilities, or intends to develop them in the near future, it should state if there is a preference for a specific commercially available software. Otherwise, this section could allow the Consultant to recommend a software package. More advanced software packages would come with higher costs.

If the country wishes to develop its planning capabilities, this section should clarify how licensing issues are going to be dealt with and stipulate the need for training and capacity building in using the software.

Capacity building

The TOR should state the type and extent of capacity building sought by the country. It should specify whether a gap analysis needs assessment is to be conducted, and the types of activities which should be provided by the Consultant. These may include, but are not limited to:

- On-the-job training;
- Coaching;
- Mentoring;
- Structured training workshops

This section should provide details on these activities, for example how many representatives from the Client or other stakeholders are to be embedded into the Consultant’s team for coaching and mentoring, or the scope and length of the training workshops.

The Consultant should provide a detailed capacity building plan which illustrates the delivery of the capacity building component and the objectives that the capacity building component will achieve. At minimum, this should include the ability to understand the planning process, interpret IRP’s results and appreciate the constraints of the models deployed. Where models are handed over, the Consultant should provide sufficient capacity building to ensure the stakeholders are able to become proficient users of the model at a later stage.

Stakeholder engagement

This should provide an overview of the nature of stakeholder engagement, and the role of the Consultant in supporting these efforts. For example, if the IRP development process is to be accompanied by stakeholder workshops, the TOR should specify the role of the Consultant in designing and delivering these workshops. If there is to be a formal consultation period, it needs to be made clear if the Consultant is responsible for analysing the submissions and incorporating them into the final IRP.

The responsibility for a successful execution of the stakeholder engagement process rests jointly on the Client and the Consultant. The Consultant should factor in stakeholder engagement as a crucial component of the IRP and ensure successful dissemination of the IRP through workshops and consultation windows. However, the Client is expected to take an equally active role due to their knowledge of the sector and key market participants.

Workplan and level of effort

This section can provide an indication of the level of effort envisaged for the study and delivery timeframes.

The level of effort that is required will depend on the scope of the IRP and the size of the electricity system being considered. Table 4 provides an indicative overview of the relative level of effort required for the different tasks outlined above. These numbers should be interpreted with caution and carry more meaning in relative terms (eg the portion of time that should be spent on developing the demand forecast). The most time-consuming tasks relate to the development of actual expansion plans and sufficient time should be allocated to those tasks.

Table 4 Indicative level of effort required for IRP components

Component	Suggested deliverable schedule	Level of effort (days)	Comments
Inception	Deliverable 1	5-20 days	If an inception meeting with the whole team is planned in-country, then considerably more time will have to be allowed.
Analysis of existing data		5-15 days	
Demand forecast including the impact of DSM and EE	Deliverable 2	20-25 days	Assumes DSM and EE studies are readily available to the Consultant team
Scenario development	Deliverable 3	40-60 days	Assumes information on candidate, committed and existing power generators is readily available to the Consultant
Generation development plan			
Capacity building	Continuous + specific courses	15-25 days	To save on travel expenses, formal training courses can be scheduled to be back-to-back with stakeholder workshops
Stakeholder engagement	Continuous + workshops	10 days	

Component	Suggested deliverable schedule	Level of effort (days)	Comments
Project management	~15%-20% of project time	15-30 days	
Total		110-185 days	

A2.2.6 Budget

Quoting a concrete number that should be spent on developing an IRP is challenging as it will depend on many factors, including the size of the system and the expected depth of analysis. The TOR should give an indicative budget to provide Consultants with an insight into the envisaged scope of work prior to putting together the financial and technical proposals. Based on our experience of power development studies, the estimated level of effort for providing assistance with limited parts of the IRP (demand forecasting and generation planning) varies between 110 and 185 days.

This translates to the budget of the order of US$140-US$235 thousand, with professional fees accounting for approximately 80% to 90% of the total. This estimate includes the cost of flights and per diems and organising workshops. If training workshops are to be residential, additional resources would be needed. Other add-on costs may include software licences. The TOR should make clear what assumptions the bidders should use to arrive at their financial proposals. This will ensure Consultants bid for a similar scope of work that is required to be delivered.

A2.2.7 Team composition

The size of the team will depend on the scope of work and size of the system. The Consultant could be requested to suggest their own team, which at minimum should include the team leader, a generation planning expert and an economist.

Table 5 Minimum qualifications of key experts

Position	Role	Minimum qualifications
Team leader	• Overall coordination of the project team; • Main contact person for the Client and other stakeholders; • Leads stakeholder engagement process; • Responsible for quality of all deliverables produced by the Client	• University degree in engineering or economics; • 10 years of experience in electricity sector planning; • Experience in developing IRPs; • Experience of working in the country/region; • Proven ability to take on team leader positions
Generation planning expert	• Leads the demand forecast and generation development plan;	• University degree in engineering or a relevant sub-discipline;

Position	Role	Minimum qualifications
	• Supports capacity building and model hand over	• Experience in generation planning; • Knowledge and expertise in generation planning software
Economist	• Works closely with other team members to bring economic analysis into electricity sector planning	• University degree in economics or a relevant sub-discipline; • Experience in power sector planning

A3 Glossary of key terms

This glossary provides an overview of the key concepts, definitions, and acronyms which are used in Integrated Resource Planning and key topics associated with it.

Accounting cost: total money expenditure or outlay necessary to achieve a particular objective

Annuity: a fixed sum payable at specified intervals over a period. In practice, there is often an initial transaction, followed by equal annual payments over a predetermined life of the annuity. See also 'Recovery factor'.

Capacity and energy: these are two different aspects of electricity supply and demand:

- ***Capacity*** is the ability to deliver ***power***, which is the rate of doing work. The power demand, which needs to be met by supply capacity, is also often referred to as the ***load***. In an IRP, a common unit for power is megawatts (MW).

- ***Energy*** is the quantitative property that must be transferred to an object in order to perform work. Electrical energy delivered to households is usually measured in kilowatt hours (kWh), but in an IRP gigawatt hours (GWh) is a more common unit.

Capacity factor: The ratio of the expected output of a generation plant over a specific time period compared to the output if the plant operated at full-rated capacity in the same time period. For example, if a power plant is only expected to produce 100 MWh in a year could provide a capacity of 1,000 MWh in a year it would have a capacity factor of 10%. Capacity factor is closely related to 'load factor':

- **Capacity factor** says how much of the capacity is being used over time.

- **Load factor** tells you how much you load your power plant relative to the capacity.

These are much the same and the terms are often used interchangeably.

Captive power: Refers to plants set up by a person or company, primarily for their own consumption (eg a large factory or hospital which has a generator). See also 'distributed power'.

Coincidence factor – see 'Diversity'

Commercialisation: requiring publicly owned supply entities to act like private companies.

Counterfactual scenarios: show what would have happened if a certain intervention were not to take place. This is important as it allows us to determine the actual impact of the intervention. Setting the counterfactual is a difficult task and requires assumptions about what would happen. In the energy efficiency space, there are two main counterfactual scenarios against which improvements can be measured:

- A **baseline** or **business-as-usua**l scenario, which includes efficiency improvements which would happen anyway in the absence of intervention.

- A **frozen** or **static** scenario, which assumes no efficiency improvements. This is easier to define but is less than realistic than the baseline/business-as-usual scenario.

Debt financing: loans which may have different conditions attached in terms of grace periods, interest rates and periods over which the loans have to be repaid

Demand: the quantity of electricity that consumers are willing to buy at a given price

- ***Supressed demand*** refers to hypothetical demand for electricity, which does not translate to actual demand because it is not available or not accessible. This is an issue for some demand forecasting methods outlined below, as supressed demand is not captured in historic demand.

Demand forecast: a component of the planning process which aims to predict demand. There are two components to the demand forecast:

- ***Energy demand forecast*** predicts the total amount of energy that needs to be supplied. It is usually expressed in GWh

- ***Peak demand forecast*** predicts the maximum demand faced by the system, measured in MW. It informs the total amount of generation, transmission and distribution capacity that need to be developed

Different methods can be used to develop the demand forecast, including:

- ***Trend***: Past demand growth patterns are extrapolated to estimate future demand. This is a fairly simple approach and is easy to apply but is dependent on the assumption that future growth will continue to follow the same trajectory.

- ***Bottom-up:*** A detailed assessment of the electricity usage of different types of consumers and how their consumption habits will change in the future. This is more accurate but requires large amounts of data and significant time resources.

- ***Econometric (or top-down):*** Demand is forecast using **regression analysis.** This involves developing a mathematical relationship which shows the relationship between electricity consumption and the primary driver (eg GDP or GDP per capita)

- ***Hybrid approaches:*** Combine two or more of the above approaches to develop the demand forecast

Demand side management (DSM): DSM is the process of managing energy consumption to optimise available and planned resources for power generation. DSM incorporates all activities that influence customer use of electricity, result in the reduction of the electricity demand and are mutually beneficial to the customers and the utility.

Depreciation: the decrease in the value of an asset over time. Even if they are properly maintained, assets which are used for production lose value (in real if not nominal terms) as they wear out. Depreciation allowances provide for the periodic replacement of physical assets.

Dispatch / despatch of power systems: the process managed by national or regional control centres of bringing power plants onto the power system to meet power and energy requirements. The power requirements vary over the day and by season – see 'load shape'. The following terminology applies:

- ***Firm power*** refers to the electricity which is intended to be available at all times.
- ***Intermittent power*** is not always available due to external factors. For example, power generated through ***variable renewable energy*** sources such as wind and solar may be intermittent as it depends on wind and sun.
- ***Dispatchable and non-dispatchable plants:*** dispatchable plants are those which can be dispatched at request to meet the current demand in the market. Non-dispatchable plants such as wind and solar cannot be controlled by operators and can therefore not be used to respond to fluctuations in system demand.
- ***Base load plants*** are capable of continuous operation which tend to operate at maximum output, such as coal, natural gas and nuclear plants. They typically have high capital costs but lower operating costs. They have less operating flexibility, meaning they are not suited to respond to short-term fluctuations in demand.
- ***Mid-merit plants*****,** also referred to as load following plants, have an output which can be adjusted throughout the day to meet fluctuations in demand.
- ***Peaking plants*** are only required for a few hours in a year, meaning they are flexible and able to be turned on and off quickly. Examples include open cycle gas turbines, battery storage and hydropower. They typically have lower capital costs but higher operational costs.

Discounting: a technique for systematically including time preference in the assessment of decisions which have consequences over a long time period.

- ***Discount factor***: The formula for the discounting process involves a discount factor being applied to each flow, the formula being **1/(1+i)^n**, where **i** is the discount rate and **n** is the number of periods (normally years) from the reference point ('the present').
- ***Discount rate***: The conventional discounting structure makes the simplifying assumption that the discount weights decline over time at a constant rate. This results in time preference being modelled by a single discount rate i. Those with a strong preference for resources now discount the future heavily (in the formula, future flows are heavily 'penalised'). See also 'Social rate of discount'.
- ***Net present value [NPV]:*** The single summary number which results from discounting a series of future flows (in the case of financial values these may be a mixture of outflows and inflows). 'Net' emphasises that both the outflows and inflows are taken into account: all flows, irrespective of their sign and when they occur must be discounted (they are all subject to time preference).
- ***Internal rate of return [IRR]***: the discount rate at which the NPV is zero (for complex projects with investments at different intervals, IRR may not be unique)

Distribution: *The network which carries electricity from the transmission network to end users. They are usually managed by* ***Distribution System Operators (DSOs).***

Distributed power / distributed generation: Small-scale generation which produces electricity close to the end users of power. This would strictly speaking include stand-alone systems and mini-grids which are not connected to the national grid, but the term is generally used for small generation systems which are connected to the grid and often installed by existing customers of the main utility.

Despatch of distributed power generators is not controlled by national control centres, but operates on a must take basis. The different distributed generation models include:

- **Self-supply:** A household or a commercial or industrial enterprise with a small generation system (eg rooftop solar panels) which is used as a supplement to the utility's electricity supply for the customer's own consumption. It may displace the requirement for utility supply, reduce the peak demand or provide a back-up to utility supply. The next item defines the associated commercial arrangement.

- **Net metering / net billing:** A commercial arrangement that allows self-generated electricity to displace some of the electricity which would be purchased from the utility at certain time, with surplus generation available at other times being sold to the utility.

  Net metering was first introduced in industrialised countries that treated each unit of electricity (kWh) as having the same value and this meant that a single, bi-directional, meter could be used. In Africa, net metering typically involves two separate meters (one for sale and another one for consumption) or a smart meter with this capability. This makes possible the price at which the electricity is sold to the grid being less than the price of electricity purchased, the difference reflecting the costs the utility bears in ensuring security of supply for the net metering customer and the fact (for solar PV systems for example) that the electricity that is purchased from the utility may be in peak hours while the energy that is sold may be in off-peak times.

- **Stand-alone system operating as buy all / sell all:** A distributed generation facility in which all electricity is sold to the utility under a **feed-in tariff**. The generator is usually bigger than those involved in net metering arrangements but small enough to be treated as **embedded.**

- **Feed-in tariff:** A feed-in tariff (FiT) is a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers. In the face of rapidly declining renewable energy prices, FiTs have fallen out of favour and renewable energy is now typically procured through auctions.

- **Embedded generation:** distributed generators which are not under the control of the National Control Centre. The generators are therefore not despatched and are instead permanently connected to grid (unless faulty or removed for maintenance) and are contracted on the basis of 'must run, must take'.

- **Wheeling:** Wheeling is the use of transmission or distribution facilities of a system to transmit power of and for another entity. Where a power purchase agreement (PPA) exists between a distributed generator and a customer in another part of the network, a payment is made to the transmission operator for the use of the network.

Diversification: Ensuring electricity is obtained from a range of different generation resources thereby minimising the risk of relying on a single type of supply. For example, an IRP might include a diversification scenario which places emphasis on developing alternative generation capacities to hydropower to limit the impact of rainfall on security of supply.

Diversity and coincidence: these are related terms which are often carelessly used leading to unnecessary confusion. Preferred definitions are given below. Their importance in IRP planning is that power can be supplied with a lower installed generation capacity (and hence at a lower cost) to customers on an interconnected grid than would be the case if each customer's peak demand had to be separately met in an individual off-grid mode of supply.

- ***Diversity*** arises from the fact that the peak demand of individual electricity consumers in a group of similar consumers will not occur at the same time, so the peak demand of the group will be less than the sum of the individual peak demands.

- ***Diversity factor***: A consumer group's peak demand as a ratio of the sum of the individual peaks of each consumer in the group. Ratio of individual customer peak demand to group peak demand.

- ***Coincidence*** arises from the fact that the peak demand of a group of electricity consumers will not necessarily occur at the same time the peak demand for the system as a whole.

- ***Coincidence factor***: A consumer group's demand at the time of the system peak demand as a ratio of the consumer group's peak demand. Ratio of customer group peak demand to system peak demand

Economic analysis: is synonymous with 'social cost-benefit analysis'. Economic analysis is normally used in preference to SCBA when it is necessary to distinguish the additional steps which SCBA involves from 'financial analysis'. The latter is the first step in a viability analysis and involves using unadjusted market prices and other basic financial data to calculate viability measures. See 'financial analysis'.

Economies of scale: a situation in which long-run average total costs decline as the output of a firm increases. This is also referred to as 'increasing returns to scale'. The profits of a firm which produces a good to which economies of scale apply would certainly increase its financial returns if it kept the price constant while increasing production and sales. One of the objectives of infrastructure regulation is to ensure that the benefits of economies of scale are largely passed on to consumers and not simply appropriated by producers.

Economies of scale are characteristic of the electricity sector. Large, shared generation plants with economies of scale are what underpin the economics of the national transmission grid. When grid electricity is so unreliable that a large proportion of a utility's customer base invests in standby generators not only are there much higher capacity costs per kW and energy costs per kWh but the benefits of diversity on a shared grid are also lost. In recent times, the alternative supplies may be PV and batteries, in which case the recurrent cost becomes negligible but initial capital costs are very high.

Efficiency is used in various different senses in economics, including:

- ***Usage efficiency***: the avoidance of waste so that the minimum amount of a commodity is used to meet a particular need.

- ***Allocative efficiency***: the allocation of resources between competing uses so as to maximise the attainment of some social goal or goals.

See *Energy Efficiency* for its application to electricity use.

Elasticity: see 'price elasticity of demand'. The concept of elasticity applies in a corresponding fashion to any factor affecting demand, such as income (the income elasticity of demand is the degree to which demand for a particular good increases – or decreases - as income rises). Elasticity also applies to any binary relationship, for example the price elasticity of supply is a measure of the responsiveness of producers of a good to changes in its price.

Energy efficiency (EE): Refers to when a fixed level of service can be provided with reduced energy input, or if the level of service provided improves with fixed energy input. For example, LED lightbulbs provide the same level of lighting while requiring less energy input. Important terms relating to EE are:

- ***Energy intensity:*** The quantity of energy required per unit of output. This often acts as a proxy for energy efficiency. Energy intensity typically falls as countries move from low to high-income, although this is dependent on the structure of the country's economy.

- ***Energy efficiency potential****:* Different definitions exists relating to potential for EE measures in a given environment, including:

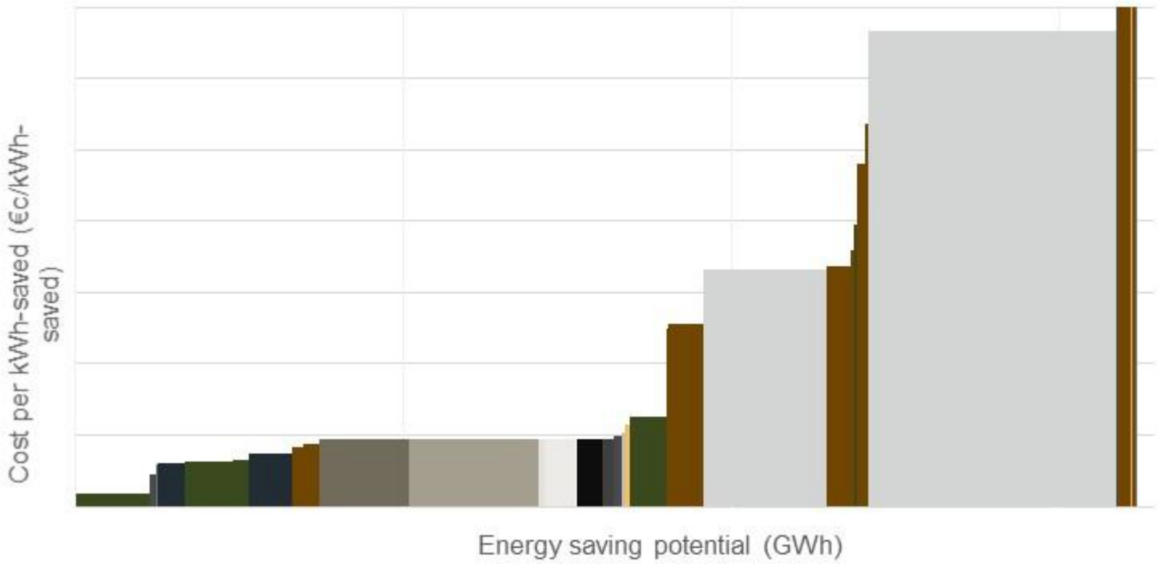
    - ***Technical potential:*** The improvements in end-use EE which could result if the most efficient technologies known today were to attain 100% market saturation during one lifetime of the technology (10-20 years).

    - ***Economic potential:*** The EE improvements that result from the maximum use of *cost-effective* technologies.

    - ***Market potential:*** The improvements which result from EE measures which can be *effectively implemented*.

- ***Energy efficiency cost curves*** show the marginal cost of energy savings delivered by EE measures (see graph below). They are developed by ranking EE measures from the lowest to highest cost – considering both the initial investment costs and ongoing operational costs – per kWh saved.

Figure 5 Illustrative energy efficiency cost curve



Source: ECA

- **Minimum Energy Performance Standards** are regulations which specify the maximum amount of energy which can be consumed by a specific product or building.

Environmental valuation: the assignment of a value (usually in monetary terms) to environmental resources and outcomes. Some of the terminology that is involved includes **active use values, passive use values, option values** and **existence values.** The chief methods are: **hedonic property value, travel cost, defensive expenditures, production function approach** and **contingent valuation.**

Equity: projects are typically financed by a mix of equity and debt, with equity being funds provided by project owners or shareholders in the expectation of earning a share of the profits in the form of dividends, while debt financing consists of various forms of loans. Interest and loan repayments associated with debt financing have to be met before profits are declared out of which dividends can be paid. Not to be confused with the concept of ***social equity.***

Externalities: costs or benefits (of production or consumption) which are not fully reflected in market prices. Externalities apply to both production and consumption:

- ***Production Externality*:** when production activities of one firm directly affect the production activities of another firm.

- ***Consumption Externality*:** when level of consumption of some good or service by one consumer has a direct effect on the welfare of another consumer (as opposed to an indirect effect through the price mechanism).

Feed-in tariff: see Distributed generation.

Financial analysis: when used with reference to national project viability studies, financial analysis typically refers to the first step in the social cost-benefit process – calculation of project viability without giving any weight to national objectives, without adjusting market prices and using some rate of interest as the discount rate in NPV calculations. See ‘economic analysis’

Generation planning: the following terminology is used in least cost generation planning:

- ***Committed power plants***: Power plants which have been commissioned or have been procured and will be coming online within the period covered in the planning process.
- ***Candidate power plants/resources***: Potential power plants (or EE measures) which could be developed in the time period covered by the planning process.
- ***Investment sequence:*** the output of the least cost generation model is a sequence of investment projects.

Green accounting: the integration of environmental resources into national accounts. Under the UN System of Integrated Environmental and Economic Accounting, the main components are (1) natural resource asset accounts (2) flow accounts for pollution, energy and materials (3) environmental protection and resource management expenditure accounts and (4) valuation of non-market flow and environmentally adjusted aggregates.

Health impact evaluation: the assignment of a value (usually in monetary terms) to health outcomes, arising for example from environmental changes. Some of the terminology that is involved includes **statistical value of life [VOSL], value of a healthy life year [VOLY]** and **disability adjusted life year [DALY]**.

Independent power producer (IPP): A non-utility generator who own plants to generate electricity which is sold to utilities and end users

Inflation: the rate of change of prices in an economy. The first step in measuring inflation is to establish a price index. This is done by tracking the prices of a particular basket of commodities, putting each of these onto an index basis and calculating a weighted average index for the entire basket. Inflation is then the change in the index relative to say the previous month, corresponding month of the previous year or some average over a specified period. Related definitions:

- ***Inflation rate:*** is some measure of inflation, usually the change in an index of the prices of a defined basket of goods. This may be measured over different time periods – monthly, quarterly, annual etc.
- ***Price indices:*** a commonly used inflation index is the consumer price index [CPI] reflecting the weighted average of changes in the prices of a basket of consumer goods. There are similar indices for other types of baskets eg the producer price index measures the weighted average increase in the price received by producers of goods and services.
- ***Nominal values:*** monetary values which are subject to the effects of inflation. Nominal values, which reflect ongoing price increases, are said to be in terms of 'money of the day'.
- ***Real values:*** monetary values which have been put onto a basis whereby they can be directly compared. This is achieved by removing the effects of inflation so as to produce values which reflect the same ***purchasing power*** or ability to acquire real goods and services.

Interest rate: proportion payable on an amount of money that is saved (savings rate of interest) or is borrowed (loan rate of interest). Banks generate income from the spread between loan and deposit rates of interest.

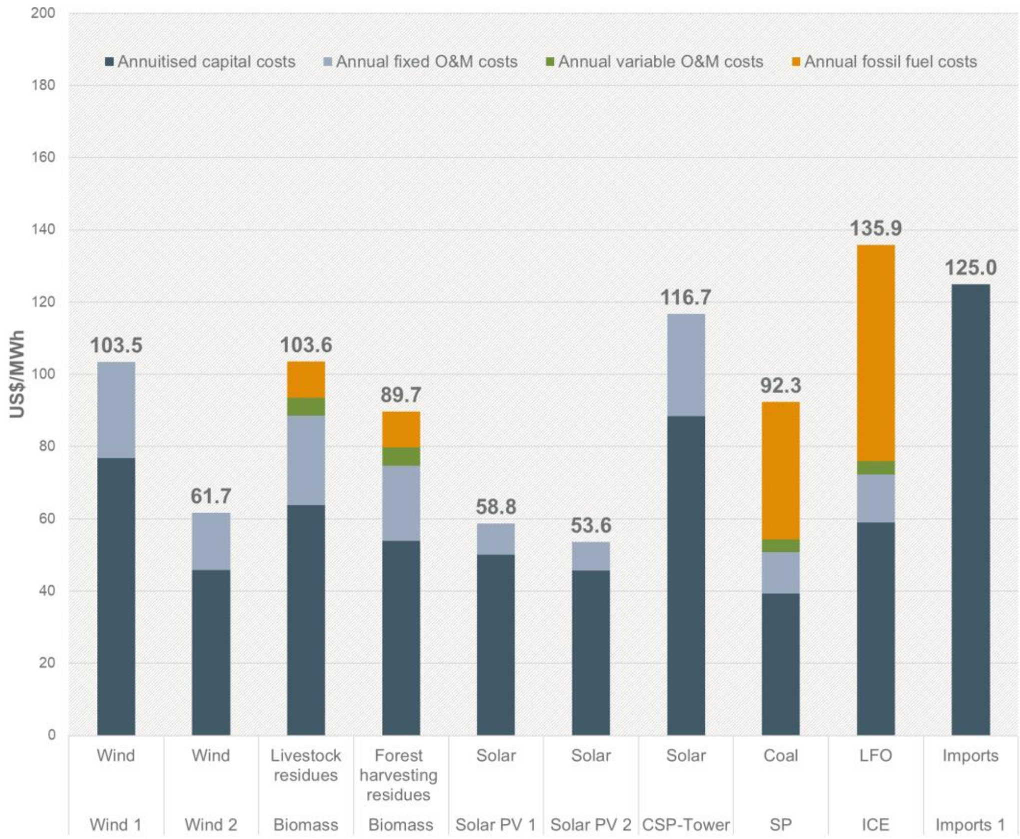
Integrated Resource Planning [IRP]: is an approach to national power system development planning that incorporates a holistic assessment of available energy resources and opportunities for demand management into deriving a least cost combination of supply and energy efficiency measures to meet long-term requirements for electricity services during a specified period, while furthering broad national objectives such as social equity and environmental sustainability.

Internal rate of return [IRR]: the discount rate at which the net present value is equal to zero. See 'discounting'.

Iterative approach/iteration: process of repeated analysis or calculation intended to involve to successive improvements.

Levelised cost of energy [LCOE] provides an indication of the average cost of a technology. It is calculated as the discounted total cost of a technology option over its economic life divided by the discounted output from that technology over the same period.

Figure 6 Illustrative LCOE for different technologies



Source: ECA analysis, 2018

The graph above provides LCOEs for different technologies in a southern African country. Although it provides a simple and common basis to compare different generation technologies, it does not provide sufficient detail for power planning. This is because LCOE does not reflect the reality that electricity is worth more at peak periods and that the capacity of non-dispatchable plant, such as wind or solar PV, does not constitute ‘firm’ power that can be used to meet peak demand. Power planning with a mix of generation technologies has to consider how the different types of plant will be despatched to meet the load profile.

Light emitting diode [LED]: type of lighting which has progressively replaced incandescent lighting, with significant reduction in capacity and energy requirements while providing comparable levels of lighting.

The savings are substantial. According to the World Bank “Under India’s UJALA (“Bright Light”) scheme, 105 million energy efficient LED bulbs have been distributed across 24 states, targeting 33 million customers. The programme is helping improve the quality of lighting and at the same time lowering electricity bills. It has also helped the country reduce peak demands for electricity by 2,700 MW. If the entire India used energy efficient LED bulbs, total electricity demand would decrease by 10%”.

Load factor [LF] is a ratio of the average load divided by the peak load in a specified time period (typically a year, but can be other periods or a load factor for a particular season). The load factor as defined would have MW in both numerator and denominators, but the load factor can also be calculated in energy terms, for example the MWH generated over a year divided by the plant capacity multiplied by 8,760 (the number of hours in a year).

‘Load factor’ is often treated as synonymous with ‘capacity factor’ – see the entry for capacity factor for a (marginal) distinction between the two terms.

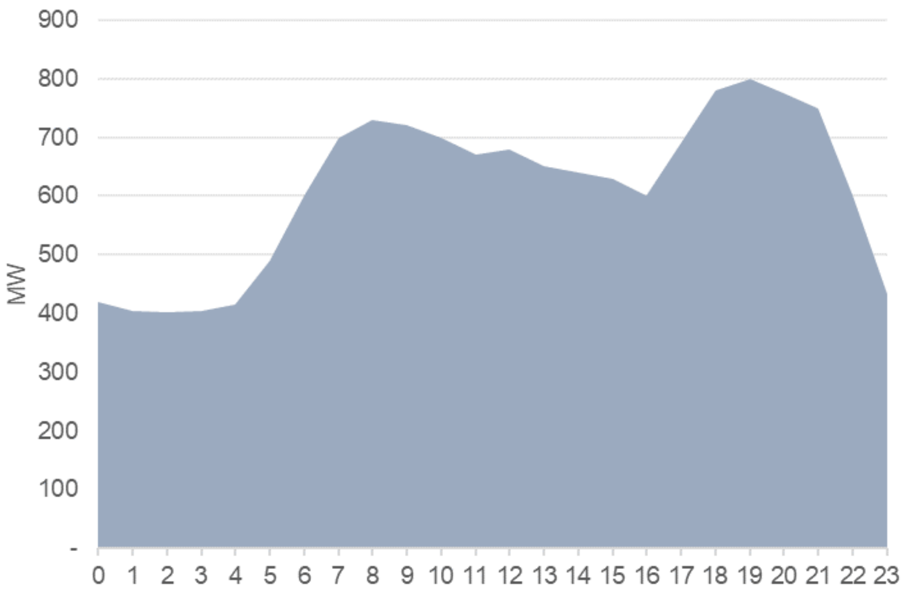
Load flow study is a quantitative analysis of the flow of electric power in an interconnected system. A load flow study usually uses simplified notations such as a one-line diagram and per unit system, and focuses on various aspects of AC power parameters, such as voltages, voltage angles, real power and reactive power. It analyses the power systems in normal steady-state operation.

In addition to load flow, comprehensive transmission studies also include short-circuit fault analysis, stability studies (transient as well as steady-state), unit commitment and economic dispatch.

Load forecasting – see ***Demand forecasting***

Load shape and load management: Shows the capacity which needs be satisfied at any given hour. It can be based on the demand over a day (see illustrative example below) or a year. Although producing an hour-by-hour analysis of demand over an entire year adds complexity, it can be useful if there are large seasonal fluctuations (for example if there is an afternoon peak in summer months when air-conditioning units are used).

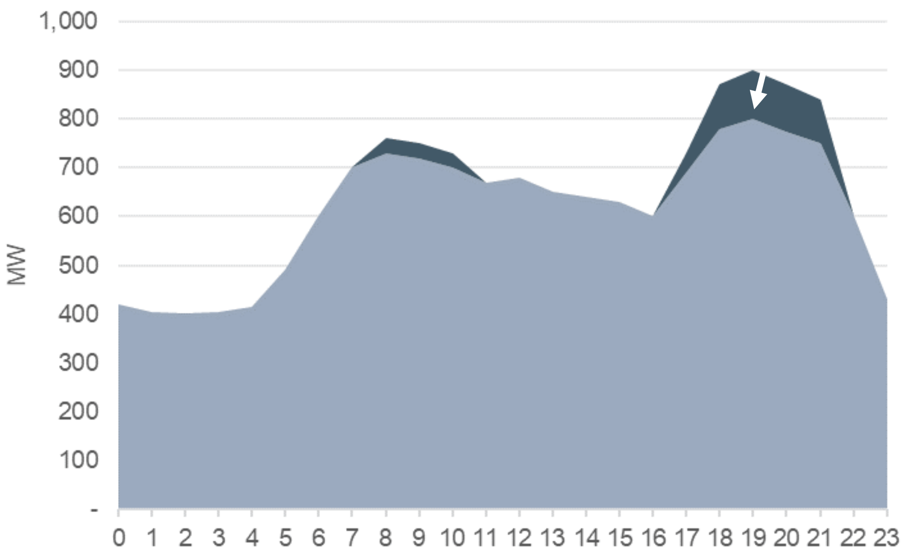
Figure 7 Illustrative daily load curve



The load shape is related to ***peak demand*** and can be used for ***load management,*** in which measures are taken to shift load. Examples of this include:

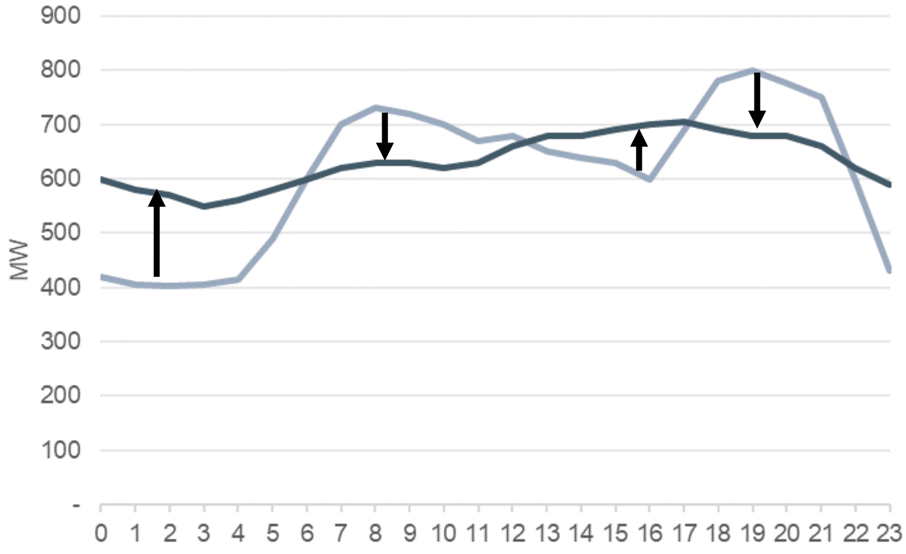
- **Peak shaving / clipping** in which measures are taken to try and reduce peak load. For example, if peak demand is driven by electric cooking appliances and heating, it may be worthwhile to invest in energy efficiency measures in these areas to lower the peak demand. This will reduce the overall level of investment needed to meet peak demand.

Figure 8 Impact of peak shaving on load curve



Load shifting, in which measures are taken to shift demand from high load periods to low demand periods. For example, smart meters and time of use pricing (see ***Tariffs***) may incentivise certain consumers to shift their demand from peak hours to off-peak hours.

Figure 9 Impact of load shifting on load curve



Marginal cost: the cost incurred in supplying the last unit demanded. This will typically be higher than the average cost incurred to supply the entire number of units demanded. One of the theorems of neo-classical economics is that allocative efficiency is achieved when the price of a commodity is set equal to the marginal cost of its supply. Further definitions:

- ***Short-run marginal cost [SRMC]***: the marginal cost incurred in the short-run, where adequate capacity is assumed to be available (the costs therefore are largely operation and maintenance costs).
- ***Long-run marginal cost [LRMC]:*** the marginal cost of supply taking into account future investment costs as well as operation and maintenance costs.
- ***Long-run average incremental cost [LRAIC]:*** the strict 'marginal' or 'last unit' cost is often difficult to calculate and instead the average cost which would be incurred to meet a specified increment in demand is calculated. This is the average incremental cost and becomes the long-run average incremental cost when successive investments to meet demand increments are considered over an extended time horizon.

Multi-criteria analysis (MCA): an evaluation technique which uses a weighting schema to take different criteria into account in systematic way.

National income: there are various different measures of national income including the following:

- ***Gross domestic product [GDP]:*** a measure of the total value of economic activity in an economy over a particular time period, normally a year. 'Gross' refers to the fact that no account is taken of the capital that is used up in producing goods and services during the year in question.
- ***Gross national product [GNP]*** is a measure of the total value of economic activity by nationals of the country in question. GNP is GDP plus income from capital invested

abroad or nationals working outside the country, less income from foreign investments and foreign workers in the domestic economy. GNP<GDP in countries which have significant numbers of foreign investors and expatriate workers (eg Zambia), while GNP>GDP in countries which have large remittances from migrant workers (eg Lesotho).

- ***GDP or GNP in purchasing power parity [PPP] terms:*** a means of adjusting for distortions in exchange rates to produce comparable figures for aggregates such as GDP or GNP per capita. The technique involves taking account of different prices for similar baskets of goods in different countries.

Nationally determined contributions (NDCs): Targets set by each on country for emissions reduction as part of the Paris Climate Agreement. An IRP may have targets on the level of renewable energy in the system or emissions produced, which may be informed by a country's NDCs.

Net metering: see **Distributed generation**.

Net present value [NPV]: see 'Discounting'.

Opportunity cost: value of the next best alternative or opportunity which has to be foregone in order to achieve a particular objective.

Peak demand: the maximum demand faced by the system. This can be a specific time (eg evenings), day/week/month, or combination of these. For example, in warm countries peak demand is experienced in summer afternoons when air-conditioning units are turned on. ***Load curves*** can be used to illustrate peak demand.

Power factor and power factor correction – see 'Reactive power'

Power sector reform – see Vertically integrated utility

Price elasticity of demand is a measure of the degree to which consumers react to prices changes. In more formal terms, the price elasticity of demand is defined as the percentage change in demand resulting from a percentage increase in price. The elasticity is a negative number since demand normally decreases as price increases, and typically the value ranges between -1 and 0.

Quality of service: These indicators are used to measure the reliability of supply to customers. Common indices include:

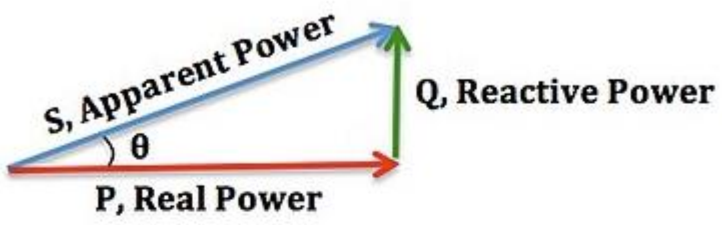
- **SAIDI – System Average Interruption Duration Index.** Measures the average outage duration for each customer served and is calculated as the ratio of duration of all customer interruptions and the total number of customers served.

- **SAIFI – System Average Interruption Frequency Index**. Measured the average number of interruptions a customer experiences and is calculated as the ratio of the total number of interruptions and the total number of disruptions.

- **CAIDI – Customer Average Interruption Duration Index**. It is the ratio of SAIDI and SAIFI and expressed the average outage duration experienced by a customer.

Reactive power: is a component of alternating current power, namely the portion of power due to stored energy in loads such as induction motors which returns to the power source in each cycle. It is measured in volt-ampere reactive (VAR). There are several related definitions to consider:

- **Apparent power S** (also call 'complex power') is the vector sum of the active power and the reactive power
- **Active power P** (also called 'real power') is the actual power that is being delivered (MW)
- **Reactive power Q** (also called 'wattless power') is the notional power that arises when the voltage and current are out of phase
- **Power factor = P/S** is the ratio of the active power to the apparent power, which is equivalent to the cosine of the angle **θ** in the power triangle.



The power factor is important because a low power factor implies there are higher circulating current (due to energy stored in the load returning to the source) and hence higher losses, which reduces transmission efficiency. Tariff structures often include a **Power factor charge**, which is a penalty for having a low power factor and constitutes an incentive for the customer to install **power factor correction** equipment (such as capacitors).

Recovery factor: Factor used to mimic an annuity. Applying a recovery factor to the net present value of the costs of a major project (these being incurred in different years of the project) gives an annualised equivalent capital cost.

Regression analysis: See **demand forecast.**

Reliability of a power system is its ability to ensure continuity of supply. The reliability of an existing power system is assessed through quality of service measures (*see **Quality of service***). When planning the expansion of a power system, there are a number of reliability-related terms which are used:

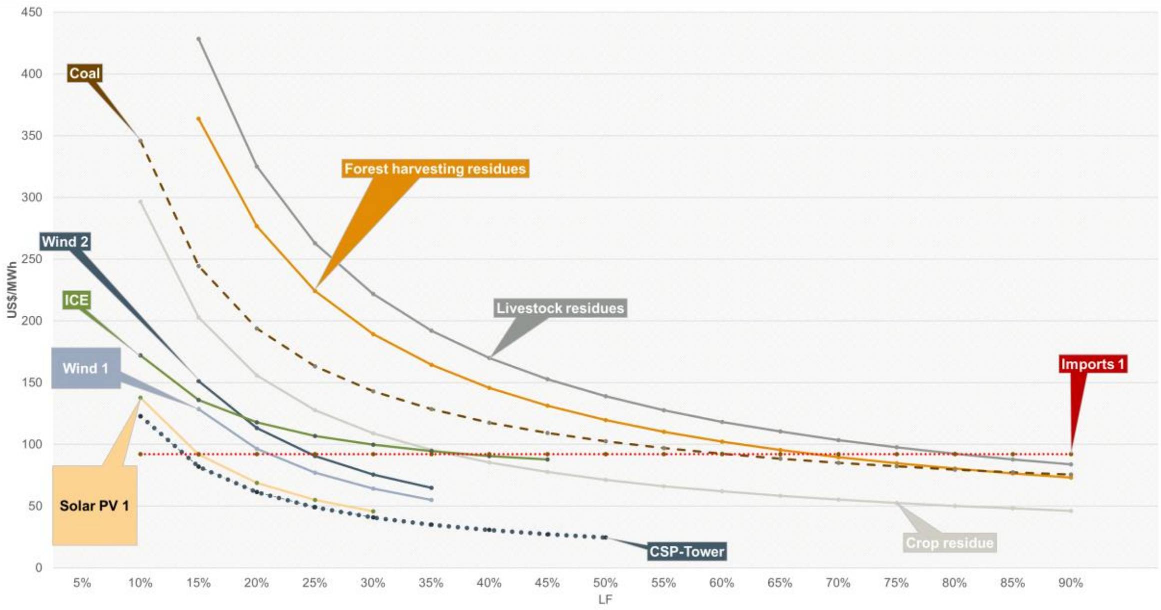
- **Loss of load probability (LOLP)**: a measure of the probability that a system's load will exceed the generation and firm power contracts available to meet that load. The reliability criterion of a system can be specified as a maximum LOLP.
- **Reserve margin:** amount of capacity over and above the expected peak demand (usually expressed as a percentage of peak demand). For stand-alone systems 15% would be a common reserve margin, but consideration also needs to be given to the largest single generation unit on the system. In interconnected systems, reserves can be shared and a lower national reserve margin can be adopted for planning purposes (or, equivalently, a lower LOLP).

- **Expected Energy Not Served (EENS):** the amount of electricity demand that is expected not to be met by supply in a given year.
- **N-1 reliability level:** specifies that the system should be able to meet peak demand even if one transmission line, main transformer or main generator is out of service.
- **Cost of unserved energy:** economic cost arising from customers being denied access to electricity. Strictly the cost is related to the time of day and season when the demand for electricity is not met, but is typically calculated as an average value (the amount of energy that is not provided multiplied by the value of lost load).
- **Value of Lost Load (VoLL)** The value of lost load is a measure of the economic cost arising from demand for electricity not being met. VoLL is typically an order of magnitude higher than the prevailing tariff (eg $1/kWh when the tariff is 10 c/kWh). It is often imputed from data about the economy, but can be empirically determined through surveying customers about their willingness to pay to avoid a disruption in their electricity supply.

Renewable energy (RES) refers to generation technologies which do not rely on the combustion of fossil fuels. Many renewable energy sources are variable as they are intermittent and depend on external resources, such as sunshine (PV), the amount of water that is available (hydropower), or the amount of wind. Such sources are also referred to as ***variable renewable energy (VRE).*** A key limitation of VRE is that it may not match the system load profile. For example, solar generation may not coincide with a peak load in the evening. Due to the intermittency of VRE it is important to assess it in the context of a system-wide planning model that balances VRE with other plant to meet the overall load profile.

Screening curves provide the LCOE for a range of load factors and technologies. An example is shown in the figure below. This can help identify which generation options are economic for base or peak load generation. For example, coal plants are clearly uneconomical as a peaking plant due to the relatively high cost at low load factors.

Figure 10 Screening curve for a Southern African country



Source: ECA analysis, 2018

Service provision management as applied to electricity: the deployment of electricity generation capacity to meet the demand of consumers. Two broad approaches to the management of service provision can be distinguished:

- ***Supply-oriented approach***: an approach in which demand is largely taken as 'given' and the responsibility of the electricity provider is deemed to be to meet that demand through augmentation of generation capacity. The level of demand is often artificially high, in that for social reasons the price of electricity is deliberately kept below the costs of supply, with the result electricity is used by those that have access to it in a wasteful and inefficient manner.

- ***Economic approach***: an approach which values electricity as an economic good and which seeks, through effective tariff mechanisms and other electricity demand management strategies, to ensure that electricity is used efficiently (in both the usage and allocative sense of efficiency). The economic approach is progressively supplanting the supply-oriented approach.

Single buyer: this is a situation where a single agency buys electricity from generators (which may be competing), has a monopoly on transmission, and sells electricity to distributors and large power users without competition from other suppliers.

Shadow price: Notional price used in social cost-benefit analysis to reflect the economic opportunity cost of a resource (in relation to government objectives and policies).

Social, environmental and climate change tools (SECT): The set of tools needed to analyse to the impacts of different generation options on the environmental and local communities. These include an analysis of greenhouse gas emissions, and ***Environmental and social impact (ESI)* assessments,** which consider the impact on the local environment, communities and economy. In SAPP countries, the ***Environmental and Social Management Framework (ESMF)*** is a tool which ensures that the analysis aligns with the compliance and safeguarding guidelines of the World Bank and AfDB.

Social cost-benefit analysis: an example of a SECT which can be used for the systematic analysis of projects or programmes from a national or 'social' viewpoint. This involves considering the benefits incurred from a project or programme (such as generated employment, lower energy bills) and comparing it to the costs (such as the impact on the environment and public finances).

Social equity: considers the fairness of the allocation of resources across a given population. This can be applied to various aspects of IRP planning. For example, tariffs should be socially equitable and avoid low-income households paying a disproportionally large share of their income on electricity. In the context of generation planning, it should be considered in social impact assessments of different generation options.

Social rate of discount: rate of discount to be used in calculating present values in social cost-benefit analysis - it is the rate which reflects society's preference for present as opposed to future consumption, ie measure of society's inter-temporal and inter-generational preferences. See 'discounting'.

Stranded assets are assets which are not able to make an economic return prior to the end of their economic life. This means that they have been written-down earlier than expected or experienced a devaluation. Stranded assets are often the result of a policy change. For example, if a government imposes a policy to rapidly move away from coal, coal generators may become stranded assets.

Supply: the quantity suppliers are willing to sell at a given price.

Tariff: the price of electricity charged by a supplier to a consumer. There are several related definitions which are useful to have in mind for tariff-setting:

- ***Allowed or required revenue***: the level of revenue that a regulator would consider reasonable for a utility to recover from the tariffs it charges its customers.
- ***Building block approach***: a systematic approach to estimating allowed revenue with three main elements – operation and maintenance costs, return of capital (also known as depreciation or capital maintenance) and return on capital (to allow for investment).
- ***Regulatory asset base (RAB)***: the value of existing and proposed new assets that is relevant to calculating the allowed revenue. The RAB will usually be somewhat different to the asset base that is reflected in the utility's financial accounts.
- ***Tariff level:*** the average level of tariff which is determined by the required or allowed revenue
- ***Tariff structure***: the ratios of charges (fixed and consumption-related) between customer categories and ratio of charges within each category. To achieve economic efficiency, tariff structures should reflect marginal costs.
- ***Cost recovery tariffs:*** revenues from tariffs fully recover efficient costs (ie, the allowed or the required revenue)
- ***Cost reflective tariffs***: the tariffs charged to different customers reflect difference in the cost of service between those customers.
- ***Time of use [ToU] pricing:*** tariffs which vary by the time of day with the objective of reducing the system peak demand. Tariffs are therefore higher during the peak hours to provide an incentive to consumers to shift their consumption to off-peak periods for which lower tariffs apply.
- ***Seasonal time of day [STOD] pricing:*** tariffs which vary by the time of day and season, often reflecting different levels of demand resulting from heating and cooling.
- ***Maximum demand [MD] charges***: a monthly charge applied to the highest level of a customer's demand during the peak hours. MD charges have the same objective as ToU tariffs (reducing system peak demand) but the way the incentive is structured is different.
- ***Power factor [PF] charges***: these charges are levied as a component of the tariff structure to provide an incentive to large consumers with reactive power loads to install power factor correction equipment such as capacitors (see 'Reactive power' for details).

Tariffs may recover costs while not being cost reflective across different customer categories (for example if cross-subsidies have deliberately been introduced to meet social objectives).

Time preference is preference for resources (such as energy) now or in the near future over having the same resources at some later time.

Transmission: the movement of electricity from generators to electrical substations (where it enters the distribution network). The transmission network is managed by a ***Transmission system operator (TSO).*** See also 'wheeling'.

Vertically integrated utility is a utility which provides services across the spectrum of generation (G), transmission (T), distribution (D) and supply. T&D are sometimes described as the 'wires business' or network businesses which constitute natural monopolies that are the main trigger for regulation of the power sector. Generation and supply (the direct commercial interface with final customers) are potentially competitive. **Power sector reform** requiring as a first step the unbundling of traditional, vertically integrated state-owned national utilities and the subsequent development of wholesale and eventually also retail competitive markets was in vogue at one time and shows signs of coming back into fashion.

Weighted average cost of capital [WACC]: average cost of finance, usually composed of equity and loan finance. The WACC is commonly referred to as the firm's cost of capital. The WACC represents the minimum return that a company must earn on an existing asset base to satisfy its creditors, owners, and other providers of capital, or they will invest elsewhere.

Typically the most difficult element in estimating the WACC to use in an IRP is the determination of the cost of equity. The most commonly used approach is the **capital asset pricing model [CAPM]**.

Wheeling: wheeling is the transportation of electric power over transmission lines. 'Wheeling' and 'transmission' can be used interchangeably, but wheeling tends to be used when a specific/unusual transmission arrangement is being referred to, for example the transfer of power from a distributed generator (see **Distributed generation**) or the wheeling of power through an intermediate country in a regional trade arrangement.

Transmission tariffs are also referred to as wheeling tariffs. A more precise term is 'transmission use of system' (TUOS) tariffs.

Wholesale competition: Electricity is traded between generators and retailers before being delivered via the grid.

A4 Bibliography and useful resources

Department of Energy. Republic of South Africa. *Integrated Resource Plan (IRP 2019).* Available at http://www.energy.gov.za/IRP/irp-2019.html

Ministry of Mines and Energy. The Government of the Republic of Namibia. *National integrated Resource Plan for the Electricity Supply Industry in Namibia (2016).* Available at https://www.ecb.org.na/images/docs/Noticeboard/ELECTRICITY%20SECTOR%20NATIONAL%20INTEGRATED%20RESOURCE%20PLAN%20(NIRP)%202016%20Version%201.pdf

Ministry of Natural Resources, Energy and Mining. The Government of Malawi. *Integrated Resource Plan (IRP) for Malawi (2017).* Available upon request.

International Finance Corporation (IFC). *Regulatory and Tariff Review for Distributed Generation in the Commercial and Industrial Sectors in Southern Africa (2020).* Available at https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/infrastructure/resources/southern-africa-tariff-review

SAPP Planning Sub-Committee. *SAPP Pool Plan (2017).* Available at http://www.sapp.co.zw/sapp-pool-plan-0

IRENA. *Insights on Planning for Power System Regulators (2018).* Available at https://www.irena.org/publications/2018/Jun/Insights-on-planning-for-power-system-regulators

Bharath Jairaj, Sarah Martin, Davida Wood, Shantanu Dixit, Ashwini Chitnis and Amrita Kundu. *10 Questions to Ask about Integrated Resource Planning (2014).* Available at https://www.wri.org/research/10-questions-ask-about-integrated-resources-planning

Joel N. Swisher, Gilberto de Martino Jannuzzi, Robert Y. Redlinger, UNEP Collaborating Centre on Energy and Environment. *Tools and methods for Integrated Resource Planning (1997).* Available at https://www.unep.org/pt-br/node/13783

Frank Vanclay, Ana Maria Esteves, Ilse Aucamp, Daniel M. Franks. International Association for Impact Assessment (IAIA). *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects (2015).* Available at: https://www.iaia.org/uploads/pdf/SIA_Guidance_Document_IAIA.pdf

The Tellus Institute. *Best Practices Guide: Integrated Resource Planning for Electricity (2010).* Available at https://cleanenergysolutions.org/es/resources/best-practices-guide-integrated-resource-planning-electricity