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SAIPPA IRP webinar

Important considerations for the IRP in South Africa

Insights from an Energy Modelling perspective

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The IRP is developed using a capacity expansion model

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The IRP deals with multiple disciplines (social, environmental, technical, political …) this presentation focuses on **energy modelling**

Increasing availability of low-cost computational resources, and improved access to high quality data in the last decades has led to increasing complexity in capacity expansion modelling analysis - have to **balance** operational detail with computational complexity

Due to the intricate nature of the system being modeled, the energy modelling setup relies heavily on the **judgment of the modeler**.

Various approaches and models are available, each with its unique strengths and weaknesses tailored to address specific inquiries. e.g. PLEXOS can do both capacity expansion modelling and unit commitment and dispatch modelling

Varying results between different energy models can be caused by either different **assumptions** with respect to technologies, or by differences in the general **model structure**.

The solution to these problems is to be **transparent and honest** in designing models and reporting their results and shortcomings.

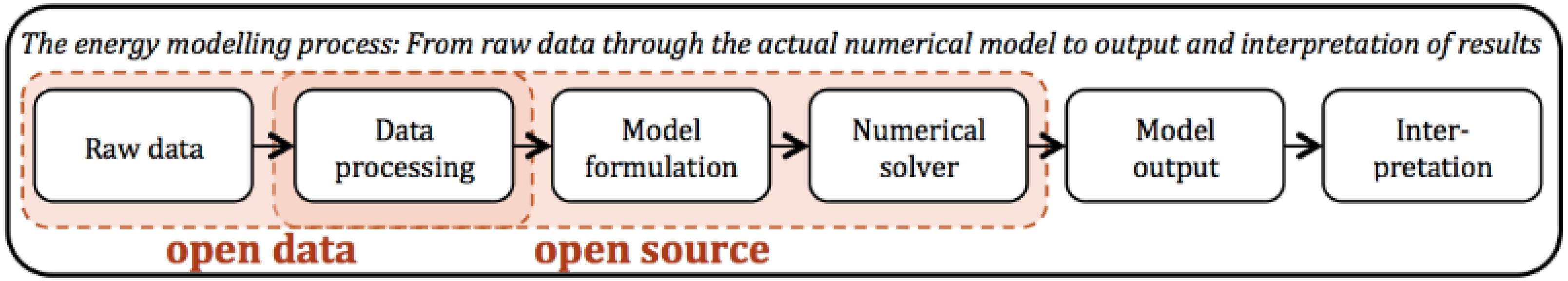
A global move to "Openness" of data and energy models

In recent years, there has been a strong movement towards using **open-source energy models and data**.
An open-source energy model, unlike proprietary models developed by private companies or organizations, have their **source code freely available** to the public, allowing anyone to view, modify, and distribute the software.

Fulfilling scientific standards of **transparency and reproducibility** leads to higher quality and credibility.

The EU funding programme "Horizon Europe" demands openness in its invitations to tender -it is expected more and more that the findings of publicly-funded research are accessible to all.

PyPSA-ZA is an open energy model of the South African power system that can be utilised for both operational studies and generation and transmission expansion planning studies.



https://openmod-initiative.org/manifesto.html https://pypsa-za.readthedocs.io/en/latest/

Temporal Resolution and splitting of horizons

Splitting of horizons

Firstly, was a capacity expansion model run?

Two main methods in determining the modelling foresight:

- **myopic** (i.e. short-sighted, dealing with each time period separately) or
- **intertemporal** (taking into account all time periods simultaneously).

Splitting of horizons could be done for myotic optimisations but would be challenging for intertemporal

In the case of an intertemporal optimization, the energy model is able to pre-build or delay new build as it can “see” the future.

For example, the model may make early investment decisions when the annual build rate of a technology is constrained and major decommissioning of existing assets or a substantial increase in demand is expected in the near term.

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Temporal Resolution and splitting of horizons

Splitting of horizons	Temporal resolution
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Capacity expansion models are designed to minimise unserved energy/load shedding

In capacity expansion models, there are different methods to ensure **system adequacy** (below we focus on unserved energy).

The use of a high **cost of unserved energy** in the mathematical formulation serves as a powerful mechanism to **minimize** unserved energy in the modelling outcomes. A small amount of unserved energy is typically economically optimal.

The IRP uses a high cost of unserved energy which would be sufficient to ensure system adequacy **but only if**:

- The model is **allowed** to build new capacity to meet demand (e.g. lead time constraints or no expansion optimization run)
- And/or new build capacity is completely **unconstrained or non-binding** (i.e. not setting too low annual build limits preventing demand being met)
- The temporal resolution of the model is sufficient to capture the variability in supply and demand (can use capacity reserve margin to ensure adequacy if temporal resolution too coarse)

The failure to meet the criteria above is the reason why Horizon 1 includes unserved energy/load shedding.
Similarly, significant or growing amounts of unserved energy should not be present in Horizon 2 (fig. 20, IRP2023) if new capacity can be built and there are no build limits imposed on the model. **All scenarios should have the same level of system adequacy**

Spatial Resolution and the co-optimisation of generation and transmission

Energy models can optimize the generation mix in isolation or be configured to co-optimize generation and transmission infrastructure.

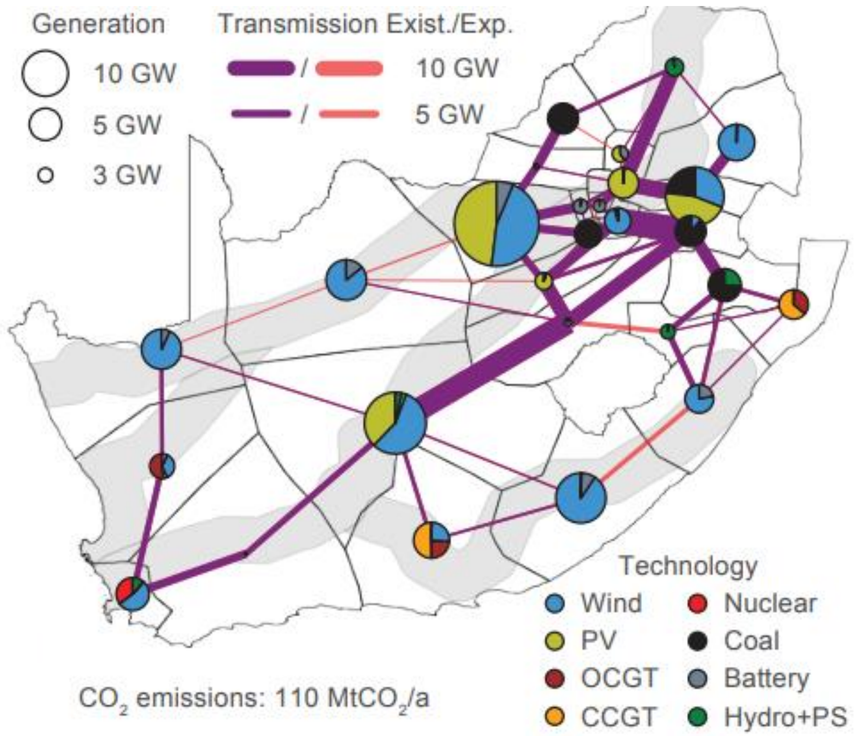
Capacity expansion models are often **simplified** to a lower spatial resolution due to the data and computational burden.

The simplification mixes sites with different renewable features while ignoring transmission lines that can cause congestion.

The IRP 2023 mentions the inclusion of the short to medium-term grid congestion constraints in the Cape. This would suggest that a level spatial disaggregation was considered but it is unclear how this was modelled and results were not shown per region.

Given that the grid constraints may have a material impact on Horizon 1, it is important to give more information on this topic in the next IRP iteration

Example of spatially disaggregated model



https://arxiv.org/pdf/1710.11199.pdf

Constraints are used in energy models to better represent the real world

Common types of constraints included in capacity expansion models:

Capacity constraints: These constraints limit the amount of energy that can be generated or transmitted by individual generation units, transmission lines, or other infrastructure components.

Demand constraints: These constraints represent the energy demand requirements that must be met over the planning horizon.

Reliability constraints: Reliability constraints ensure that the energy system can meet demand with a certain level of reliability, typically expressed as a minimum reserve margin or a maximum loss-of-load probability.

Environmental constraints: These constraints limit the emissions of pollutants such as greenhouse gases

Resource availability constraints: These constraints represent the availability of renewable energy resources (solar and wind)

Technological constraints: These constraints capture the technical characteristics and limitations of different energy generation technologies, such as efficiency, ramp rates, startup times, and operational constraints.

New build constraints: These constraints limit the amount of new build capacity per technology

Due to the large unserved energy in Horizon 1 (and in some scenarios of Horizon 2), the constraints leading to this outcome should be clearly explained and mitigation options explored. This is critical in understanding our options to get out of the electricity crisis

Some amount of curtailment is cost-effective in power systems

Curtailment is a **reduction in the output** of a generator from what it could produce.

All generation technologies experience curtailment, i.e. by not running at maximum available capacity. The concept of **overbuilding capacity** in a power system is not novel.

The goal of a capacity expansion model is not to achieve a zero-curtailment scenario. Instead, it can identify the level of curtailment that results from a **least-cost mix** of resources.

Typically, system-wide curtailment would likely be less than 10% at high renewable energy penetrations as the financial punishment becomes too large. Curtailment can also vary per region if a spatially disaggregated model is built.

It is not clear how curtailment was considered in the IRP.

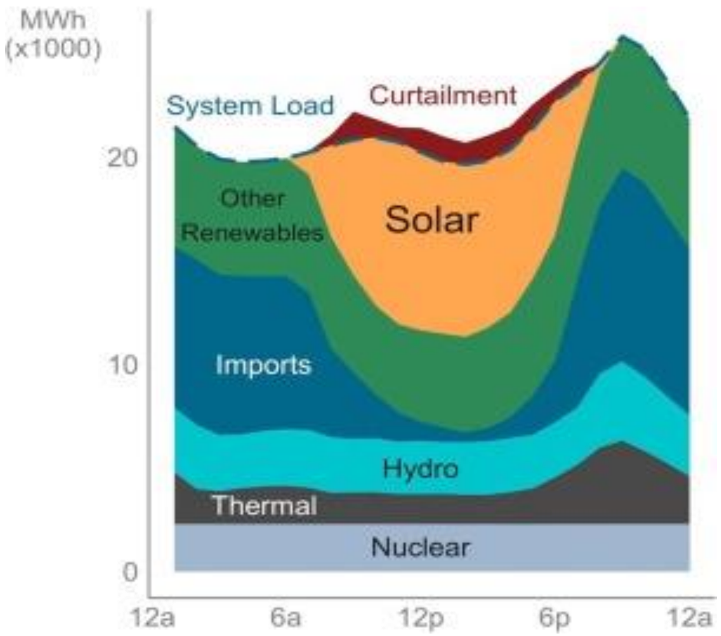


Image source: NREL

The curtailment of wind and solar PV has an inherent penalty cost due to the capital cost being paid upfront. This means that any wind/solar PV curtailment resulting from a capacity expansion model is already costed in the overall system cost.

What typical results should an IRP include?

Energy and capacity

Both **installed capacity** (new build and decommissioned) and **energy production** per technology source. Storages should also be reported in energy terms (i.e. GWh)

100 MW CCGT
producing **175 GWh/a**

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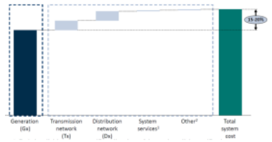
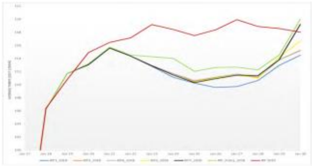
100 MW CCGT
producing **700 GWh/a**

Costs

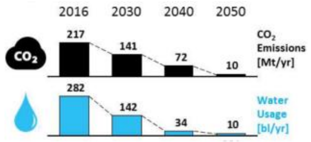
Investment and operating costs
Price paths

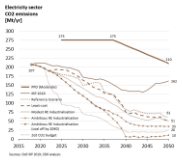




Environmental

Impacts of emission constraints
Greenhouse gas emissions, water demand
Other emissions (SOx, NOx, particulates)





Results discussion

Greatest room for improvement
Why do the results look the way they do? What are the results showing? What conclusions can be drawn? How do the results differ from the previous IRP and why? What uncertainties matter the most and what can we do about them? What kind of implementation plan would this require?

IRP = Integrated Resource Plan; CCGT = Combined cycle gas turbine. Source images: CSIR and DMRE

Important considerations in conducting an IRP

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Configuration of the model

- There are **different types** of energy models to answer different questions
- The way an energy model is configured **influences** the modelling outcomes
- Assumptions which do not speak to the energy model type and configuration are **incomplete**
- Encourage the next IRP iteration to give more context on the model configuration

Modelling constraints

- Constraints are **critical** as they ensure that the energy system best represents reality
- **Any** constraint imposed in the IRP should be **clearly documented** and the reasoning behind the constraint should be justified. Arbitrary constraints are not recommended.
- Uncertain constraints which pose a material impact on results should be dealt with via sensitivity and/or scenario analysis
- Encourage the next IRP iteration to give more context on how **system adequacy** is modelled

Dealing with uncertainty

??

- **Identify** which assumptions have high uncertainty - which one's impact results significantly
- Do sensitivity and/or scenario analysis to **understand** and quantify the impact
- **Dive deeper** into assumptions which are critical – solicit expert opinion, market research etc.

Reporting and interpreting results

- The results should be **complete** in order to give the whole picture (i.e. generation and capacity)
- The value of **clear**, informative graphs cannot be underestimated
- A **comprehensive discussion** on the results is critical to guide decision making and next steps
- Why do the results look the way they do? What are the results showing? What conclusions can be drawn? How do the results differ from the previous IRP and why? What kind of implementation plan would this require?

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Let‘s go together one energy ahead.

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