MAPS

Mitigation Action Plans & Scenarios

ENERGY MODELLING FOR THE ELECTRICITY SUPPLY SECTOR

A summary of the SATIM methodology

TECHNICAL // Electricity

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Purpose

Energy economy environment models such as TIMES are often used to look at opportunities and costs of reducing greenhouse gases (GHG's). The South African TIMES model (SATIM) has been developed for this purpose and its methodology is documented online. This document presents an overview of the SATIM electricity supply sector methodology and may be of interest to researchers grappling with practical ways of integrating solar, wind and other emergent technologies into their models.

The full SATIM methodology is available on the Energy Research Centre website http://www.erc.uct.ac.za/

Introduction

Electricity production in South Africa was estimated to account for 50% of total greenhouse gas emissions in 2000, by far the largest sectoral source (Mwakasonda, 2009). This stems from a reliance on coal-fired power plants and has resulted in South Africa being one of the world's most carbon intensive economies. Unsurprisingly, given the sector's profile, its critical economic importance, and high costs in public funds, the electricity supply system has been modelled more than any other part of the South African energy system. Data is relatively good on the activity, stock and costs of the system and existing and future technological options.

Model structure

The electricity supply sector can be split into generation, transmission, and distribution components. This is reflected in the model as depicted in Figure 1. In SATIM, the generation component is modelled in the most detail. Since the country is modelled as a single node, transmission is modelled as a single technology linking centralised/high voltage electricity (ELCC) to medium voltage levels (ELC). The medium voltage electricity is distributed to each sector using a different technology to capture the different losses incurred in the different sectors. Note that for purposes of simplicity, the supply technologies and sector distribution legs have been shown in aggregate form.

Aggregate losses are modelled for transmission and distribution. The structure and assumptions underlying the transmission, distribution and generation components of SATIM are discussed in the SATIM methodology document.

Parameterisation of existing power plants

The technologies in the demand-side sectors of SATIM are defined by a limited number of parameters such as efficiency, demand share and cost. The supply-side technologies are more complex and many parameters exist in TIMES that can be used to profile them and introduce constraints into the model. Both existing and new power plant technologies are modelled in a similar way and all have the basic parameterisation listed in Table 1.

FIGURE 1:
SIMPLIFIED SCHEMATIC OF SATIM MODEL OF THE SOUTH AFRICAN POWER SECTOR

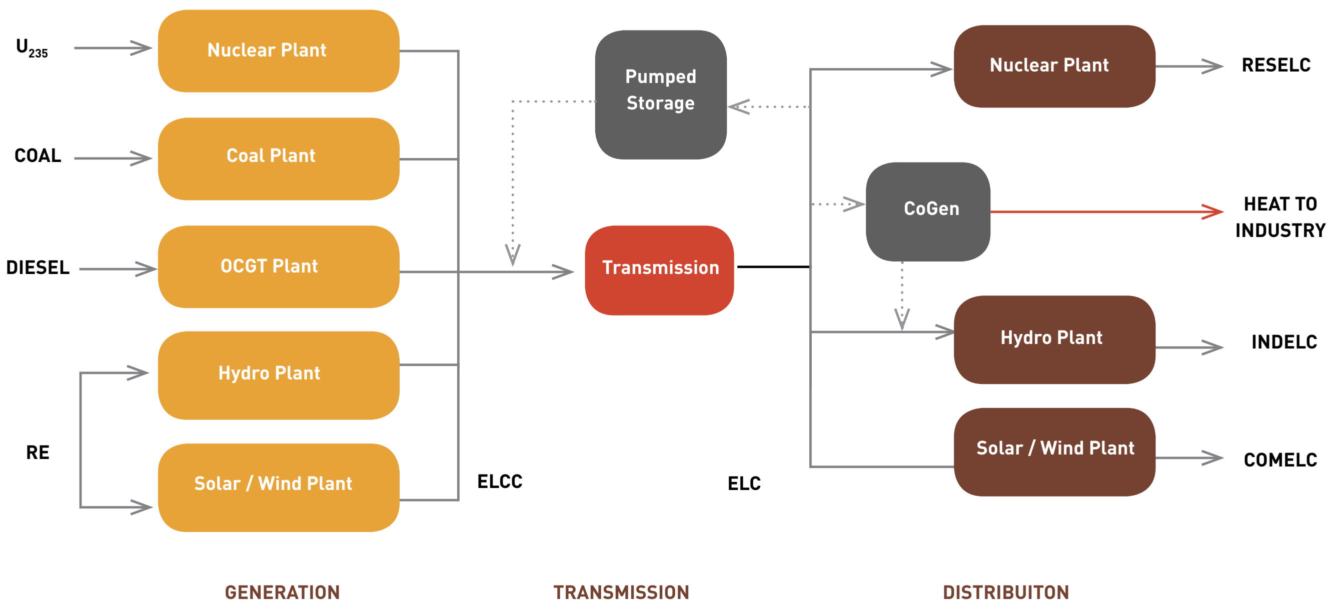

TABLE 1:
SATIM PARAMETERISATION OF POWER PLANT TECHNOLOGIES

PARAMETERS	ADDITIONAL PARAMETERS FOR CHP PLANTS	ADDITIONAL PARAMETERS FOR NEW PLANT TECHNOLOGIES
Energy input commodity or fuel	Industrial process heat	Limits on capacity
Water consumption[1]	Operation in back pressure	Investment cost
Efficiency	Additional input fuel	Technology life
Output commodity	**ADDITIONAL PARAMETERS FOR PUMPED STORAGE PLANTS**	Technology lead-time
Energy availability	Night storage technology	Lower bound on new capacity
Capacity availability	Input commodity – downstream electricity	Lower bound on capacity factor
Capacity credit	Output commodity– upstream electricity	Bounds on wind classes
Fixed operating and maintenance cost		Wind intermittency
Variable operating and maintenance cost		Capacity credit of wind
Refurbishment/retirement profile		Diurnal production of solar with and without storage by timeslice
"Season" & "Daynite" operating categories		

[1] Water is tracked as an emission rather than an input commodity

These parameters are explained in more detail in the main methodology document but a few are outlined below as examples:

Water consumption is tracked in the model as an emission rather than an input commodity. If the latter were implemented, all technologies would have at least two input commodities and the model would apply the plant efficiency to both, complicating implementation. By tracking water consumption as an emission, a consumption rate of litres/MWh can be loaded like an emission factor, a cost can be allocated and constraints placed on consumption without the complications arising from modelling water as an input commodity.

Energy availability relates the total annual output to the installed capacity. The availability is less than 1 to account for maintenance and unplanned down-time. Availability is calculated as follows:

$$[NCAP\_AFA] = (1-POR) \times (1-FOR)$$

Equation 1

Where:

[NCAP_AFA]	=	Availability Factor
POR	=	Planned Outage Rate
FOR	=	Forced Outage Rate.

Capacity Credit gets used in the reserve margin constraint calculation which is similar to the reserve margin calculation. Reserve margin (RM) is the capacity (in %) above peak demand required to compensate for the outage rates discussed above and is conventionally calculated for systems dominated by base load as follows:

$$RM = (\text{Installed Capacity})/(\text{Peak demand}) - 1$$

Equation 2

Where RM = Reserve Margin

The growth in intermittent generation capacity has resulted in a modified form of this equation, the Reserve Constraint, coming into common use.

$$\sum_{1}^{i} \text{to } n(CC_i \times \textit{Installed Capacity}_i) \geq (RM+1) \times \textit{Peak Demand}$$

Equation 3

Where CCi = Capacity Credit of technology i

Capacity credit is set to 1 for dispatchable plants such that for n dispatchable plants the equations above are equivalent. For an intermittent technology like wind however capacity credit will be less than 1 and depend on the local resource, spatial distribution of sites and installed capacity.

Basic structure and assumptions for new/future power plants

As with the transport sector, many technologies are possible candidates for future supply of electricity in the power sector. The level of detail selected here is a trade-off between capturing as many of these possibilities and not wasting effort on very marginal future prospects or on disaggregation that is still not useful because the sector is diversifying slowly and trends are unclear. New power production technologies need to reflect the many emerging renewable and clean coal technologies, and all possible options for import from neighbouring regions. South Africa has, for instance, a rich solar resource and therefore there is reasonable disaggregation of these technologies. Thirteen distinct technologies are loaded in the model, covering central receiver, parabolic trough, concentrated photovoltaic and rooftop photovoltaic, as well as storage options for the first two. SATIM has two wind classes, with capacity factors of 29% and 25%, to reflect the varying quality of sites.

Parameterisation of new technology power plants

TIMES offers a powerful level of parameterisation for new technologies, allowing the modeller to characterise the technical specifications, costs, and future variation in both sets of parameters. The learning rate of renewable technology costs is, for instance, a crucial assumption affecting the cost optimum future technology mix. New technologies have the same parameterisation as discussed above for existing technologies with the addition of the parameters listed under 'new power plant technologies' in Table 1.

A few parameter examples are outlined:

Investment costs for renewable technologies decrease over time to capture the effect of learning from globally installed capacity (note that in SATIM this parameter is set exogenously).

Intermittency of wind is captured by setting the capacity availability equal to the energy availability. For instance, a 100MW wind farm at a 29% capacity factor will be modelled as producing 29MW of output in any time-slice.

Capacity credit of wind is fixed below the capacity factors in SATIM, at a conservative 2.3. A research project has begun to assess this with more certainty.

All parameters are explained in more detail in the main methodology document.

South Africa's LTMS

The Long Term Mitigation Scenarios (LTMS) was a cabinet-mandated process from 2005-2008, led by the then South African Department of Environmental Affairs and Tourism, to establish the evidence base for a national low carbon development path. Key to the process was its unique blend of facilitated stakeholder engagement and rigorous research.

The LTMS arose out of the realisation that South Africa would need to contribute its fair share to greenhouse gas mitigation. Greenhouse gas emissions in South Africa come mainly from energy use and supply. Moving to a low carbon development path would require a major shift in thinking and in action. Hence a blend of process and research was critical when assessing mitigation potential within the country. Having accurate numbers would build confidence, but equally important was that a wide range of key stakeholders within South Africa agreed that the numbers were credible.

The LTMS research was peer-reviewed and found to be of best practice. Reviewers recommended sharing the experience with other developing countries. From this recommendation the MAPS Programme was born. For more information see http://www.erc.uct.ac.za/Research/LTMS/LTMS_project_report.pdf.

Conclusion

The electricity supply sector is a critical consideration in any climate change mitigation study given the cross-sectoral reliance of energy services on electricity and the likely growth of technologies, like electric cars that use electricity. Even countries that posses abundant hydropower face the prospect that when the capacity of this clean power source is reached or its reliability is undermined by climate change, the demands of the energy sector have the potential to cause large increases in emissions. The SATIM methodology for the electricity supply sector has been shaped by concerns around the sector's carbon intensity in South Africa and the large amount of local data available. Researchers active in modelling this sector could benefit from consulting the more detailed methodology documentation.

References

Mwakasonda, S. (2009). Greenhouse Gas Inventory South Africa 1990 to 2000. Pretoria: Department of Environment & Tourism, Republic of South Africa.

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