MAPS

Mitigation Action Plans & Scenarios

WATER & ENERGY

in the LTMS

October 2012

TECHNICAL // Water & Energy

Authors: Alison Hughes, Alfred Moyo, Adrian Stone, Brett Cohen

Purpose

The purpose of this paper is to provide an overview of the relationship between energy and water in South Africa and how these have been included in the Long Term Mitigation Scenarios (LTMS) and other modeling exercises. It aims to provide context, examples and guidance for modellers embarking on similar processes in other countries.

Background

South Africa is a water stressed country, fast approaching water scarcity. The mean annual rainfall in South Africa was 495 mm in 2008, low compared to the world average (UNEP 2010). Currently only about 9% of rainfall is converted to river run-off and projected impacts of climate change indicate that rainfall could reduce in several areas and evaporation from dams may increase as areas in the country become hotter. In several areas in the country, over the coming decade, the demand for water will outstrip yield. For instance, it is projected that water demand on the Vaal River System will outstrip supply by 2013 (Herold, 2009). The Vaal River System currently supplies an area which contributes half of the gross national product (GNP) of South Africa, it has large residential and industrial areas and many coal fired power stations. For these, and other reasons, increasing effort has been put into including water and energy interactions in South African energy models.

Energy and water connect on both the demand and the supply side. On the supply side, thermal power stations use water for cooling, as do coal-to-liquid plants. Electricity generation using hydro and pumped storage make valuable contributions to electricity supply particularly during peak periods. Increased demand for water means increased demand for energy as water is treated, pumped to where it is required and waste water is pumped back to where it is treated. Together the interaction between energy and water on the supply and demand side form the energy water nexus.

1. Water and energy considerations in the South African energy system

Water use in the transformation sector is briefly discussed below, energy required to heat or cool water is included as a demand for energy services in the demand sectors of the model and is not considered further in this brief.

1.1 Power plant cooling

Cooling of coal fired thermal power plants is currently a large user of water in South Africa, using an estimated 1.5% of the country's total annual water consumption (292 million m³) (Eskom, 2010). The majority of power stations are located alongside coal mines in catchment areas which are water scarce, requiring the transport of water between basins for cooling purposes.

A typical wet cooled thermal power plant loses 85% of the water used for cooling through evaporation in cooling towers. To reduce the water used by power plants for cooling, dry cooling technology has been adopted in South Africa. Dry cooling does not rely on evaporation for cooling but uses radiator-like cooling systems. Two examples of dry cooled stations are Matimba, a large coal plant in Mpumalanga, with an installed capacity of 3690 MW, and Kendal, which has an installed capacity of 3840 MW. Matimba uses closed circuit cooling which has lowered water consumption considerably to around 0.1 liters per kWh of electricity sent out, compared to 1.9 to 2.1 liters per kWh used in wet cooled power stations. Kendal uses indirect dry cooling, which has reduced water consumption to 0.08 liters per kWh sent out. Dry cooling does, however, come at a cost, as it lowers the efficiency of power plants by about 2%.

Due to increasing pressure on water resources in the country it is likely that all thermal plants will be dry cooled in future, and the reduced water consumption as well as the reduced efficiency is accounted for in the models.

South Africa is also considering the introduction of flue gas desulphurization technologies on new power plants.
This comes with a significant water consumption penalty as shown in Table 1.

WATER FOR COAL POWER STATIONS

Eskom currently operates 12 coal fired electrical power stations, which receive water from the Integrated Vaal River System. Some of these stations were decommissioned and are now being de-mothballed to increase supply in response to the growing demand for electrical power to fuel the South African economy. There are also plans to develop three new power stations, envisaged to receive water from the Vaal River System. Two are scheduled to receive water from Vaal Dam, and current planning is that the third will be located close to the existing Kendal Power Station and receive water from the Eastern Vaal River Sub-system (a component of the Integrated Vaal River System). A summary of water requirements of existing coal power plants by the Department of Water and Forestry (DWAF) in 2006, shows a total consumption of 312.9 million m³ in 2006 increasing to a projected consumption of 396.3 million m³ in 2020.

These projections do not include any new plants envisaged under the LTMS. Additional plants would have a less significant impact if they are dry cooled, i.e. they would add less than 4 million m³ per annum per new dry-cooled station to the total of about 400 million m³.

TABLE 1:
WATER CONSUMPTION ASSOCIATED WITH FLUE GAS DESULPHURISATION

FGD TECHNOLOGY	SO_2 REMOVAL CAPACITY	Ca/S MOLAR RATIO	TYPICAL WATER CONSUMPTION (l/kWh)
Spray-Dry Scrubber	70 - 90%	1.01 - 1.05	0.14
Sorbent Injection Processes	30 - 60%	2-4	N/A
Dry-CFB Scrubber	93 - 97%	1.2 - 1.5	0.14
Wet Scrubber	90 - 99%	1.1 - 1.6	0.21

Source: Singleton (2010)

South Africa also has one nuclear power plant located on the west coast. The nuclear power plant is cooled with sea water and it is likely that any future nuclear power plants will also be cooled with sea water. For the purposes of modeling, therefore, it is assumed that nuclear plants do not require fresh water for cooling.

1.2 Coal to liquid plants

South Africa has a coal-to-liquid (CTL) plant and a gas-to-liquid plant (GTL) with a combined capacity of 195 000 bbl/day. CTL using Fisher Tropsch was initially adopted due to energy security concerns as South Africa has very limited reserves of oil and gas. The CTL and GTL plants located in Sasolburg and Secunda are strategically important as they are located inland, close to Gauteng the major economic hub. However this also means that they are located in a water stressed area as they are using water from the Integrated Vaal River System. The plants had a combined water usage of 118 million m³ in 2006, and this is projected to rise to 148 million m³ by 2020 and 166 million m³ by 2030. Due to the high coal demand of CTL plants it is economically beneficial to locate them close to coal reserves, and therefore future CTL development is partially constrained by the high water demand.

1.3 Water and renewables

While being the preferred option in terms of greenhouse gas emissions, some renewable technologies are substantially poorer performers in terms of water consumption. In particular, solar technologies that involve wet cooling consume significant volumes of water. Dry cooled solar technologies use considerably less water than wet cooled.

Water consumption associated with solar technologies is of particular concern in South Africa, as in many parts of the world. The best solar resources are often found in areas with low water availability – notably desert areas. As such, when comparing technology options on a water availability basis, it is important to consider the geographical location of the plants relative to water sources.

During the LTMS process, this issue was not considered explicitly for solar technologies, although the issue has arisen elsewhere in the energy debate.

In terms of water implications for other renewable technologies, it is self-evident that hydropower is directly related to water availability, which in turn is determined by drivers including climate change impacts, development and population growth. Reductions in water availability can result in stranded infrastructure if this is not taken into account during planning. Hydropower is more of a regional issue than a local issue, as discussed below, and as such these issues were not considered in detail in the LTMS models – allowance was made for imported hydro power without detailed consideration of its availability.

Wind technologies are not dependent on water availability during the operational phase and hence this was not accounted for in the models.

1.4 Pumped storage

Pumped storage supplies peak demand, making up around 3.6% of existing capacity, with additional capacity being built. As with hydro stations, water is required to produce electricity, however no water loss is accounted for from these plants, it is assumed that water is available to other users after passing through the turbine.

1.5 Regional hydro contributions

Generation of electricity from hydro and pumped storage stations is an important component of supply in South Africa. Hydro capacity in South Africa is small, but electricity is imported from hydro plants in the region, and it is likely that this will increase over time. Currently hydro-electric stations located in South Africa make up 1.5% of existing capacity (670GW), hydro imports from Cahora Bassa, Mozambique add an additional 1450GW.

The countries of the Southern African Development Community (SADC) have a large interconnected grid, and there is opportunity to import electricity generated by hydro-electric plants into South Africa from several SADC countries, notably Zambia, Mozambique and the Democratic Republic of Congo. Whilst hydro provides an attractive greenhouse gas mitigation option, it is often subject to drought, and risks of interruptions in supply may increase in future due to climate change which may reduce precipitation and increase evaporation from dams. For these reasons imports of hydro could be considered as a risk to security of supply and may be subject to constraints.

ABOUT MAPS

MAPS is a collaboration amongst developing countries to establish the evidence base for long-term transition to robust climate compatible economies that align economic development with poverty alleviation. Through its collaboration MAPS aims to establish synergies and share lessons among participating developing countries as well as the wider climate change community.

Central to MAPS is the facilitated interaction between key stakeholders and in-country research teams. The rigour of information generated by research and the support facilitated through the stakeholder engagement, produces results that are credible, legitimate and relevant. These results provide a sound basis for key policy questions.

2. Accounting for water use in modelling

To date, only the use of water for cooling in thermal power plants, and the use of energy for heating water to supply steam and water for bathing, has been directly accounted for in the South African energy system models. Water used in other sectors and the energy required to transport and treat water are hoped to be included in future model developments.

Water use by power stations and liquid fuels production is allocated to the technologies as an output of water per unit of activity of the stations, similar to the way emissions are allocated. By doing this it is possible not only to account for the amount of water used by different technology types in the model, but also to restrict or constrain water use in the model where desired.

3. Modelling of pumped storage and regional hydro

Pumped storage stations are modeled with a pump, turbine and dam. Pumping requires electricity and has electricity as an input commodity, the output of pumping is a dummy commodity which flows to the dam. The output of the dam then flows to the turbine which produces electricity. Efficiency losses are accounted for in the pump, availability is accounted for at the turbine, as are the capital, and operation and maintenance costs.

Electricity used by the pump and produced by the turbine can either include or exclude transmission losses, depending on the commodity chosen as input for the pump and output of the turbine. Where pumped storage stations are located both far from where electricity is generated and from where it will be used, both electricity used by the pumped storage plant and electricity flowing from the pumped storage plant may be subject to transmission losses.

Imported hydro is represented very simply in the LTMS model as a single technology with bounds and costs. Existing hydro is lumped together as a single technology whilst options for future imports of hydro from the region are included explicitly for each option available as the costs and capacities differ. Hydro plants within the model are also represented as a single technology and therefore seasonal limitations of storage capacity and seasonal availability of water are accounted for only through the seasonal availability of the power plant. The representation of hydro plants in South Africa as a single technology is considered to be sufficient as electricity generation from hydro is a small portion of total generation.

It is possible to represent hydro in the model in greater detail to allow for the representation of storage capacity of dams and seasonal and annual rainfall variation within the catchment. For run of river hydro plants where water flow is not regulated, seasonal variation in the flow of rivers can be represented by altering the availability of the hydro power plants in each season.

References

DWAF 2001. Thukela water project feasibility study: Main feasibility report. PB V000-00-9700. Prepared by BKS Incorporated Water Division. November 2001.

Fraser, R 2007. Personal communication. Response to Long Term Mitigation Scenario project. 27 June 2007.

Herold, C E 2009. The Water Crisis in South Africa Paper 14th SANCIAHS symposium.

Rademeyer, J 2007. Personal communication. Vaal River system planning. 3 August 2007.

Singleton, T 2010. The decision to install flue gas desulphurisation on Medupi Power Station: Identification of environmental criteria contributing to the decision making process. MSc Thesis. University of the Witwatersrand. Available online: http://wiredspace.wits.ac.za/handle/10539/8387, accessed February 2011.

UNEP 2010. http://www.unep.org/dewa/Portals/67/pdf/South_Africa.pdf, accessed June 2012.

Van Rooyen, J 2007. Personal communication. Vaal River System planning. 13 July 2007.

MAPS Programme
Tel: +27 21 461 2881
Email: info@mapsprogramme.org
Twitter: MAPSProgramme
www.mapsprogramme.org