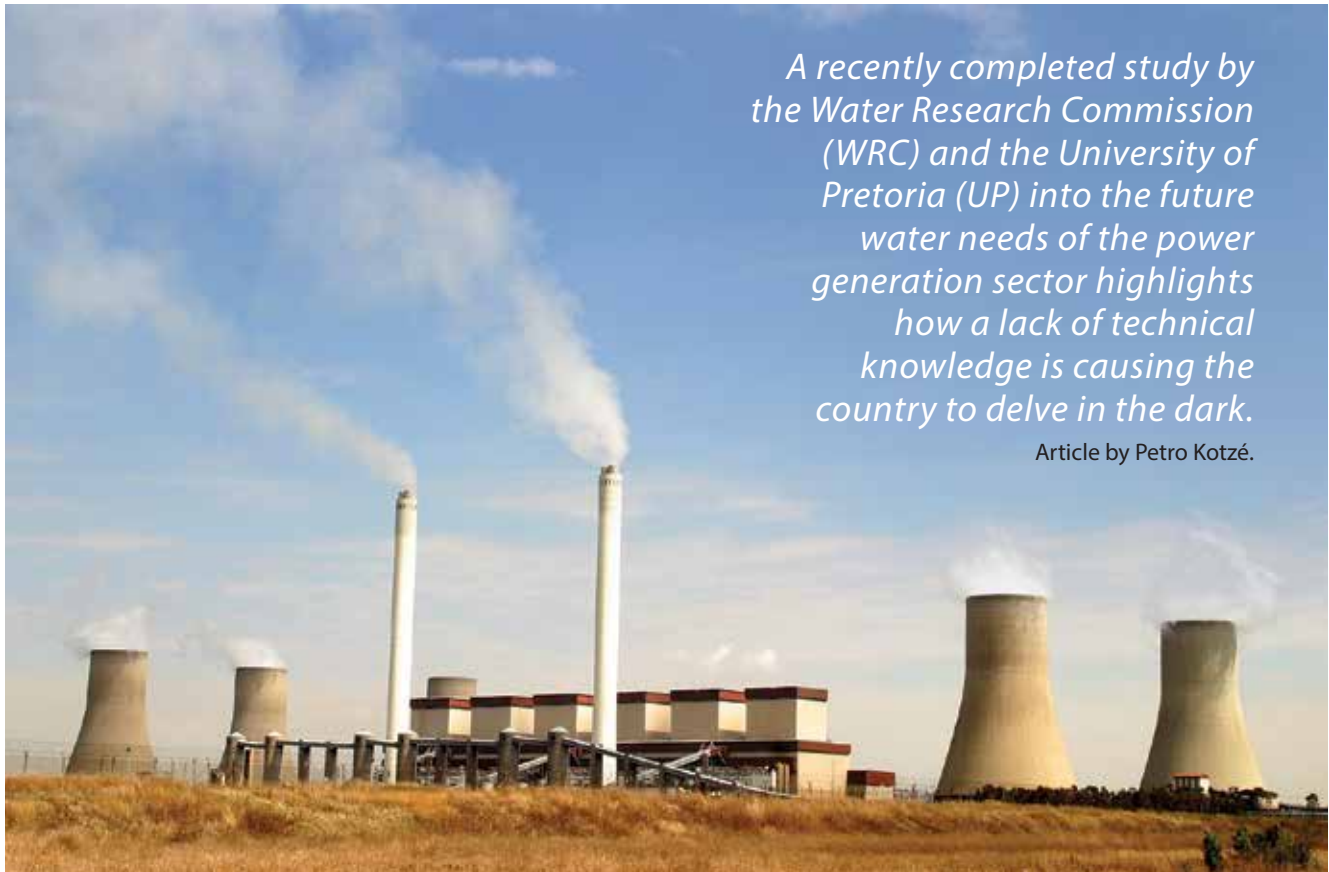


Water and energy

How much water will we need to keep the lights on?



A recently completed study by the Water Research Commission (WRC) and the University of Pretoria (UP) into the future water needs of the power generation sector highlights how a lack of technical knowledge is causing the country to delve in the dark.

Article by Petro Kotzé.

That there are challenges in South Africa to meet the country's electricity demand is no secret. Currently, our main electricity supplier, Eskom, is intermittently applying load-shedding in an effort to balance electricity supply and demand. In a nutshell, load-shedding means that Eskom is rotating and shedding the load in a planned and controlled manner to avoid the collapse of the electricity supply grid, which would have disastrous outcomes. Should this happen it could take up to a month to restore power to the entire country.

Yet, while much attention is given to the availability of electricity, one of the most integral resources necessary to generate it is not being talked about – water.

This is an important conversation to have, especially considering how scarce a resource water naturally is in South Africa.

While South Africa's electricity generation activities only account for 6% to 8% of the country's total freshwater resources used, power generation plants are mostly located within moderately to severely strained water management areas – close to coal reserves rather than water supplies. Seeing as conservative estimates would have it that South Africa is staring a 234 gigalitres shortfall of water in the face by 2025, water will have to be used more efficiently across all sectors in order to preserve the country's water security.

"The field of water supply shortage is a hidden crisis. We already have shortages of water in areas of South Africa, but we have not seen many studies investigating the expected demand for, and supply of water," says Prof Anastassios Pouris, Director of the Institute for Technological Innovation at UP.

Prof Pouris lead the WRC study that aimed to make a long-term forecast of water usage for electricity generation in South Africa until 2030. "It's been forecast that by 2030 water demand nationally and globally will exceed supply," says WRC Research Manager, Dr Jo Burgess, explaining the rationale behind the study. "We need to close the gap before then."

The study team used their findings to propose water saving measures for power generation. In order to do this, they first aimed to forecast water usage patterns associated with coal-based electricity generation as well as water consumption factors. Secondly, they assessed scenarios of water usage patterns based on cooling technology and power plant type, in particular wet-cooled and dry-cooled power plants. Necessary historical data for the project was readily supplied by Eskom.

While the study found that there are ways in which Eskom's water use can be curbed substantially in future, the application of promising technologies are scuppered by a lack of research.

Eskom's power supply setup

As much as 90% of the electricity that Eskom generates is fired by coal. There are 13 coal power plants spread across the country, of which ten are base-load power plants. These operate during normal demand. In order to meet growing energy demands, three power plants that were previously mothballed were brought back to the grid in recent years. Camden, Komati and Grootvlei, the so-called return-to-service (RTS) power plants, are used in conjunction with the base-load power stations during times of peak demand.

Water is used for a number of processes during power generation, such as operating flow gas desulphurisation devices, ash handling, wastewater treatment and wash water. The most water is, however, used for cooling the thermos-electric power plants and this has, together with the choice of fuel technology, by far the biggest impact on the overall water supply needed as well as the ecological health of surface water bodies where it is subtracted from.

Of Eskom's ten base load plants, eight use wet recirculation cooling technologies, which applies cooling water through condenser tubes with steam on the outside. The temperature variations between the water and steam cause condensation. The warm water in the condenser is collected in the cooling tower where an upward draft of air removes the heat. The cooled water is then recirculated to the condenser. A major drawback of this technique is that the water lost through evaporation when the warm cooling water comes in contact directly with air.

Two of the base load plants (Kendal and Majuba) use dry cooling approaches. The dry cooling technology uses air instead of water in the heat exchange mechanism to cool down high temperature steam.

The RTS plants use wet recirculation techniques while Grootvlei also incorporate dry cooling technologies. These plants are water guzzlers, but their impact is exacerbated by their locations in the severely constrained water management areas of the Olifants and the Inkomati. While they satisfy energy requirements they adversely affect water needs.

The yet-to-be-completed Medupi and Kusile power plants will use direct-dry technology, drastically reducing water use.

Yet, all technologies have both advantages and disadvantages. For example, while dry cooling systems are more water-efficient, they are more expensive to build and the plant is less efficient. In the case of Medupi and Kusile however, they will be made more efficient from a system thermal efficiency perspective, because of the use of super-critical boilers.

Study findings

The researchers found that Eskom's total water requirements are expected to increase from roughly 360 gigitalitres on current levels to just above 370 gigitalitres in 2020. Furthermore, the water use consumption of the RTS fleet is the most significant, and is set to increase

Table: Cooling technologies in Eskom coal power stations (current and future)

Category	Name	Cooling technique	Location	Year of completion
Base load	Arnot	Wet recirculating	Mpumalanga	1975
	Duvha	Wet recirculating	Mpumalanga	1984
	Hendrina	Wet recirculating	Mpumalanga	1970
	Kendal	Indirect dry	Mpumalanga	1993
	Kriel	Wet recirculating	Mpumalanga	1979
	Lethabo	Wet recirculating	Limpopo	1991
	Majuba	Wet recirculating and dry	Mpumalanga	2000
	Matimba	Direct dry	Mpumalanga	1991
	Matla	Wet recirculating	Mpumalanga	1983
	Tutuka	Wet recirculating	Mpumalanga	1990
Return-to-service	Camden	Wet recirculating	Mpumalanga	1967
	Grootvlei	Wet recirculating and dry	Mpumalanga	1973
	Komati	Wet recirculating	Mpumalanga	1966
New build	Medupi	Direct dry	Limpopo	On-going
	Kusile	Direct dry	Mpumalanga	On-going

to unsustainable levels by 2020. As such, it is integral that this fleet be decommissioned on a unit by unit basis as soon as Medupi and Kusile can support the national grid, which will make up the power shortfall.

According to the report, "though the RTS fleet has been important in reducing the constraints placed on electricity supply due to increased demand and maintenance, lower performance parameters lead to an increased need of water while supplying electricity during peak hours. The water consumption factor for the RTS fleet is expected to reach 3 ℓ/kwh by the year 2020. It is vital to note that the RTS fleet has to be decommissioned on a unit by unit basis as soon as Medupi and Kusile can support the national grid."

It was found that water requirements could be reduced to 320 gegalitres depending on the retirement of the RTS fleet. This would bring about a reduction of approximately 40 gegalitres of water per annum, which is roughly the amount of water used by one of the larger power stations such as Kriel, Tutuka, Matla or Lethabo. Medupi and Kusile are expected to consume four to five gegalitres thereby creating a net saving of 35 gegalitres, when the RTS fleet is decommissioned.

This saving could account for almost 15% of the forecasted deficit of 234 gegalitres by 2025.

It is hoped that the two new stations will be completed earlier than that, resulting in larger water savings, notes Prof Pouris. It is expected that as the newer coal plants are built and older plants are retired, the new build fleet will be entirely integrated into the base load fleet, thereby relying more on dry cooling technology.

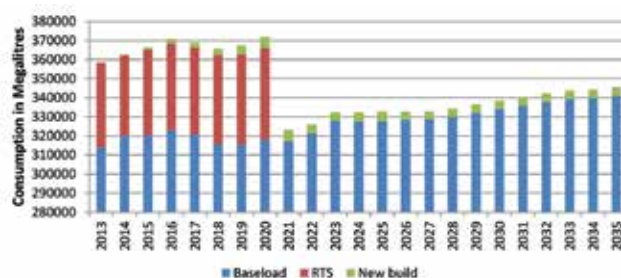
According to Prof Pouris, Should the RTS fleet be decommissioned and Medupi and Kusile brought online, the fleet would have five (four full and one partial) power plants out of 12 using wet cooling. Currently only three (two full and one partial) out of 13 uses dry cooling technologies.

Regards the forecast of total electricity generated, the researchers found that the expected output from the coal power plant fleet could reach 260 TWh by the year 2035. These forecasts are in accordance with the expected installed capacity of 36 900 MW being operated at a capacity factor of 80%.

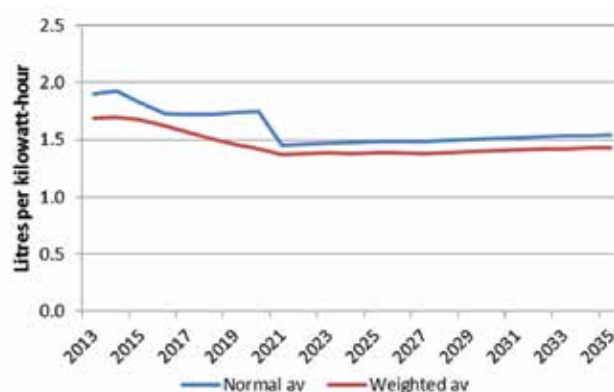
More questions

"With our findings we have created additional questions regards the best technologies to use," notes Prof Pouris. While the decommissioning of the RTS plant looks like the most appropriate solution to Eskom's projected water-shortfall, new technologies could create more opportunities to use current power plants more efficiently. However, due to a lack of actual operational figures it is not possible to conclusively forecast their water usage.

Combined coal power plant water consumption projection



Coal fleet average consumption forecast (weighted vs average)



Combined coal fleet generation forecast. Source: Eskom (2014) data to 2012



Grootvlei is one of the previously mothballed power stations that have been returned to service.

Looking for answers

The WRC is supporting a project to assess and map opportunities for water desalination as well as water-use optimisation of concentrated solar power generation in South Africa. While South Africa has a high resource potential for the use of CSPs, it has limited water resources. An integrated CSP cost efficiency and water usage model will be developed for the three major CSP technologies incorporating air cooling, hybrid cooling and evaporative cooling.

The latter will be used as benchmark and will consider freshwater and saline water options. Results will be used to identify areas most suitable for CSP development from a cost and water usage point of view. This model will then give an accurate indication of the cost per MWh produced on an hourly basis for locations within South Africa with suitable solar resources. Distance from existing and planned transmission infrastructure and from transport infrastructure will be included, to give an indication of infrastructure-related costs for each location.

In considering water availability, fresh water, brackish water, and produced water from other industries will be included. In this way the optimal locations can be chosen for future CSPs so that electricity can be produced by CSPs as cost- and water-efficiently as possible.

"There are a large number of technologies of interest," says Prof Pouris, "but they are stuck at the issue of water, and there needs to be research on this."

He is referring to technologies that are also mentioned in the South African Coal Roadmap, a multi-scenario analysis of the future possibilities and interventions in the local coal industry.

New coal technologies include Underground Coal Gasification (UCG), where deep coal seams are burnt underground, and Fluidised Bed Technology (FBC). While there are some expectations of lower water usage and emissions, there are also risks. These include the risk of contaminating underground water reserves during UCG.

Though it has not been receiving much public attention, Eskom has put out feelers in this direction. Their Majuba UCG pilot plant is a pioneering project in this technology, and FCB technologies are proposed to be viable for the Waterberg coal field which has large reserves of high ash and low-calorific value coal. While, emission reduction mechanisms such as retrofitting existing power plants with Flue Gas Desulphurisation (FGD) are also being investigated, these are again expected to increase the water footprint of power plants.



Matimba power station is one of many power stations in South Africa located in a water scarce area.

Eskom has conducted a number of feasibility studies into the water consumption factors of some of these technologies, but these cannot be used for conclusive forecasting due to a lack of actual operational figures. According to Prof Pouris, the issue of what the other available technologies are is potentially useful, but we also need to ask what their capabilities to limit water consumption are going to be. "The technologies are being investigated, but not their impact on water use. So the issues that are being investigated are not always that relevant."

Other inhibiting factors are money and technology, he notes. "We can develop desalination plants and take water from the sea and pump it wherever we want. The issue is not the water, but the cost."

"The reviewers of the report article asked why we are not talking about the other possibilities to limit water use further," says Prof Pouris. But, he adds, internationally there is a limitation of data.

"So it's not just local research that is lacking, but also the monitoring of international research to see if it will be profitable to go there." While the location of the RTS plants is critical, shutting them down is only a temporary solution, and Prof Pouris is making a call that more research is critical to find the long term solution. Not only that, but research that looks at the long-term needs of the country.

"I think that the most critical finding from this study is for the government to recognise that if they are not going to support research we will be in trouble again, in the same way that we are in trouble with Eskom now." He adds that they hope that this study might be the first step towards realising this. "Our report aims to highlight this issue, not only so that policy makers can understand it, but also so the layman can understand."

"In summary, the need for water use forecasting in the topic of energy-water nexus, is essential in South Africa."

The final report based on this study will be published later this year.