Managing water use in energy production

Case study: Eskom, South Africa
Company overview

Established in South Africa in 1923 as the Electricity Supply Commission, Eskom was converted into a public, limited liability company, wholly owned by the South African government in July 2002. The Company is one of the top 20 utilities in the world by generation capacity, generating approximately 95% of the electricity used in South Africa and around 45% of the electricity used in Africa. Eskom also directly provides electricity to around 45% of all end-users in South Africa with the other 55% being resold by redistributors (including municipalities).

Eskom operates a wide portfolio of power generation technologies which includes thirteen coal-fired power stations, four gas turbine, four hydroelectric (two conventional and two pumped storage) and South Africa’s only nuclear power station (Figure 1). In 2010, total production exceeded 40,870 GW with coal-fired power stations accounting for the largest proportion (34,658 GW; 84%).

The demand for electricity in South Africa continues to grow within a supply-constrained environment. The Mass Electrification Programme, which started in the 1990s, and aims to provide energy services to urban low income households as well as the ongoing rapid industrialisation in the country. This has put enormous strain on energy sources. As such, in 2005 Eskom embarked on a capacity expansion programme which aims to increase its generation capacity by a further 17,120 MW to both meet increasing demand and to diversify Eskom’s energy sources. In the six years ended 31 March 2011, the programme has cost R140 billion (including capitalised interest). The total cost of the programme to completion in 2018 is estimated to be R340 billion (excluding capitalised interest). As part of this programme Eskom has approved and committed to:

- Building two new coal-fired power stations (Medupi and Kusile), two new gas-turbine plants, and a pumped storage plant
- Recommissioning three coal-fired plants that were previously mothballed
- Upgrading other existing plants
- Building new infrastructure, including new transmission lines and two renewable energy plants.

Water use

Water is a scarce resource in South Africa, but it is critical in electricity production. During 2010 Eskom used about 320 million m$^3$ of water which is mainly abstracted from government water schemes (dams) and accounts for around 2% of South Africa’s national freshwater resources.

The majority of Eskom’s coal fired power stations are cooled through a conventional re-circulating system in which cooling takes place via evaporation in an open cooling tower. Typically, the cooling water is led through heat exchanger(s) systems and is cooled by contact with an airstream in a cooling tower where the majority of the heat is discharged to the environment through evaporation. In the cooling tower, the cooled water is collected in a reservoir and pumped back to be re-used as a coolant. However, approximately 85% of the total quantity of water supplied evaporates through the open cooling towers.

As a result of evaporation, windage and drift the cooling water systems have to be supplemented. Evaporation causes a concentration of salts in the cooling water recycle process, which in turn limits the recycle volumes. To overcome this, Eskom practices alkalinity control of the cooling water, using acid neutralisation (at two plants) or cold lime softening by precipitation (at six plants). By controlling and optimising these processes cooling water effluent volumes are minimised.

The Tutuka and Lethabo power stations operate desalination plants to treat contaminated mine water which is produced from the mines that supply coal to these power stations. This process uses microfiltration and reverse osmosis and the treated water. While the capital and operational costs are high the process, delivers permeate water recovery rates of 87% and 80% respectively. The benefit to Eskom is a reduced water intake for the two stations, with a combined potential saving of around 5 million M$^3$ per annum.

In meeting the increased demand for electricity it is expected that Eskom’s water consumption will increase over the next 10 years. As such water use targets in terms of litres of water used per unit of electricity distributed are set for each power station every year. Over the last five years Eskom has increased production by around 18% with the corresponding net water consumption increasing by only 9% (Table 1). During this period specific water consumption has remained relatively stable and in line with Eskom’s target of 1.35 l/kWh distributed. This compares favourably with the average water consumption for power generation in the EU which ranges from 1.4 and 2.0 l/kWh, depending on the process$^1$, and an average consumption around 1.8 l/kWh in the USA$^2$

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<th>2010</th>
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<tr>
<td>Net raw water consumption (Million M$^3$)</td>
<td>291</td>
<td>313</td>
<td>322</td>
<td>323</td>
<td>316</td>
</tr>
<tr>
<td>Specific water consumption by power stations (L/ kWh distributed)</td>
<td>1.32</td>
<td>1.35</td>
<td>1.32</td>
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<td>Total production (MW)</td>
<td>36,401</td>
<td>37,764</td>
<td>38,747</td>
<td>40,506</td>
<td>40,870</td>
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Constraints on water use

Water resources are under considerable pressure in South Africa (Figure 2) with concerns including the growing water scarcity and the conflicting demands for the right to use water, the lack of access to water to meet basic human needs, depleted environmental flows, population and economic growth and the implications of climate change. 2030 projections depict a net deficit of around 2.7 billion m$^3$, increasing to 3.8 billion m$^3$ under plausible climate changes scenarios.

Figure 2 Gap between South Africa’s existing supply and the projected demand in 2030

The water catchment areas in which many of Eskom’s power stations were built are relatively water scarce, necessitating the need for inter-basin transfers. Over the years, various water supply schemes have been constructed to supply the necessary water to the power stations. These schemes consist of dams, pipelines, pumping stations and reservoirs and are inter-linked and operated as a system. Figure 3 highlights the current status of these key water systems.

Eskom currently operates 12 coal fired electrical power stations, which receive water from the Integrated Vaal River System and around 90% of Eskom’s generation capacity is dependent on this system. Some of these stations were decommissioned and have now been reinstated 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 Subsystem (a component of the Integrated Vaal River System). The water requirement scenario that was used in the planning analysis indicated that the total water demand for all the

Source: WRC, DWAF, Statistics South Africa, 2030 Water Resources Group, McKinsey
power stations is expected to increase from 291 million m$^3$ in the year 2006 to 397 million m$^3$ in the year 2030.

**Figure 3 Status of the key water systems in South Africa.**

At present the key risks associated with the provision of water for Eskom are:

- Medium to long water resource security in question due to competing interests, increasing water demands and growing water deficits, illegal water use, water losses, and climate change impacts
- Adequate maintenance and reliability of water supply infrastructure.
- Pollution of water resources will make water unusable or drive up costs of treatment and management of waste
- Climate variability will impact on yield of water resources and infrastructure availability at local, catchment and national level. The higher ambient temperatures will also impact on the efficiency of dry cooled power stations with the predicted higher rainfall impacting on the coal supply chain.

In the future climate change has the potential to impact on availability, quantity and demands for water, thus is a major risk to water and energy security in South Africa. New power station developments will be constrained by the availability of, and accessibility to, the required water resources.

**Water reduction measures**

Eskom has introduced a number of innovative technologies and approaches over the last two decades to save water. These include dry cooling, desalination of polluted mine water for use at the power stations, and technical improvements on treatment regimes to maximize the beneficial use of water. In so doing, Eskom has saved more than two hundred million litres of water every day.

**Dry cooling technology**

Eskom has implemented dry-cooling technology on its power stations wherever feasible. Since it does not rely on evaporative cooling for the functioning of the main systems overall power station
Water use is approximately 15 times lower than a conventional wet-cooled power station. However, this is offset by the fact that dry cooled stations comparatively are less efficient than wet-cooled stations and there is higher capital and operating costs associated with the technology.

Matimba Power Station in the Limpopo Province is the largest direct-dry-cooled station in the world, with an installed capacity greater than 4000 MW. It makes use of closed-circuit cooling technology reducing water consumption to around 0.1 litres per kWh of electricity distributed, compared with about 1.9 litres on average for the wet-cooled stations. The choice of dry-cooled technology for Matimba was largely influenced by the scarcity of water in the area.

Kendal Power Station near Witbank in the Mpumalanga Province, is the largest indirect dry-cooled power station in the world with an installed capacity of greater than 4100 MW. Indirect dry-cooling entails the cooling of the water through indirect contact with air in a cooling tower, a process during which virtually no water is lost in the transfer of the waste heat. Water consumption at the plant is around 0.08 litres per kWh of electricity distributed.

The move to dry cooled technology has resulted in estimated combined savings in excess of 70 million m³ per year. Eskom

**Desalination**

Where power station design permits, Eskom has endorsed a policy of zero liquid effluent discharge (ZLED) at its wet cooled stations in which water is cascaded from good to poor quality uses until all pollutants are finally captured in the ash dams. The effective use of this practice has seen the company introduce the use of desalination plants at Lethabo and Tutuka. These treatment processes allow the company to introduce polluted mine-water from the tied collieries for re-use at the power stations. This assists with the prevention of negative environmental impacts on both the surface and groundwater.

**Water infrastructure**

Over the past 40 years Eskom has worked closely with the South African Department of Water Affairs and Forestry (DWAF) to development of an extensive network of pipelines and dams. These projects, primarily aimed at providing a secure water supply to the power stations and their associated collieries, has had a significant impact on the viability of supplying water to both industries in the area and water for domestic use.

**Water metering and monitoring**

The DWAF measures the water they supply to Eskom’s power stations. A metering procedure has now been adopted which has seen the implementation of ‘revenue’ class meters that measure to a level of accuracy of 0.5%. This is an improvement on the previously accepted 5% level of accuracy.

**Managing energy demand**

Eskom has undertaken a number of electricity demand side management measures to influence the manner in which its customers use electricity to increase the beneficial use of the commodity. Although water conservation has not been the primary motive for these initiatives, water savings have been generated. For every kilowatt-hour of electricity that is saved, on average approximately 1.26 litres of is also saved.

As a result of the implementation of these measures, overall specific water consumption had been reduced significantly since 1980 from 2.85 L/kWh to 1.35 L/kWh in 2011 (Figure 4).
Over the coming years, Eskom aims to further increase efficiency to reduce water consumption. Both coal-fired new-build projects at Medupi and Kusile, will use dry-cooling technology, which will significantly reduce the relative water consumption per unit of electricity produced, by as much as 90% compared to a wet-cooled station.

As part of its long term plan Eskom also intends to apply a number of new innovative water-saving technologies. Its water management strategy sets out how it aims to reduce fresh water intake at power stations and to re-use effluent water. In addition Eskom has engaged with the DWA national water resources planning directorate to ensure that water resources and infrastructure planning needs are factored into the national water resources strategy.

Through these measures, Eskom aims to bring down water consumption per unit of electricity produced from the current 1.35 litres per kWh to 0.99 litres per kWh in 2030, representing a reduction of approximately 26%. Should these measures prove effective, instead of requiring 397 million m$^3$ of water to generate electricity in 2030, it is projected that only 270 million m$^3$ will be required (Figure 5).