Water-energy nexus

Water-smart energy planning in South Africa – World Bank report

Water and energy are often entwined in the sense that the use of one depends on the availability of the other, a concept known as the water-energy nexus. Improving our understanding of this complex interdependence and developing appropriate tools to assist decision-makers with future infrastructure planning are essential for continued sustainable development in the face of the uncertainties posed by climate change. Starting with South Africa, the World Bank has embarked on a global initiative called Thirsty Energy to help countries tackle the challenge of managing the water-energy nexus in an integrated manner. Compiled by Lani van Vuuren.

According to the World Bank, South Africa represents an ideal case study of the challenges that the Thirsty Energy initiative is designed to address. South Africa is a water-stressed country that is also experiencing a crisis of electricity supply. The sustainability of water and energy supplies is uncertain, as is the impact of shortages on social well-being, the national economy, and the environment, particularly in the context of climate change.

In contrast to many other developing countries, South Africa has long had processes for long-term planning related to the supply of energy and water. Planning for one has historically taken into account the cost and scarcity of the other, though to varying degrees. For example, Eskom has a policy known as 'zero liquid-effluent discharge', and has made significant historical investments in dry cooling for coal-fired power plants as well as plans to use dry cooling for all future plants. (This despite the fact that dry-cooled plants are, on average, 10% more capital intensive and 2% less efficient than wet-cooled plants) In addition, the National Water Resource Strategy and other water resources planning studies consider the future water needs of the power sector. This has resulted in the development of an integrated system of large dams and interbasin transfers to ensure a reliable water supply to the energy sector.

Overview of the modelling methodology

The World Bank case study is the first time the cost of water supply has been assessed in a sector-wide energy-supply expansion plan. By documenting the methodology, the authors aim to help energy sector planners and modellers properly incorporate water constraints in their work.

The so-called South Africa TIMES model (SATIM), a public domain energy systems model developed by the University of Cape Town's Energy Research Centre, was selected as the basis for the development of a water-smart energy planning tool as an important first step towards an integrated water-energy planning methodology. SATIM is a national model built using the TIMES modelling platform, a partial-equilibrium linear optimisation framework capable of representing an entire energy system, including its economic costs and emissions.

Given that virtually all water in South Africa is allocated, any future demand for water in the energy sector will require the need for new regional water infrastructure, including inter-regional exchange possibilities, to better understand the impact of water-supply costs on the energy sector. The World Bank model produces a least-cost energy-supply plan through 2050 that minimises the cost of both energy and water supply.

The scenarios selected for analysis reflect main drivers of investment uncertainty in water and energy supply that are of key importance to South Africa. Specifically, the SATIM model has been used to examine several questions facing the country, among others:

- How does accounting for regional variability in water availability and the associated infrastructure costs of water supply in different regions affect future energy planning?
- Is the current policy of dry cooling for new coal-fired power plants economically justified?
- How does a dry affect coal investments in the Waterberg region?
- How does the cost of water affect shale gas production?

Main findings

The report's most important message is that accounting for the regional variability of water supply and the associated costs of water-supply infrastructure can significantly impact energy planning, especially in a water-scarce country such as South Africa. The case study highlights the importance of the spatial component of energy and water resources — particularly in countries where water availability varies widely from region to region—and its potential impacts on the overall cost of different energy technologies.

For example, when taking water-supply infrastructure costs into account, the energy model chooses dry cooling for most coal-fired power plants. Thus, dry cooling makes economic sense in South Africa even if it decreases power plant's efficiency and has higher capital costs. This has huge implications for the energy sector's water needs.

After incorporating the true cost of water supply into the energy model, the power sector's water intensity drops to a quarter of the "no water cost" 2050 level. In contrast, omitting water costs in the energy model results in an increase of water consumption for the power sector by 77% and for the whole energy system by 58% since the model chooses technologies that are more water intense.

Summarising, if water has no cost, the model chooses to use more of it to develop energy resources. Once the costs of water are reflected in the model, technologies that are less water intense and that initially seemed more costly become more competitive. This finding is important because it shows that looking at a system as a whole (including water), results in different energy choices than if we just optimise for energy resource development alone.

The Waterberg region provides a good example of the importance of accounting for water cost in energy planning, and highlights the specific regional challenges of the water-energy nexus. In Waterberg, the energy sector is the largest water user, with power plants accounting for the largest share.

Of water costs were not taken into account in energy-system planning through 2050, water consumption would rise from 45 million m^3 in 2015 to almost 900 million m^3 by 2050, with power plants approaching 80% of the total water consumption in the region. Under the contrary scenario, power plant water consumption drops to less than 100 million m^3 by 2050, and total water consumption in the region is about 250 million m^3.

Other than the water consumed by power plants, the two reference scenarios have similar total system cost, energy-supply expenditures, and primary and final energy consumption results.

Interestingly, the reference scenario with water costs produces slightly more carbon dioxide (CO_2) emissions than the scenario without water costs, despite generating 1.3% less electricity with coal and 2% more with renewable energy technologies (chiefly wind and solar), which require no water to generate electricity. The higher CO_2 emissions stem from the higher unit emissions of dry-cooled power plants.

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What about shale gas?

The World Bank study confirms that, while shale gas appears to be quite attractive for electricity generation, it will require investment in additional water-supply infrastructure for major development as well as careful consideration of broader water-related risks.

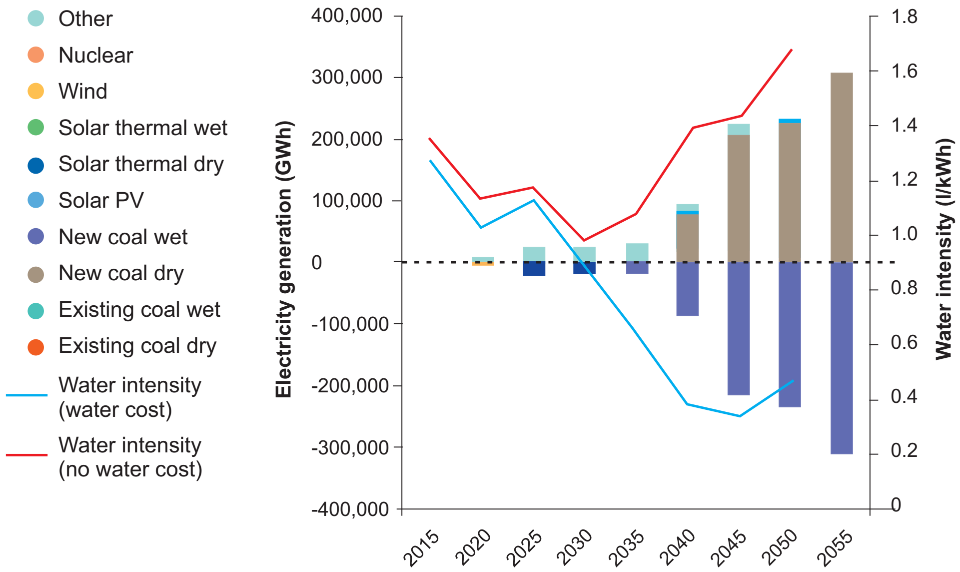

Figure 1 – Difference in electricity generation by type and water intensity for reference (water cost) and reference (no water cost)
Source: Modelling the water-energy nexus: How do water constraints affect energy planning in South Africa?

"the analysis demonstrates the importance of identifying a water-smart energy development plan, in which infrastructure investment levels and water-supply costs are taken fully into consideration."

Using the limited data available, the model suggests that the use of shale gas for power generation will grow at a similar rate once the costs of supplying water are taken into account. In other words, the cost of water does not appear to be the main driver of decisions about whether to invest in shale gas to generate power. However, regional water-supply costs could potentially double in certain regions because of demand from shale gas production, thereby affecting not only the producers but other water users as well through lowering of the groundwater table and increased risks for surface and groundwater pollution.

Under the modelled scenario, an assumed limit on on-site groundwater usage of 1 million m^3/year leads to a reliance on trucked water for the early stages of development of the shale gas sector, resulting in relatively high water-supply cost. However, the construction of a pipeline in 2030 to bring water into the shale production area reduces the cost of supply by about 95%, and this assumed lower cost accelerates shale gas development.

Finally, the study notes that the highly integrated nature of the South African water-supply system creates some resilience to the impact of climate change, but increasing temperatures may affect the efficiency of dry-cooled systems. The final report highlights the fact that trade-offs between the power sector, urban water supply, and water for agriculture need to be explored further, particularly for key systems (e.g. the Vaal and Orange River).

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The findings of the World Bank study exemplify how integrated and regionally disaggregated water-energy modelling and analysis can better inform decision-makers of the potential costs, benefits, and risks of alternative policies and technology choices under a range of possible water and energy conditions. In particular, the analysis demonstrates the importance of identifying a water-smart energy development plan, in which infrastructure investment levels and water-supply costs are taken fully into consideration.

To access the World Bank report, Modelling the water-energy nexus: How do water constraints affect energy planning in South Africa?, Visit: https://openknowledge.worldbank.org/handle/10986/26255