TECHNICAL BRIEF

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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Exploring opportunities for desalination and water-use optimisation of solar power generation

A recently-published Water Research Commission (WRC) project has seen the completion of a strategic assessment and mapping of opportunities for water desalination and water-use optimisation of concentrated solar power generation in South Africa.

Background

South Africa has a high solar resource potential for use in concentrated solar power (CSP) plants and other solar thermal (ST) plants, but it has limited water resources.

Most thermal power plants require steam to be cooled after it has passed through the turbines (steam condensing at back end of turbine increases the pressure differential and thus increases the power output). This can be done using dry-cooling, wet-cooling or a combination of the two technologies (hybrid-cooling). Wet-cooled plants use a large amount of water and thus, especially in water scarce regions, dry-cooling or hybrid-cooling are more desirable options. Wet-cooling technology using brackish or saline water is an alternative to freshwater evaporative cooling. With large amounts of inland brackish and saline groundwater in South Africa, this resource could be utilised more efficiently; seawater may also be used. In either case the post turbine condensing energy can be used to drive desalination processes.

Whatever the cooling regime, a CSP plant still requires water of a reasonable quality for the steam cycle and mirror washing. Depending on the quality of the water resource available, varying degrees of treatment, including desalination, are necessary and this treatment inevitably results in brine that needs to be disposed of.

Rationale

Renewable energy projects, including CSP, are being increasingly developed in South Africa while the country attempts to minimise its reliance on fossil fuel-based power production. CSP plants use a thermal power generation process which requires a steam cycle; the steam is required to be condensed, and this requires cooling.

Wet-cooling, dry-cooling, or hybrid-cooling technologies may be used. While wet-cooling is the most efficient technology, it requires large amounts of water.

CSP offers potential for combined power generation and desalination. Areas that have a high Direct Normal Irradiance (DNI) usually have limited or no water resources and therefore wet-cooled CSP plants may compete for scarce water resources unless alternatives of CSP, including optimally sited dry cooling, CSP saline water cooling and CSP desalination, are investigated.

Thus, the overall aim of this WRC-funded project was to undertake strategic assessment and mapping of opportunities for water desalination and water use optimisation of concentrated solar power generation in South Africa. A set of GIS maps has been produced for the scenarios identified as being of interest.

Methodology

A CSP cost of energy/cost of water model was developed to include a technical and financial component. The model was developed using the NREL SAM model as a backbone.

Ambient weather data and DNI were modelled using WRF. The base case SAM model was initially set up for the wet/evaporative cooling option.

Before running the model for the different scenarios, a verification of the system architecture and WRF forecasting for DNI was undertaken. The model was then scripted to run in batch mode, i.e. receive the ambient weather and DNI data for a grid cell, perform the SAM CSP simulation for the grid cell; write out the relevant parameters of interest, before moving to the next grid cell and repeating the operations.

The DNI input into the model was obtained through WRF modelling and verified against three months of observations of DNI data. The verification revealed over-prediction of the DNI on cloudy days to the extent that the WRF model was not capturing the frequency of cloudy days, resulting in an over-prediction of DNI and consequently power produced. Corrections were made when the WRF model misses clouds, or WRF overestimates clouds.

This process corrected the initial overestimation in the WRF DNI and provided a more reliable spatial distribution of DNI.

The model outputs were then post-processed and interfaced with GIS mapping functions to produce maps reflecting the combined costs of output, i.e. cost of energy and cost of water for the different cooling options, water sources and desalination technologies considered.

The scenarios that were modelled include wet, dry, and hybrid cooling, different cooling water supplies, and different desalination methods.

Key findings

With the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) two-tier tariff regime for Round 4 CSP projects, all of the scenarios considered offer reasonable returns on investment. It would be economically feasible to operate CSP plants in South Africa under the two-tier tariff for all the scenarios that were modelled. Storage allows the plant to be optimised for part load operation which could see better Internal Rates of Return (IRRs) achieved than those predicted in the non-optimised scenarios.

Hybrid wet/dry cooling employing between 0 and 30% fresh water cooling during different hours of the day is the most attractive option in terms of IRR. Wet cooling using brackish or saline water with saline cooling towers is also attractive, with slight penalties for the additional cost of the cooling towers as well as brine disposal. These are nevertheless viable options as there is a significant amount of freshwater demand that is avoided and the IRR achieved is competitive with that of an air cooled plant.

Desalination costs are greatly decreased by co-locating the desalination plant at a CSP facility in order to exploit the CSP infrastructure. Reverse Osmosis (RO) plants appear to have a marginally better return than Multi-Effect Distillation (MED) plants, but MED is still very competitive.

With increasing electricity prices and potential insecurity of supply, RO-based water production could face some challenges in future. The other important benefit of CSP coupled to MED or RO plants is derived from the amount of freshwater use avoided in the cooling as well as being produced as a saleable product.

In terms of IRR, MED and RO plants coupled to a CSP plant can compete with air-cooled CSP plants. However, in terms of the cumulative effects of power produced, Freshwater Demand Avoided and IRR, the scenarios involving the MED and RO plants are the most attractive.

All the scenarios modelled included costs for brine disposal to an evaporation pond. For the MED and RO scenarios the cost of the brine disposal is shown to have a significant effect on the financial viability of the plant as is the well-field establishment and operation cost, however the results indicate that projects are still economically competitive under all the scenarios using an evaporation landfill as method of brine handling.

Further reading:

To obtain the report, *Strategic assessment and mapping of opportunities for water desalination and water-use optimisation of concentrated solar power generation in South Africa* (**Report No. 2382/1/16**), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.