Looking beyond the boundaries: An approach for Water Neutral Electricity Production

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Indian Power sector is dominated by coal based thermal power plants, constituting58% of total installed capacity of 331Gigawatt (GW), as on 31stOctober 2017. In India, production of coal has increased by 7.5 times and production of electricity has increased by 13 times since 1970-71. Furthermore, NitiAayog projects that the total installed capacity for electricity generation in the country will range from 300-700 GW by 2047 under different policy initiative scenarios. Considering the practicality of implementation, even with best of efforts to diversify the fuel and technology mix in the power generation sector, India would continue to rely heavily on coal based electricity generation, accounting for atleast 50-60% of the total capacity.

Country is witnessing 6-8% growth in electricity consumption per decade since 1980. This is accompanied with approximately 24% transmission and distribution losses of electricity produced in the country, ranking India among the countries with highest Transmission & Distribution (T&D) losses. This also implies that 24% of water (equivalent to 4 million m^3 water per day) consumed by power plants, also gets wasted due to T&D losses of electricity. In the purview of water stress scenarios of the country, this is a significant loss.

Ministry of Environment, Forests and Climate Change has stipulated rules for water consumption by thermal power plants, and has asked them to reduce their maximum specific water consumption to 3.5 m^3/hr per MW by 2017. Once implemented, it has a potential to save water equivalent to per capita water requirement of about 8% population of the country. However, implementation of these norms will lead to trade off with reference to electricity production and improvement in operational efficiency by thermal power plants. For example, improvement in plant load factor to enhance production capacity will negatively influence the water consumption requirements of the plants.

Therefore, these measures are not sufficient to ensure sustainability of water resources in the region. There are many other competing users for water in the surrounding areas of the power plants. With the growing population, increasing urbanization, demand for water will increase manifold, which would create more inter-sectoral competition for water. As per the National Water Policy 2012, the priority for water supply is for domestic purpose and industries are less prioritized compared to domestic sector. With the burgeoning water stress, and considering priorities of the National Water Policy, industries will be the worst hit in the coming years. Hence the need of the hour is that the industries including power plants look beyond their boundaries and adopt a holistic view leading to the sustainable management of water resources in the region of their operation.

Water scarcity has the potential to impact the financial viability of thermal power plants by affecting the project's rate of return. This could be due to delays in project execution leading to cost escalation and revenue losses, as well as due to affects during operating life of the project. During operations, any drop in plant load factor may reduce the revenues. It has been assessed that each 5% drop in plant load factor results in drop of nearly 0.75% in the projects rate of return[1]. Also, additional expenses may be required for digging ponds/ drawing canals or pipelines, for extracting water from alternate/ backup sources.Moreover, compliance with the environmental regulations related to maintenance of discharge water quality or quantity of water extracted from the source, have cost burden on the plant operations. Also, quality of intake water affects the operational expenses related to production of Demineralized (DM) water. For example, presence of colloidal silica in intake water could increase the cost of DM water production, exorbitantly.

Thus, it is important to adopt a more comprehensive approach for managing the water resources and ensure sustainable water availability for the power plant operations. With this perspective, TERI in collaboration with NTPC Energy Research Alliance (NETRA) and Shakti Sustainable Energy Foundation conducted a study to assess the feasibility of 'Water Neutral Electricity Production' in India. This paper through a case study discusses how the power plants can adopt watershed approach to reduce the larger water footprint of the power plants. The selected power plant was studied using hydrological modelling and water demand modelling to identify the stress in the region surrounding it, and how that could be managed through adopting various strategies.

WATER NEUTRALITY

As Specific Water Consumption (SWC) is a measure of the water consumed by power plants per unit of electricity produced, it indicates only the direct water footprints of electricity production. While it is a necessity to use water for production of electricity through thermal processes, it's not possible to reduce their SWC beyond a certain limit, currently stipulated as $3.5m^3$/ hr /MW. This means that under future growth scenarios, power plants would still be consuming more than 1 million m^3 water every hour, which is a significant amount considering future water scarcity scenarios.

Water neutrality is an approach to offset this irreducible water use. The approach has potential to make an activity 'water neutral' by promoting water saving technology, water conservation or environmental protection measures, wastewater treatment and water supply to the poor that do not have proper water supply'. It has two aspects attached to it. First and foremost is to reduce the water footprint of the operations, product, etc. Second is to offset the water the residual water footprint.

This approach or concept can be applied at variety of contexts, and with the growing water crisis it becomes imperative for all water intensive users like power plants to offset their water consumption by giving back to the system through different modes. 'Water neutral' generally does not mean that water use is brought down to zero, but that the negative economic, social and environmental externalities are reduced as much as possible and that the remaining impacts are fully compensated.

In case of thermal power plants, efforts to reduce the specific water consumption to the prescribed standard help to achieve (partially) only the first aspect of the concept of water neutrality. The second aspect of off-setting the water usage requires power plants to look beyond their boundaries and implement/undertake the potential strategies to reduce water stress in the watershed from where water is sourced. These strategies should be able to conserve water, enhance the water availability of the area and return back the equivalent amount of residual water to the system.

WATER NEUTRALITY OF POWER PLANTS: A CASE STUDY

For the purpose of assessing the feasibility of 'Water Neutral Electricity Production' in India, Tanda Thermal Power Plant located in Tanda development block of Ambedkar Nagar district in Uttar Pradesh was selected. It is a coal based power plant being operated by NTPC. The capacity of Tanda power plant is 440 MW and its specific water consumption is around 5.05 m^3/ MWh.

Approach and Methodology

For theoretical verification of the hypothesis i.e., Water Neutral Electricity Production in India, the overall approach comprised of 4 main steps which were:

- Hydrological modelling of the watershed
- Water demand modelling of various demand sectors
- Assessment of water stress – natural, due to power plant and on power plant
- Identification of strategies to reduce the water stress

The methodological framework is represented below:

Figure 1: Methodological framework for the study

Identification of stress with respect to power plant and recommendations to reduce the stress and water footprint of the power plant depends on the assessment and results of hydrological and demand modelling exercise. Watershed based assessment for the availability and demand of water was conducted. SWAT based hydrological modelling conducted for the watershed provided important information about the spatial and temporal variability in water availability. Further, developing an understanding about the water dynamics within the watershed can help in reducing the competitive stress with other users in the watershed. Quantification of water demand from various competitive sectoral users in the area was conducted, by conducting a comprehensive survey among various users. Subsequently, water demand modelling was conducted which together with results from water availability modelling helped in assessing the water-stress for the region.

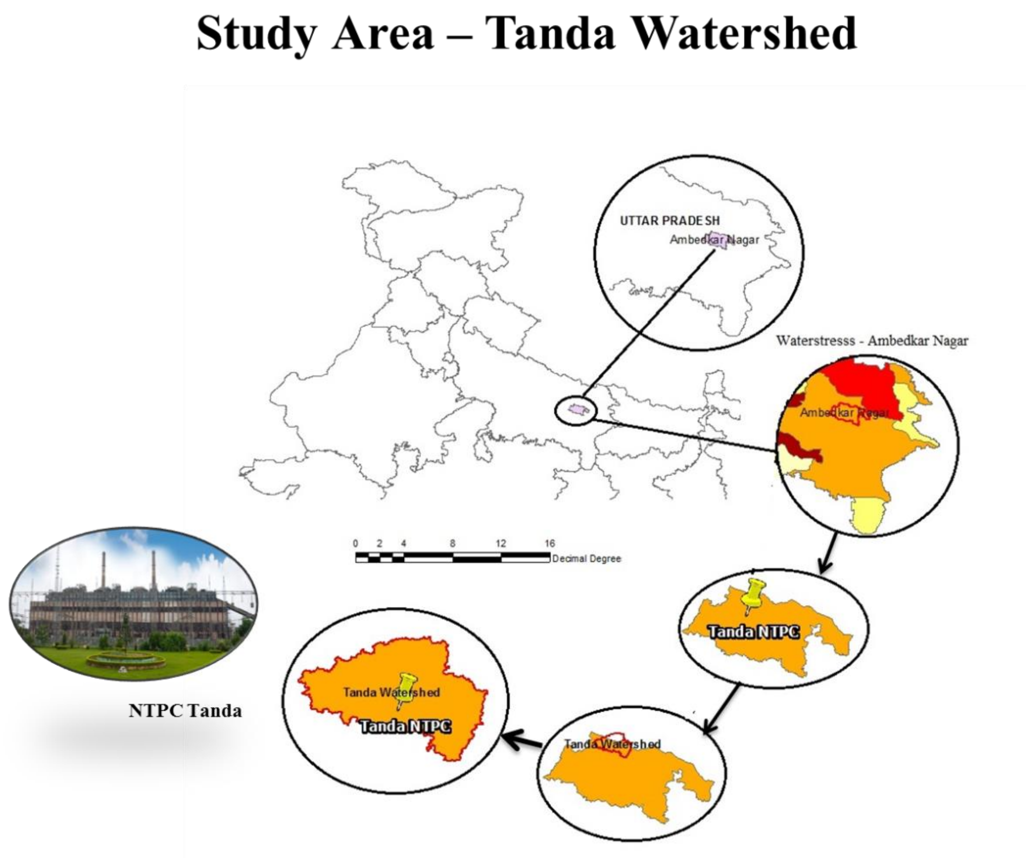

Figure 2: Tanda Thermal power plant and the area surrounding it, as delineated using Geographical Information System (GIS)

RESULTS AND DISCUSSIONS

Both surface and ground water resources that can be potentially utilized form the total utilizable water resources potential of the area. Water yield for the watershed as produced from water availability modelling through SWAT was used to estimate the water balance of the area. The total water available in the waterhsed is the sum of total utilizable water resources and the net transfers into the basin. It has been estimated that Potentially Utilizable Surface water resources in Tanda watershed are 238 million m^3 and Potentially Utilizable Groundwater water resources are about 19 million m^3. It is estimated that Tanda watershed receives about 98,000 million m^3 water annually, through water flows in river Ghaghra.

Total water demand from different users in the Tanda watershed is around 2760 million m^3. Total consumptive water requirement for the watershed has been estimated to be about 70% of its total water demand i.e., 1940 million m^3, which is significantly higher than its potentially utilizable water resources. Thus, the watershed is heavily dependent on the inflow of water from upstream parts of the basin, to meet its water requirements. Sectorally, agriculture is the biggest consumer of water in the watershed, followed by industries and domestic sector. But industrial water demand is almost 1.5 times the domestic water demand for the watershed, indicating intense competition between the two sectors.

Seasonal variation in water demand

Similar to very high seasonal variability in water availability in the watershed, agricultural water demand varies significantly between kharif and rabi season. But considering the uniformity of water demand from domestic and industrial sectors, seasonal stress within the watershed is more intense as compared to water stress on an annual scale. During the 9 months of non-monsoon period, water yield from the watershed is only 25% of its annual availability i.e., 50 million m^3 while the domestic and industrial demand itself is 20 million m3.

As such water balance for the watershed is extremely stressed at both the annual and seasonal scales, and the watershed is highly dependent on the inflow of water in river. Seasonal fluctuation of water in the river has very high potential to affect the delicate balance among the different users within the watershed. This is also noted through ground survey in the watershed, which indicates that inspite of existing extensive canal system, people are more dependent on groundwater extraction to fulfil their water requirement, as canals remain dry for most part of the year.

Thermal power plant and water stress in Tanda

Analysis of the modelling results of both hydrological and demand model indicate that agriculture sector is the biggest water consumer in the region. Water availability depends on the season. During summers water availability in the watershed is comparatively lower than monsoon and post monsoon periods.

Tanda thermal power plant is 440 MW plant which has been taken over by NTPC from Uttar Pradesh government. Considering an average load factor of 70%, power plant is producing 308 MWh of electricity. We estimated that with an average specific water consumption of 5.05 m^3/ MWh, Tanda power plant is consuming about 14 million m^3 of water annually or approximately 1.12 million m^3 monthly. As such, water demand by the power plant is much lower than agricultural water demand, but it is more than domestic water demand in the watershed. Agricultural water demand is almost 20 times higher than the water demand of Tanda power plant. While water demand of Tanda power plant is atleast 25% higher than the water demanded by the domestic sector in the watershed.

Compliance with the MoEF&CC directives has the potential to reduce the water consumption of the Tanda power plant by 30%, however, it will still be consuming about 11 million m^3 of water annually. Considering the encroachment of agricultural land for construction and residential activities, it is not projected that additional agricultural land can be brought into crop cultivation. As a result, water consumption for agriculture is projected to decrease slightly. However, water consumption for domestic and industrial activities will increase and it is projected that domestic water demand for Tanda watershed will be 12-14 million m^3 indicating an increase of 40% over the next decade. Domestic sector being the priority sector for water supply, increase in domestic water demand will further intensify the existing stress in the watershed.

Hence, reducing its specific water consumption to the levels as prescribed by MoEF&CC will be helpful only in complying with the regulatory norms, and will not provide any long term benefits in ensuring the sustainable water availability to power plant.

WATER NEUTRALITY: A TRIPLET APPROACH

Reducing water footprints of thermal power plants and achieving water neutrality of their operations has a significant potential to reduce water related stress among different sectors within a watershed. Also, it ensures a harmonizing relationship among different water users while maintaining an appropriate hydrological balance within the watershed. The approach to reduce the water footprint of power plant comprise of two aspects: One is to reduce water footprint using *in-situ* measures and other is to adopt *ex-situ* measures. *In-situ* measures mainly comprise of modification in technology and processes of thermal power plants. There has been a progressive development in the technologies used for power production across the world, which help to reduce the water consumption of power plant. These technologies to some extent have been introduced in India but there are many that needs to be implemented.

The other aspect of the approach is to look beyond the boundaries. It comprises of adopting measures to offset the impact of water footprint of thermal power plants indirectly. It includes measure like adopting water conservation strategies and managing water demand in the surrounding watershed. In other words, it means giving back to the system. By adopting the techno-process modifications plants can reach the minimum level of water requirement, but still would be one of the most water intensive entities. Therefore to reduce the water footprint impact further, power plants have to take a lead and look beyond their boundaries. By implementing water conservation and water demand management strategies, power plants can return significant amount of water back to the system and community. This would not only offset their water footprint but will help to maintain a cordial relationship with the community. As per the requirement and local conditions, plants can adopt various available technologies and interventions to reduce the impact of their huge water footprint.

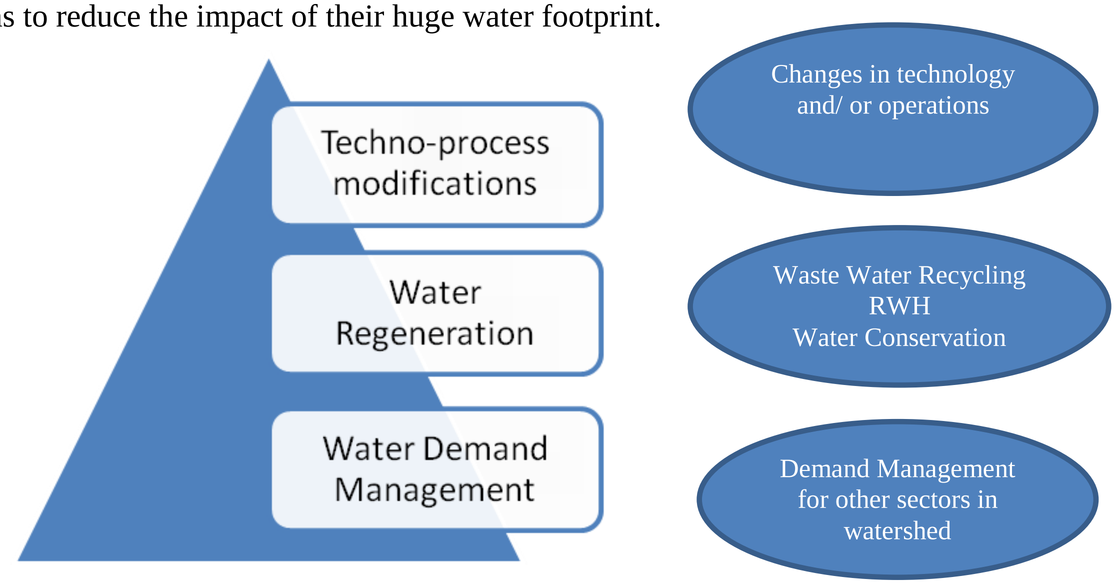

Figure 3: Triplet approach for water neutral electricity production

INTEGRATED WATERSHED MANAGEMENT: AN APPROACH TO WATER NEUTRALITY

Water availability in a water body is the function of characteristics of the watershed surrounding it. Hence, it is necessary to manage the watershed surrounding the source of water, to ensure the continuity of water availability for power plant operations. Integrated watershed management refers to the management of human activities and natural resources across the hydrological boundary surrounding the water source. It considers the watershed wide water availability and its demand from various sectors holistically, and refers to the measures like water demand management in the watershed, rainwater harvesting, artificial groundwater recharge etc. This approach also leads to improvement in water quality, while ensuring water availability for future demand scenarios, from both power plant as well as other competing users in the region. Moreover, Integrated Watershed Management approach has the potential to make the electricity production (near) water neutral, while also striking goodwill with the local communities and adding to the fulfillment of corporate social responsibility. Thus, power plants need to adopt a wider approach and push themselves beyond their own boundaries, taking care of the local watershed to ensure not only their own sustainable operations but overall ecological balance of the system and other competing users.

To make them water neutral, the study assessed potential of returning equivalent amount of water to the nature, through two modes: (1) Water conservation measures like rainwater harvesting and aquifer recharge and (2) reduction in water demand of agricultural and domestic consumers by improving water use efficiency.

The study revealed that bringing about 1000 hectare of agricultural land under 3 most water intensive crops (rice, wheat, cotton/ sugarcane) under micro-irrigation system (MIS) can reduce water footprints of a typical 500 MW thermal power plant to near neutrality. This will require an investment of about 10 crore rupees at the current commercial price of micro-irrigation systems. Further, a similar investment on improving water use efficiency in the domestic sector can reduce the water footprints by as much as 50% of the total water consumed by power plant. Considering the cost of installation of power plants (~2500 cr/ 500 MW), environmental cost associated with huge water extraction and the long term potential benefits in water balance of the watershed, incurring this cost will be an economically wise investment. Moreover, reorientation of CSR strategies towards integrated watershed management could result in mutual benefits across different stakeholders.

Additionally, investing in interventions such as construction of rainwater harvesting structures, farm ponds, etc. can bring in additional water into the watershed. Undertaking a suitable mix of such interventions, power plants can offset the impact of their water footprint and can gradually achieve the goal of water neutral electricity generation. This ultimately will help to reduce the overall water stress in the country and would set an example for many other water intensive industries.

WAY FORWARD

While future holds uncertainty, it's certain that with the growing population and increasing industrialization water demand will increase. Thus it is important to understand the water availability and demand dynamics for future. This exercise is extremely helpful for power plants to understand how water dynamics would change in their respective watershed and if they are already in a water stressed watershed then how the situation can be improved.

With limited water saving potential by increasing Cycle of Concentration, practical, technical and financial difficulties in transformation from wet cooling to dry cooling, and wet ash disposal to dry ash disposal systems, options for reducing specific water consumption of thermal power plants are extremely limited. Hence, a wider strategy focusing on reducing water footprints of thermal power plants shall be adopted to reduce vulnerability to future water scarcity scenarios.