Water for electricity in India: A multi-model study of future challenges and linkages to climate change mitigation

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ABSTRACT

This paper provides projections of water withdrawals and consumption for electricity generation in India through 2050. Based on the results from five energy-economic modeling teams, the paper explores the implications of economic growth, power plant cooling policies, and electricity CO₂ emissions reductions on water withdrawals and consumption. To understand how different modeling approaches derive different results for energy-water interactions, the five teams used harmonized assumptions regarding economic and population growth, the distribution of power plants by cooling technologies, and withdrawals and consumption intensities. The multi-model study provides robust results regarding the different but potentially complementary implications of cooling technology policies and efforts to reduce CO₂ emissions. The water implications of CO₂ emissions reductions depend critically on the approach to these reductions. Focusing on wind and solar power reduces consumption and withdrawals, a focus on nuclear power increases both, and a focus on hydroelectric power could increase consumptive losses through evaporation. Policies focused specifically on cooling water can have substantial and complementary impacts.

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1. Introduction

India is one of the most water-stressed nations in the world. Fifty-four percent of India’s total area faces high or extremely high water stress [1], and the country is close to being categorized as “water scarce” nation [2]. According to a World Resources Institute study, India’s baseline water stress scored 3.6 out of 5.0 in 2010, which indicates a high ratio of total annual water withdrawals to total annual available renewable supply [3]. The country relies heavily on groundwater, and 54% of India’s groundwater wells face falling water tables [1]. India is one of the countries with the world’s highest rates of groundwater depletion [4].

Continued economic development will lead to increasing demands for water—for agriculture, electricity, industry, and households—putting pressure on local and national planners to develop long-term and forward-looking solutions. Climate change could substantially alter the timing, quantity, and location of runoff, including changes to monsoon patterns. Climate change mitigation will also alter the demands for water through, for
example, changes in the electricity mix or the production of bioenergy.

India is the fifth largest electricity producer in the world, but nearly 288 million Indians still have no access to the electricity grid [5,6]. The Indian government aims to substantially increase energy access for millions of Indians and increase the use of electricity by those who already have access. The Indian government has started the Power for All campaign to achieve electrification of all villages in India by the end of 2019. Projections from the International Energy Agency (IEA) indicate that India could add about 600 million new electricity consumers by 2040. That electricity demand might grow by 5% per year [7].

Expanding electricity production could exacerbate potential water scarcity. Given limits to water availability, satisfying agricultural and other needs could result in the curtailment of electric power plants and associated blackouts or brownouts. Conversely, increasing water demands for electricity could have repercussions for agriculture and households. Several regions in India are increasingly relying on pumped ground water to meet municipal and agricultural needs, as is seen in some water-scarce countries where conventional water resources are inadequate to meet demands [8,9]. A failure to plan adequately for the long term could lock in approaches to water management, agriculture, and electricity that could prove limiting for decades to come.

India declared a voluntary goal of reducing the emissions intensity of its GDP by 30–35% over 2005 levels by 2030 [10]. The power sector contributes 51% of CO₂ emissions in India [11]. Policies to “decarbonize” electricity generation could help constrain future water demands, but the effect will depend on the approach to decarbonization. On April 22, 2016, India, along with 174 member countries of the United Nations, signed the Paris Agreement to reduce greenhouse gas emissions across the globe. India ratified the Paris Agreement on October 2, and the agreement entered into force on November 4, 2016. Reducing CO₂ emissions from electricity generation is critical for achieving a reduction in emission intensity. As part of that agreement, all countries will need to make major changes in the way that they produce electricity, moving from freely emitting coal and gas generation to increased use of some combination of renewable power (such as wind, solar, and hydroelectric power), nuclear power, and coal or natural gas with carbon dioxide capture and storage (CCS). These different options will have very different implications for electricity water demands. Solar photo-voltaic (PV) and wind power for example, require no carbon dioxide capture and storage (CCS). These different options provide a means to identify areas of agreement and robust understanding as well as areas in which substantial uncertainty remains. The unique contribution of this study is that this is the first time that four Indian modeling teams and one US-based team have come together for an India-specific assessment. This assessment and the results will provide policy makers and other stakeholders with a more robust assessment of India’s future needs for water for thermal power plants.

This study analyzes water withdrawals and water consumption by India’s electricity-generating power plants. Following the same definitions given in the literature [49,50], “water withdrawal” is “water removed from the ground or diverted from a surface-water source,” and “water consumption” is “the portion of withdrawn water not returned to the immediate water environment.”

The remainder of this paper proceeds as follows. Section 2 provides a brief overview of water use for electricity in India today. Section 3 explains the methods used in the paper, including the models, the scenarios, and the common assumptions. Results are provided in Section 4, and Section 5 provides final thoughts.

2. Electricity water use in India today

The estimates of water use in India’s statistics are not based on measurements of actual use but on specific assumptions for each sector [51], and there is no comprehensive database to gauge reliance of the power sector on fresh water resources. The Center for Study of Science, Technology and Policy (CSTEP) estimated that in 2010, the majority of the plants (about 84% of coal-based thermal power plants by count) in India used fresh water resources. Plant-level data from the Central Electricity Authority database for existing plants was cross-referenced with data collected on water sources. These included 48% authenticated data points [52], 36% non-authenticated sources (newspaper articles, industry
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