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The Demand For Storage Technologies In Energy Transition Pathways Towards 100% Renewable Energy For India

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Abstract

The initiatives taken by India to tap its renewable energy (RE) potential have been extraordinary in recent years. However, large scale deployment of renewables requires various storage solutions to balance intermittency. In this work, a 100% RE transition pathway based on an hourly resolved model till 2050 is simulated for India, covering demand by the power, desalination and non-energetic industrial gas sectors. Energy storage technologies used in the model that provide flexibility to the system and balance the demand are batteries, pumped hydro storage (PHS), adiabatic compressed air energy storage (A-CAES), thermal energy storage (TES) and power-to-gas technology. The optimization for each time period (transition is modeled in 5-year steps) is carried out on assumed costs and technological status of all energy technologies involved. The model optimizes the least cost mix of RE power plants and storage technologies installed to achieve a fully RE based power system by 2050 considering the base year's (2015) installed power plant capacities, their lifetimes and total electricity demand. Results indicate that a 100% renewable energy based energy system is achievable in 2050 with the levelised cost of electricity falling from a current level of 58 €/MWh_e to 52 €/MWh_e in 2050 in a country-wide scenario. If the capacity in 2050 would have been invested for the cost assumptions of 2050 the cost would be 42 €/MWh_e, which can be expected for the time beyond 2050. With large scale intermittent renewable energy sources in the system, the demand for storage technologies increases from the current level to 2050. Batteries provide 2596 TWh, PHS provides 12 TWh and gas storage provides 197 TWh of electricity to the total electricity demand. Most of the storage demand will be based on batteries, which provide as much as 42% of the total electricity demand. The combination of solar PV and battery storage evolves as the low-cost backbone of Indian energy supply, resulting in 3.2 – 4.3 TWp of installed PV capacities, depending on the applied scenario in 2050. The above results clearly prove that renewable energy options are the most competitive and least-cost solution for achieving a net zero emission energy system. This is the first study of its kind in full hourly resolution for India.

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1. Introduction

In the next few decades, the role of India in transitioning itself to a net zero emission based energy system till 2050 as agreed in COP21 will be keenly observed by the world. In turn, its success will be a major step in restricting the global temperature rise to 2°C. Working towards the COP21 agreement, the government of India has initiated a radical transformation of the energy sector, especially power generation from renewable energy sources [1]. The government has set a target of installation of 175 GW of renewable capacity by 2022 which includes 100 GW of solar and 60 GW of wind energy. Also during COP21, India launched the International Solar Alliance, which is a coalition of the countries located between the Tropic of Cancer and the Tropic of Capricorn to help transfer and collaborate on solar energy [2].

In India, population growth, access to modern services, increasing electrification rates and rapid growth in gross domestic product (GDP) in the last decade have driven a large increase in energy demand and put pressure on the security, reliability and affordability of energy supply, all of which are strongly linked to economic stability and development [3]. As of today, imports of oil, gas and coal form a substantial part in meeting the energy demand, and high dependence on imports of fossil fuels has created a serious threat to the energy security and environment of the country [4]. To keep up with economic development and improving the living conditions of the poor, a rapid increase in installed capacities of power generation sources would be needed without additional greenhouse gas emissions [5]. In 2014, 240 million people in India did not have access to electricity, while 840 million people relied on wood, crop waste, dung and biomass to cook in traditional cook stoves, which are the major cause of indoor air pollution and premature death [6]. Climate change will affect most Indians due to flooding, change in the monsoon cycle and water scarcity [7,8]. Coal has been the dominating fossil fuel in the energy mix of India [6]. Coal-fired power plants are associated with high health costs and heavy metal emissions [9-12], which are rarely taken into account in optimizing the societal cost of energy supply in a region. Therefore, in future, India will hold the key for minimizing the impacts of climate change.

The government is taking efforts to curb the effects of climate change and provide electricity for all in a sustainable way by taking initiatives in renewable power generation and particularly utilizing the abundant solar potential. According to a research by KPMG [13], electricity generation from solar power will find a breakeven to the price of electricity from imported coal in 2015 and domestic coal in 2019. With the rapid decrease in solar prices, producing power from a new solar plant is cheaper than a new coal fired power plant [14]. However, large scale deployment of renewables in future would require various storage solutions to balance intermittency and to create a more reliable and flexible electricity distribution system. According to the IEA [15], energy storage offers the required flexibility for the energy systems of the future as they are capable of overcoming the problem of intermittent supply of the resources. For India energy storage technologies could bring reliable and uninterrupted basic energy services to remote areas [16].

For India there is little research till now on the sustainable energy transition pathways into the future decades or none which has integrated all aspects in the required manner, including storage technologies. The approach applied in this study is more comprehensive, such as an hourly based model that guarantees that the total electric energy supply in a year in the sub-regions covers the local demand from all sectors (which is most relevant during the monsoon season); transmission grid connecting different regions that are able to reduce the need of energy storage and total costs; and an integrated scenario that assumes demand by power, water desalination and non-energetic industrial gas sectors.

2. Methodology

The transition of the Indian power system from 2015 to 2050 in 5-year time steps was modelled with the LUT energy system modelling tool. Bogdanov and Breyer [17] describe the model in detail, giving equations and constraints used in the modelling. The LUT energy model is based on a linear optimization of the energy system parameters under previously defined constraints, applied to the system with the assumptions for the future RE power generation and demand. The main input parameters and output of the model can be found in Figure 1. The full set of all technical and