Decarbonizing the Indian Energy System until 2050
An Application of the Open Source Energy Modeling System OSeMOSYS

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INDIA ON THE WAY TOWARDS DECARBONIZATION

India has emerged as a major energy producing and consuming country, and it is also one of the largest emitters of greenhouse gas emissions worldwide. With a doubling of its energy use since the turn of the century, and still a relatively modest per capita energy consumption, India faces significant challenges when addressing the low-carbon energy transformation. On the one hand, its nationally determined contributions (NDCs) are at least partially ambitious, i.e. with respect to renewable energies (Ministry of Environment, Forest and Climate Change, 2015), foreseeing not less than 100 GW of solar capacities by 2022, and 175 GW of renewables overall (2016: ~ 35 GW). On the other hand, the future use of coal is uncertain; the draft plan by the Central Authority of India stating that beyond 2022 no more additional coal plants would be needed in the country (Central Electricity Authority of India (CEA), 2017).

There is an increasing state of literature on different decarbonization pathways for India. These range from the IEA's "new policies" (NPS) and "450ppm" scenarios (International Energy Agency, 2015) to low-carbon scenarios by Indian scholars such as IRADE (2014) and Singh (2017), to scenarios targeting a 100% renewable energy system for India by 2050, such as Jacobsen (2016) and Gulagi et al. (2017). In this article, we analyze alternative pathways to decarbonizing the Indian energy system until 2050, using an energy system model adapted to the specifics of the Indian electricity, heating, and transportation sectors.

METHODOLOGY, DATA, AND ASSUMPTIONS

We have adapted the Open Source Energy Modeling System OSeMOSYS (http://www.osemosys)org/ to India, adding several features including the transportation sector and equations for storage; a stylized representation of our model setup is displayed in Figure 1. We rely on much of the input data for 2015 provided by Gulagi et al. (2017), including the split of India into 10 regions; from there, we calculate pathways to 2050 in five-year steps. Every year is split into several time-slices which are differentiated by seasons, different days of a week, and different hours of a day. We develop three different scenarios, two of them leaning on the IEA scenarios "New Policy Scenario" and "450 ppm", including the CO_2-budgets determined by the International Energy Agency (2015), and a third one that targets 100% renewables energy supply by 2050. In addition, we use cost assumptions from Schroeder, et al. (2013).

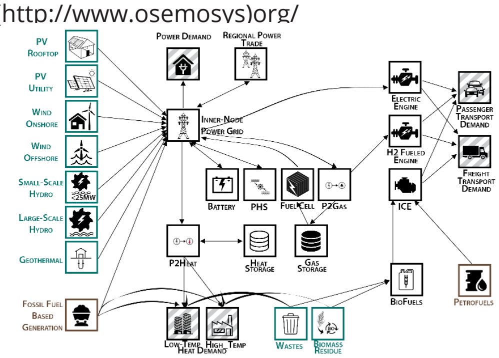

Figure 1: Model representation
Source: Own illustration

SOLAR POWER LIKELY TO DOMINATE THE FUTURE INDIAN ENERGY SYSTEM

The results indicate that the least-cost solution of different low-carbon scenarios include a dominance of solar energy, whereas coal is more expensive and loses significantly in market share. Other renewable energy sources such as wind and biomass also play a significant role, whereas natural gas and nuclear power are not part of any 2050 scenario, due to their high costs. Figure 2 shows the energy mix in 2050 under the NPS, 450ppm, and 100% RES scenarios, respectively; whereas solar plays a dominant role, the share of coal is determined by the available CO2-budget, which is highest in the New Policy Scenario (159000 mn. t).

Figure 3 shows the dynamics of electricity generation from 2015 to 2050, for the middle-scenario "450ppm". Contrary to the status quo prevailing in India, with the largest share of electricity coming from coal and some from wind, solar is expected to outpace wind which is growing at a much lower rate. After 2025, the share of coal in electricity generation is decreasing, and it reaches 5 % in 2050. Once again, natural gas plays no role; contrary to other transformation processes, e.g. in the United States, India seems to leapfrog the age of natural gas; instead, coal is the "transformation fuel".

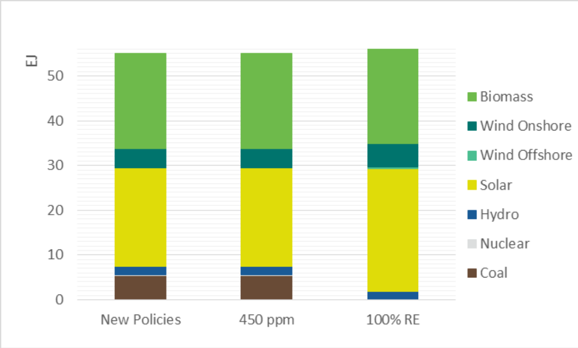

Figure 2: Energy mix in three scenarios (NPS, 450ppm, 100%RES) in 2050
Source: Own illustration

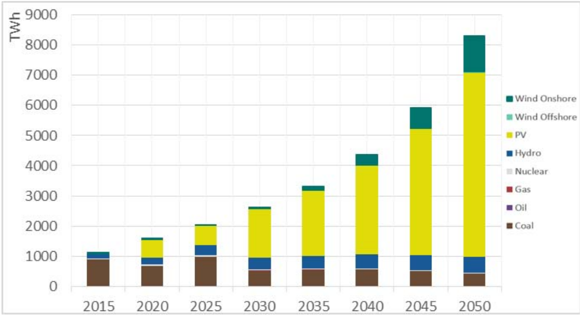

Figure 3: Development of electricity generation in the "450ppm" scenario, 2015 – 2050
Source: Own illustration

For the electricity sector, hydro and wind in combination with storages (Pumped hydro storage, gas storage and batteries) are used to satisfy the demand during nighttime. This mix of technologies is able to handle the greatly increased power demand of India, in addition to the sector coupling with the heat and transport sectors. The heat sector is divided up between space and water heating and process heat. Coal still plays a major role, especially in the industrial heating sector; in the 100% RES scenario, it is replaced in the 2040's by biomass and electric heating.

REGIONALIZATION OF PRODUCTION PATTERNS

India is a very large and federally structured country with a lot of regional diversity. The regionalization of our model based on Gulagi, et al. (2017) allows us to derive first insights into the regional distribution of electricity generation, once again taking the 450ppm as the middle scenario (Figure 4). Clearly the share of coal electrification remains significant in the Center and in the East, hydropower is important in the North and the North-East, and wind plays a significant role in the South. The regional patterns also provide some insights into the upcoming structural reform process, in particular in the coal-intensive regions of the country.

CONCLUSIONS

India plays an increasing role in the global energy and climate policy discussions, and the Indian government has stepped up its commitments significantly. Model-based analysis of different low-carbon pathways to 2050 indicate that solar energy is likely to play a dominant role in the future, because it has clear cost advantages over coal, the environmental benefits not even being considered. A regional differentiation proves to be useful to identify specific challenges of structural change of the energy mix. Future research needs to provide a more detailed disaggregation of the analysis, both with respect to time slices, trade between regions, and the role of storage in the energy transformation.

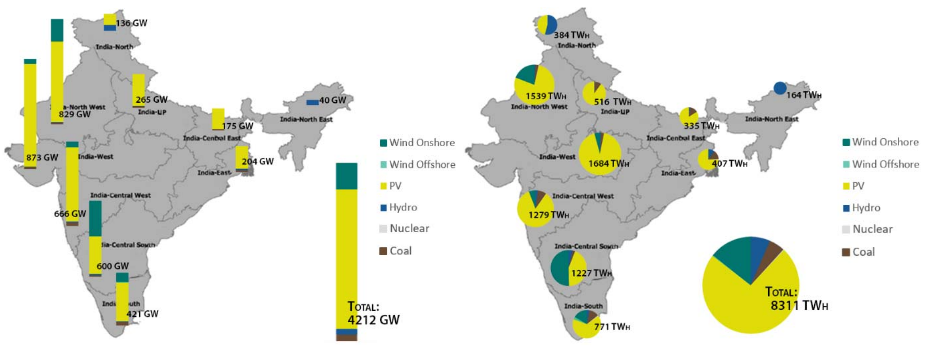

Figure 4: Installed capacities [GW; left] and electricity production [TWh, right] in the "450ppm" scenario" for 2050
Source: Own illustration

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