MODELING THE ENERGY, CLIMATE, AND WATER NEXUS AND TRADEOFFS IN CHINA'S POWER SECTOR

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Overview

China's power sector accounts for 25% of the world coal consumption, fully about 13 % of total global carbon emissions from fossil fuel. Decarbonizing China's power sector will shape how the country, and to a large extent, the world, uses energy and addresses pollution and climate change. Integrating variable renewable energy resources requires power system planning models that run at high temporal and spatial resolution. We first conducted a provincial level resources assessment using GIS model and capacity factor simulation to explore where, when and how much wind and solar resources are available. With the these assessments as key inputs, we develop an integrated planning model of the Chinese power sector, the SWITCH-China model, to analyze the feasibility, costs and benefits of China's clean power transition under main energy nuxus scenarios: Reference Scenario, Carbon Cap Scenario, and Water Constaint Scenario.

Methods

The SWITCH model – a loose acronym for Solar, Wind, Hydro and Conventional generation and Transmission Investment model – is a modeling tool with which many energy scenarios and policies can be explored. It is a mixed-integer linear program whose objective function is to minimize the societal cost of meeting projected electricity demand with generation, storage, and transmission between present day and future target dates to 2030 and 2050. The optimization is subject to reliability, operational, and resource availability constraints, as well as both existing and possible future climate policies.

Results

We found that China could have a potential wind capacity from 1,300 GW to 2,300 GW, and the annual wind output could reach 2,000 TWh to 3,500 TWh. The calculated average capacity factor is 0.18, which is lower compared to what has been reported. This study found that China could have a potential stationary solar capacity from 5,700 GW to 44,800 GW, distributed solar about 200 GW, and the annual solar output could reach 9,700 TWh to 78,900 TWh. SWITCH-China model helps identify the least-expensive response to achieving national energy and climate targets: to reach an 80% reduction in CO_2 emissions by 2050, as proposed by the IPCC, the resulting energy mix in 2050 would include nuclear (14%), wind (23%), solar (27%), hydro (6%), gas (1%), coal (3%), CCS coal (26%). This will result in a 37% increase in total power cost over 'BAU' scenario. There are major trade-offs between carbon-oriented policies and water-saving policies.

Conclusions

China's power sector is in the midst of fast development, and today's investment decisions will have a large impact on the country's ability to achieve its environmental and carbon mitigation goals. SWITCH-China is a "facilitator" which helps understand how technologies, policies, and investment decisions can be coupled, and enables a strategic thinking on the future of China's transition to a low carbon power system that meet the climate and water constraints at the same time. Concerted action is needed to develop such a system, including introducing a meaningful carbon price, coordinating the investment decisions, and building the necessary infrastructure for moving energy around.

References

Fripp, M., 2012. Switch: A Planning Tool for Power Systems with Large Shares of Intermittent Renewable Energy. Environ. Sci. Technol. 46, 6371–6378.

He, Gang, and Daniel M. Kammen. 2014. Where, When and How Much Wind Is Available? A Provincial-Scale Wind Resource Assessment for China. Energy Policy 74, 116–22.

He, Gang, and Daniel M. Kammen. 2016. “Where, When and How Much Solar Is Available? A Provincial-Scale Solar Resource Assessment for China.” Renewable Energy 85: 74–82.

He, Gang, Anne-Perrine Avrin, James H. Nelson, Josiah Johnston, Ana Mileva, Jianwei Tian, and Daniel M. Kammen. 2016. “SWITCH-China: A Systems Approach to Decarbonize China’s Power System.” Environmental Science & Technology.

Hu, Jianlin, Lin Huang, Mindong Chen, Gang He, and Hongliang Zhang. 2017. “Impacts of Power Generation on Air Quality in China—Part II: Future Scenarios.” Resources, Conservation and Recycling, Environmental Challenges and Potential Solutions of China’s Power Sector, 121: 115–27.

Mileva, A., Nelson, J.H., Johnston, J., Kammen, D.M., 2013. SunShot Solar Power Reduces Costs and Uncertainty in Future Low-Carbon Electricity Systems. Environ. Sci. Technol. 47, 9053–9060.

Nelson, J., Johnston, J., Mileva, A., Fripp, M., Hoffman, I., Petros-Good, A., Blanco, C., Kammen, D.M., 2012. High-resolution modeling of the western North American power system demonstrates low-cost and low-carbon futures. Energy Policy 43, 436–447.

Williams, J.H., DeBenedictis, A., Ghanadan, R., Mahone, A., Moore, J., Morrow, W.R., Price, S., Torn, M.S., 2012. The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity. Science 335, 53–59.