

Final Progress Report
Sustainability Science Program
Term: September 1, 2014 – July 31, 2015

Name: Tian Tang

Your fields:

Energy policy, technology policy, network and governance

Your degree program, institution and expected graduation date:

Doctoral program in public administration, Syracuse University, May 2016 (Expected)

Faculty hosts at Harvard name and department:

Henry Lee and Laura Diaz Anadon, Harvard Kennedy School

Description of SSP-related research activity:

Mind the Gaps – Why hasn't Chinese Wind Power Generation lived up to its Technical Potential?

Abstract: Assessments of wind energy resources around the globe suggest that wind power can provide a significant share of power generation in many major economies. But in practice, where wind capacity has been installed, power generation has often fallen short of hoped-for utilization factors due to challenges related to grid connection, grid management, and project design and operation. China, in particular, has struggled in recent years to achieve high capacity utilization factors for its installed wind capacity, despite the fact that most of its capacity is installed in its wind-rich Northern and Western provinces. The discussion of what this shortfall means for projections of future wind power generation in China and appropriate policy responses has thus far been hindered by a lack of systematic analyses of the relative contribution of different technical, economic, and political drivers of the shortfall in Chinese wind power generation. In this paper, we construct a unique database of all Chinese wind farm sites, wind resources, turbine technology, and actual power generation to quantify the gap between potential and actual wind power generation in China between 2006 and 2014. We analyze how the different drivers of the shortfall develop over time and how they compare to the evolution of the same drivers in the United States, which we use to construct an international benchmark for a country with high wind energy utilization. Contrary to popular and academic wisdom, we find that the contribution of the two factors that receive most attention – the curtailment of wind power (due to constrained grid management) and grid connection delay – are dwarfed by the generation shortfall caused by project design and operation. In particular, components of project design and operation related to turbine siting and turbine model choice are responsible for the largest share of the shortfall in Chinese wind power generation. A residual factor, unexplained by observable project siting, design, and operation characteristics is larger than that of curtailment and grid management issues, suggesting that operation learning-by-doing in operations and maintenance and micro-siting issues may be important for long-term planning. Many of the project design choices and operation practices that explain low utilization in the Chinese wind sector are driven by economic considerations on the part of the project developer, which suggests that, unless the economic incentives for market participants change significantly, Chinese wind utilization rates will continue to fall short of the sector's technical potential and of international benchmarks. We discuss implications of our findings for future projections of Chinese wind power generation as well as possible regulatory and policy reforms that could bring China closer to realizing its wind power potential.

Identification of the problem you address:

Although China is the world's largest wind power market in terms of installed capacity of wind turbines, the electricity generation from wind power remains low. This could be a challenge for the further diffusion and utilization of wind power in China. This research attempts to explain this gap between technical potential and actual utilization of wind power in China with a systematical analysis of different technical, economic and political drivers.

Key question asked about the problem:

What are the major drivers that prevent Chinese wind power generation from reaching its technical potential? How large is the impact of each driver?

The methods by which you answered that question:

This research uses a mix of qualitative and quantitative methods to analyze drivers of the wind generation gap.

Principle literature upon which the research drew:

Studies on China's wind power and electricity market; studies on US wind power; studies on wind technology innovation and diffusion

Empirical data acquisition description:

As a first step, we establish our analytical framework of wind gaps based on literature review and interview with experts and stakeholders in Chinese wind industry. In the second step, we construct a unique database of all Chinese wind farm sites, wind resources, turbine technology, and actual power generation to quantify the gap between potential and actual wind power generation in China between 2006 and 2014.

Geographical region studied:

China (We also studied US wind power generation to construct an international benchmark for a country with high wind energy utilization)

Recommendations that might be relevant for your problem:

- 1) Many of the project design choices and operation practices that explain low utilization in the Chinese wind sector are driven by economic considerations on the part of the project developer, which suggests that, unless the economic incentives for market participants change significantly, Chinese wind utilization rates will continue to fall short of the sector's technical potential and of international benchmarks;
- 2) The efficiency of wind farm siting and turbine choices could be improved by making multi-year wind measurements a mandatory requirement for obtaining loans from state-owned banks, and provincial governments should not force the construction of farms in worse sites; and
- 3) Improved wind farm design and operations, (which could benefit from learning-by-doing and wide distribution of best practices) should become an important policy priority in the Chinese wind sector.

A description of the final products you have/are aiming to produce:

Mind the Gaps – Why hasn't Chinese Wind Power Generation lived up to its Technical Potential?
by Joern Huenteler, Tian Tang, Gabe Chan, and Laura Diaz Anadon

Spatial Dynamics in the Knowledge Base of Emerging Cleantech Sectors - A patent analysis in solar PV, written by Christian Binz, Tian Tang, and Joern Huenteler

Description of major other intellectual or professional advancement activity(ies) over the past academic year:

Defended my PhD dissertation proposal in October, 2014.

Research papers:

Tang, T., Popp, D., 2015. The Learning Process and Technological Change in Wind Power: Evidence from China's CDM Wind Projects. Accepted by *Journal of Policy Analysis and Management*. July, 2015.

Tang, T., 2014. State energy policies, the learning process and technological change in the US Wind Industry. Panel paper and presentation at the APPAM 2014 Fall Research Conference.
<https://appam.confex.com/appam/2014/webprogram/Paper9853.html>

Kim, J., and Tang, T., 2014. State Renewable Portfolio Standards (RPS) and Renewable Energy Diversification. Panel paper and presentation at the APPAM 2014 Fall Research Conference.

Explaining Technological Change of Wind Power in China and the US: The Role of Technological Learning and Innovation Networks.
<https://appam.confex.com/appam/2014/webprogram/Paper9854.html>

Invited Presentation:

“The Learning Process and Technological Change in Wind Power in China and US”, at China Energy and Climate Change Project Seminar, MIT Sloan School of Management, Jan.12, 2015.

Please list citations for reports, papers, publications and presentations that built on your fellowship research:

Please describe any collaborative activities with other SSP Fellows that you are involved with.

SSP Collaborative Research Project:

Binz, C., Tang, T., and Huenteler, J., 2015. Spatial Dynamics in the Knowledge Base of Emerging Clean-tech Sectors: A patent analysis of globally leading solar PV manufacturing firms.

Principal collaborators outside Harvard:

David Popp, Syracuse University & NBER

Jung Eun Kim, University of Hong Kong, Hong Kong

An Yu, Yixin Dai, and Zhilin Liu, Tsinghua University, Beijing, China

Qiang Zhi, Central University of Finance and Economics, Beijing, China

List any awards or grants that you have received this year for the current or coming year:

SSP Fellows Collaboration Grant: \$5,435 March 13, 2015

Maxwell Scholarship: \$2500 May 7, 2015

If you are moving to a new position, please list your contact information there:

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