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What hinder the further development of wind power in China?—A socio-technical barrier study

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HIGHLIGHTS

- Use wind power niche model to illustrate the interactions among actors in the industry.
- Analyze technological, governance, infrastructural and cultural barriers.
- Multidimensionality and interconnectedness of the barriers are illustrated.
- Policy suggestions are proposed to deal with the wind power development barriers.

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ABSTRACT

Promoting wind power is a long-term strategy of China to respond to both energy shortage and environmental pollution. Stimulated by various incentive policies, wind power generation in China has achieved tremendous growth, with the cumulative installed capacity being the largest worldwide for five consecutive years since 2010. However, obstructed by various barriers, wind power provides only 2.6% of national electricity generation in China, despite the strong support from the government. From a socio-technical transition perspective, this paper aims to systematically analyze the barriers hindering the further development of China's wind power. A wind power niche model is established to illustrate the complex interactions among actors in the wind power industry and electricity supply regime. Then, qualitative content analysis is adopted to process the related evidence and data, and four categories of socio-technical barriers are identified, including technology, governance, infrastructure and culture barriers. The study shows that various interrelated barriers form a blocking mechanism which prohibits the further development of wind power in China. Policy suggestions are proposed to eliminate the barriers and further empower the wind power niche. The lesson learned from China can offer useful references for other economies to promote wind power industries of their own.

1. Introduction

In order to tackle the problems of environmental pollution and energy crisis, a growing number of countries have given priority to developing renewable energy. Due to rich resources and comparatively mature technology, wind power has shown a huge development potential (Zhang et al., 2011). In China, the wind power resources are abundant, with the exploitable capacity of onshore and offshore wind resources being 23,800 GW and 2000 GW respectively (Xinhua News, 2010). Under the impetus of a series of supporting policies, wind power industry in China has achieved rapid growth in the last decade (Liu et al., 2015). In 2014, the new installed capacity of wind power generation units in China achieved 19.8 GW and the cumulative installed capacity amounted to 96.4 GW, which were both ranked first in the world (NEA, 2015). Along with the rapid development of the Chinese wind power industry, participants in this industry improved their technology and a complete industry chain has gradually formed. Chinese manufacturers now are able to produce most of the wind turbine components and the power capacity of wind turbines is increasingly larger. In addition, the country is developing the seven GW level wind power bases planned by the central government. It seems that wind power is transitioning China's electricity supply infrastructure into a more sustainable system.

However, the Chinese wind power industry is still in its early development stage and various problems have emerged, seriously

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challenging the healthy functioning of the industry. Some scholars have noted that the Chinese wind power industry is facing problems. Wang et al. (2010) proposed that power grid enterprises in China are not willing to accept wind power due to geographical, technical, economic, management and other reasons. Li et al. (2012) discovered that compared to wind farms, the construction lag of grid and peaking power plants is a key factor constraining wind power grid connection. Zhao et al. (2012) argued that the conflict between strict planning and market mechanisms restricts large-scale utilization of wind power in China. From an institutional perspective, Luo et al. (2012) concluded that resulting from the lack of a coordination mechanism between the central government and local governments and between the governmental departments, the inconsistency between wind power farms and grid planning results in the wind power development problems. Many other problems have also been found such as low operational efficiency of wind farms (Han et al., 2009); overcapacity of wind turbine manufacturers (Liu and Kokko, 2010); challenges associated with wind power policies (Wang et al., 2012); weak international cooperation (Zhao et al., 2013a, 2013b, 2013c); lack of research and development (R&D) investment (Ling and Cai, 2012); and poor wind resource prediction (Zhao et al., 2012a, 2012b).

The Chinese government also noticed that some barriers exist hindering the further development of the wind power industry, and thus introduced a series of measures to respond to these barriers and challenges. In August 2011, "*Design Regulations for Large-scale Wind Power Connecting to the System*" was issued and it proposed explicit requirements on the low voltage ride ability of wind turbines and wind farms (NEA, 2011a). Also in August 2011, "*The Provisional Measures on Administration of Wind Power Development and Construction*" was promulgated to strengthen the project approval management of the wind farms with an installed capacity less than 50 MW (NEA, 2011b; Zhao and Chang, 2013). With regard to wind power grid connection, the National Energy Administration (NEA) issued relevant regulations in 2012 and 2013 to emphasize wind power grid connection, and in March 2014, the NEA again issued "*Notice on Implementing Wind Power Grid-Connection and Market Consumption for 2014*", which strongly urges wind power plant developers and grid companies to promote grid connection of wind power (NEA, 2014). The NEA issued relevant regulations to emphasize wind power grid connection in three consecutive years, which shows the severity of the grid connection problem of wind power in China.

To develop effective policies to promote the large-scale application of wind power in China, it is important to understand the various challenges and barriers existing in the industry. Although existing studies have identified certain challenges in the industry, the multidimensionality and interconnectedness of these challenges is seldom explored systematically. Existing studies have shown that the barriers the Chinese wind power industry is facing are multi-dimensional. Institutional, managerial, technological, and cultural factors have been discussed. How to understand these different kinds of barriers and the interrelationships among them is the prerequisite to develop effective policies. In addition, the wind power industry in China is such a complex system where different kinds of participants in the industry may face different development barriers and thus, without further differentiating the barriers according to different stakeholders, it is hard to generate concrete policies addressing the barriers effectively. This paper aims at filling the gap of knowledge by analyzing the barriers and blocking mechanisms of the Chinese wind power industry based on the socio-technical transition perspective. The socio-technical inertia hindering the take-off of the wind power industry in China is critically analyzed. Since China has the largest wind power market in the world, the barriers and challenges that the Chinese wind power industry is going through can be useful lessons for other countries.

2. Socio-technical transition and the energy sector

To understand the socio-technical transition perspective, the concept of "system" and "socio-technical system" should be clarified firstly. In innovation study, a system is a model of reality comprising interacting elements designed for analytical purpose (Bergek et al., 2008; Markard and Truffer, 2008). Based on the system concept, Markard et al. (2012) explained socio-technical systems in the following way: "sectors like energy supply, water supply, or transportation can be conceptualized as socio-technical systems. Such systems consist of (networks of) actors (individuals, firms and other organizations, collective actors) and institutions (societal and technical norms, regulations, standards of good practices), as well as material artefacts and knowledge". The concept of socio-technical system highlights both concrete human actors and material artefacts, as well as the abstract institutions and knowledge.

There are various definitions of socio-technical transitions. One definition is that transitions are shifts from one socio-technical system to another (Wachter, 2012). A more sophisticated definition is that "a transition is a gradual, continuous process of change where the structural character of a society (or a complex subsystem of society) transforms" (Rotmans et al., 2001). Similarly, Alkemade et al. (2011) defined a transition as a fundamental change in the fulfillment of societal needs. Since socio-technical systems are complex systems that have various components such as actors, social and technical norms, regulations and knowledge (Markard et al., 2012), socio-technical transitions have the following characteristics:

- involving far-reaching changes along different dimensions: technological, organizational, political, economic, behavioral, and belief systems (Markard et al., 2012; Rotmans et al., 2001);
- requiring interactions among multiple actors such as the industry, the government, users and social groups (Wachter, 2012);
- long-term process which takes decades to unfold (Geels, 2012; Rotmans et al., 2001);
- requiring the development and diffusion of a wide range of innovations, including new technologies, policies, standards, and social practices (Geels et al., 2008).

Simply put, a transition is a set of connected changes. These changes need to be completed by various actors in different areas through the adoption of innovations, and thus a transition is a long-term process (Rotmans et al., 2001). In the course of a socio-technical transition, new products, services and business models emerge, complementing or substituting existing ones (Geels and Schot, 2007; Markard et al., 2012). Many historical developments have been studied based on the socio-technical transition perspective, for instance the transition from sailing ships to steamships (Geels, 2002), from horse-drawn carriages to automobiles (Geels, 2005), and from cesspools to sewer systems (Geels, 2006). The usefulness of the socio-technical transition approach has been justified and the main theoretical models of this approach, for instance the multi-level perspective (MLP), have been tested and refined (Geels, 2012, 2011, 2004; Geels and Kemp, 2007; Geels and Schot, 2007; Markard et al., 2012). Currently China aims at largely improving the ratio of renewable energy in the national energy supply structure, which is exactly an energy transition.

In socio-technical transition research, the MLP is a fruitful framework which aims to explain why transitions happen. The MLP views transitions as non-linear processes resulting from the