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A regional analysis of excess capacity in China's power systems

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ABSTRACT

China's economy has entered a "new normal," characterized by slower economic growth and widespread overcapacity in its industrial sectors. Nevertheless, construction of power plants, especially coal-fired plants, continues at a rapid pace. Our analysis examines the extent of overcapacity in China's regional electricity grids. We show that already in 2014, the average reserve margin across China's regional grids was roughly 28%, almost twice as high as a standard planning reserve margin in the U.S. In addition, we find large variations in reserve margins across regional power grids in China, with the highest reserve margin (64%) in the Northeastern grid. This paper examines future reserve margins across regions in China under three growth scenarios. The results suggest that the majority of China will not need new baseload coal power (at least for reliability purposes) before 2020, and potentially not until 2025, under the low- and mid-growth scenarios. Under the high-growth scenario, China's central and eastern regions will need to import more power or built new capacity by 2020. As China's energy sector enters this new normal, our results highlight the growing importance of establishing mechanisms — planning processes and markets — that coordinate generation and transmission investments across grid regions, and that align the country's energy sector investments with its longer-term air quality and climate goals.

1. Introduction

Transitioning away from coal is critical for China's low-carbon growth, and for global efforts to reduce the risks of climate change. Reducing the share of coal in China's generation mix is an important part of this transition, particularly as electricity accounts for a growing share of China's final energy consumption.

China's rapid economic growth over the past two decades was driven by industry and exports and fueled by coal, leading to a sharp increase in global greenhouse gas (GHG) emissions. However, it is widely recognized that the Chinese economy has entered a so-called "new normal," characterized by a lower overall economic growth rate, a structural shift toward a service economy, and widespread overcapacity in industrial sectors (Gu et al., 2017; Hu, 2015). As a consequence, in 2015, China's energy consumption grew only 1.0%, and electricity consumption growth slowed to 0.96% (China Electricity Council (CEC), 2016).

Despite this slowdown in electricity demand, power plant construction and permitting continued at a rapid pace. Government agencies reported that 130 gigawatts (GW) of new generation capacity was added in 2015 (National Energy Administration of the People's Republic of China (NEA), 2015); Yuan et al. estimates that an additional 200 GW of coal-fired generation capacity is under construction, with more in the permitting process (Yuan et al., 2016a).

Recently, many have posited that China's power sector likely has an excess of generation capacity, particularly coal-fired generation capacity, relative to what is needed to reliably meet demand (Yuan et al., 2016a; Kahrl, 2016; Slater, 2016; Myllyvirta et al., 2015; Yuan et al., 2016b,c, 2017). Average annual operating hours for thermal generation units, a commonly used barometer of capacity utilization, dropped to 4364 h in 2015 (a 50% capacity factor), reaching its lowest level since 1969 (Electricity Council (CEC), 2016).

Even though, in recent years, power overcapacity in China has been widely recognized as a major issue, few analyses have taken a systematic approach to assessing overcapacity. Within China, operating hours (or "utilization hours") are often used as the principal indicator of overcapacity (Yuan et al., 2016a; Ming et al., 2017; Zhao et al., 2017). However, operating hours are a measure of asset utilization, and do not necessarily provide information about reliability or economic efficiency. For instance, an electricity system with large amounts of hydropower, wind, or solar generation may have low operating hours for thermal generators, but will not have excess generation capacity.

Another, more accurate way of measuring overcapacity would be reliability metrics. Typically, reliability studies calculate the probability of power outages in the high-voltage transmission system, given demand characteristics and the probability of unexpected generator

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failures. This probability, referred to as a loss-of-load probability, requires detailed information on electricity demand (loads) and generator failure probabilities. This information is, however, not publicly available in China.

An alternative approach is to use reserve margins, which are defined as the percentage of available generating capacity during an annual peak demand period in excess of peak demand. Many international studies have used reserve margins (or "security margins") to evaluate power grid reliability and generating capacity needs (Del Río and Janeiro, 2016; Laleman and Albrecht, 2016; Ibanez-Lopez et al., 2017). This paper contributes to the current literature as the first analysis of reserve margins at the regional level in China.

In this study, we use regional grids as the unit of analysis for two reasons. First, publicly available, systematically reported data on peak electricity demand is only available for regional grids. Second, although electricity supply-demand balancing for planning purposes is typically done at the provincial level in China, for decades China's electricity system has been organized into six regional synchronous grids. Regional grid operators play an important role in addressing supply and demand imbalances among provinces in China (Chen et al., 2010), and this role is likely to grow as regional and interregional transmission systems evolve (Li et al., 2016; Yi et al., 2016; Zhang et al., 2017) and China moves toward regional wholesale markets for electricity.

International trends also suggest a movement to wider-balancing areas to reduce generation costs and absorb variable renewable generation. For example, the development of U.S. Regional Transmission Organizations and Independent System Operators since Federal Energy Regulatory Commission (FERC) Order No. 2000 (United States of America Federal Energy Regulatory Commission, 1999), demonstrates the benefits of coordinated regional planning and the use of electricity resources (Borenstein and Bushnell, 2015). Similarly, understanding reserve margins at the regional grid level will be important to developing a more systematic approach to power system planning in China.

This paper is timely as China's 13th Five-Year Plan (FYP) for Electric Power Development (the Plan) was just issued in late 2016, after a 15-year absence (NEA, 2016), The Plan recognizes that surplus capacity is likely to stay and demand growth is significantly slower than in the past. However, it also sets fairly aggressive targets for new generation capacity across various sources, including 200 GW of thermal coal plants. Given this newly released Plan, this paper not only assesses the current regional nature of generation overcapacity in China, but also evaluates if the power capacity goals specified in the Plan will exacerbate the overcapacity issue in the near to medium term (2020 and 2025).

The rest of this paper is organized as follows: the Background section reviews current electricity planning and project approval processes in China as well as new policies to limit coal power plants; then the Methods and Results sections show how we apply our methodology to estimate China's current and future reserve margins by regional grids for 2020 and 2025. The final section proposes future research areas and delineates policy implications.

2. Background

Many of the current overcapacity challenges facing China's electricity sector have their roots in an antiquated planning and project approval process which has caused several boom-and-bust cycles in the last three decades. Before 2004, electricity investment projects were reviewed and approved by different government agencies based on investment size, with larger projects approved by the central government and smaller projects approved by local governments. Declining electricity demand growth during the Asian Financial Crisis (1997–1998) led to a slowdown in central government approvals, resulting in severe power shortages in 2003 and 2004 and a surge in construction of small-scale coal-fired power plants that were approved by local governments (Kahrl and Wang, 2015).

To address this rapid expansion, China's State Council centralized approval authority for most new generation and transmission projects in 2004 (State Council, 2004). However, it did so without also initiating a national planning process for electricity during the 11th FYP (2006–2010) and the 12th FYP (2011–2015). New projects were required to receive a green light from the National Energy Administration (NEA) before beginning the formal approval process, but there were no transparent, rigorous criteria with which to evaluate new projects. This gap between planning and project approval led to a disconnect

among electricity demand, generation and transmission investment, and policy goals.

In mid-2014, NEA simplified the approval process for coal-fired power generation and tried to link it to a national planning process, where NEA would determine an allowed amount of new coal generation capacity for each province each year over five to seven years, and each year provincial governments would decide which projects to approve. Local governments were required to submit the entire portfolio of projects to NEA for review and approval, using transparent criteria to evaluate different projects (Energy Administration of the People's Republic of China (NEA), 2014).

By early 2015, the approval process for new coal-fired generation had been largely decentralized to local governments. Decentralization of authority was accompanied by a large increase in new coal generation projects. At the same time, however, electricity demand growth had begun to slow dramatically.

In April 2016, the National Development and Reform Commission (NDRC) and NEA issued three policies to limit the permitting and construction of new coal power plants and the retirement of inefficient power plants: (1) *Announcement on Promoting Proper Development of Coal-fired Power Plants* (National Development and Reform Commission (NDRC) and National Energy Administration of the People's Republic of China (NEA), 2016a), (2) *Announcement on Further Eliminating Inefficient Capacity for Coal-fired Power Plants* (National Development and Reform Commission (NDRC) and National Energy Administration of the People's Republic of China (NEA), 2016b), and (3) *Announcement on Establishing a Risk Warning System for Coal-fired Power Plant Planning and Construction* (National Energy Administration of the People's Republic of China (NEA), 2016a). It is too early to tell whether these policies will reduce the number of coal plants to be built by 2020.

In addition to policies controlling coal power plants, NEA released a *Management Guidelines for Electricity Planning* in June 2016 (National Energy Administration of the People's Republic of China (NEA), 2016b), which was the first official guideline for electricity planning published by the government since 2003. The document designated the NEA to develop national electricity plans, including regional electricity plans, and designated provincial energy departments to develop provincial electricity plans, which were required to be harmonized both between national and provincial electricity plans and between electricity export provinces and electricity import provinces. The electricity plan is meant to be a five-year plan, and it can allow adjustments to be made in two or three years after the plan is published. However, the document does not explicitly state whether or how project approval and investment decisions should follow the electricity plans.

Then on November 7, 2016, NEA published the long-awaited 13th FYP on Electric Power Development (2016–2020) (NEA, 2016). In addition to setting forth key principles on shifting China's generation sources toward clean technologies, increasing system efficiencies and flexibility, optimizing location of generating resources, and further development of the power market, the Plan also set numeric targets for overall demand growth of 3.6%–4.8% per year, and targets for total generation capacity of various generation technologies by 2020 as follows: hydro, 340 GW; wind, 210 GW; solar, 110 GW; nuclear, 58 GW; coal, 1100 GW; and gas, 110 GW.

Given the ongoing economic transition and slowdown in demand growth, the range of total power demand growth remains on the high side. In particular, the target of 1100 GW of coal generation implies that