China Power Sector Reform: Key Issues for the World's Largest Power Sector

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Introduction

The overarching challenges for the global power industry are to reduce emissions, integrate higher penetrations of variable renewable energy resources, and increase end-use energy efficiency, while maintaining reliability and minimizing costs. China's power sector is now the largest in the world by a number of measures, including total installed generation capacity (1,507 GW as of December 2015), thermal generation capacity (990 GW),[1] wind generation capacity (129 GW),[2] and coal consumption.[3] Accordingly, China will have a leading role in grappling with these global challenges.

In March 2015, the State Council and the Central Committee of the Communist Party—representing the highest levels of authority in China—launched a new round of power sector reform with a policy statement known as "Document #9,"[4] followed by six "accompanying documents", which appeared in December.[5] Document #9 is framed in terms of several "guiding principles": the need for reliability; increased use of market mechanisms; protection of residential and agricultural consumers; energy savings, emissions reductions, and increased use of renewable and distributed generation; and better governance and regulation, including better planning and strengthened capacity in terms of regulatory agencies and approaches[6]. Creation of detailed and well-implemented policies, regulations, and market mechanisms to realize these principles will be crucial for global climate goals as well as for China's domestic environmental objectives—particularly reduction of air pollution.

This article synthesizes several recent reports published by the Regulatory Assistance Project (RAP) that analyze the context and current status of power sector policy and regulation in China, draw parallels with international experience, and offer recommendations for reform. These reports include overviews of the major issues,[7,8] as well as more detailed reports on specific issues. The reports analyze the historical context for power sector policy in China and discuss "low-cost and low-risk" recommendations for reform, drawing on experience in other countries. In the present article, we focus on three key topics that will be crucial issues for China's power sector: power sector planning, generator operations and pricing, and grid company regulation.

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[1] Rose, 2016.
[2] National Energy Administration, 2016.
[3] International Energy Agency, 2015.
[4] Central Committee of the Communist Party and the State Council, 2015.
[5] National Development and Reform Commission, 2015.
[6] Dupuy & Weston, 2015.
[7] Dupuy et al., 2013.
[8] Dupuy, Crossley, Kahrl & Porter, 2015.

Power Sector Planning

China is emerging from a period of extremely rapid growth in electricity demand, in which the government put great emphasis on securing adequate investment. Policymakers sought to head off recurring periods of shortage by rapidly expanding capacity, with little attention given to careful planning studies.[9] As a result, the planning procedures that exist are weak, are not well coordinated, and are not adequately focused on China's overarching policy goals, such as the guiding principles of Document #9 and air quality improvement targets. China has been successful at acquiring huge amounts of new generation and transmission capacity, with one terawatt of new capacity coming on line between 2000 and 2014. Now, with demand growth slowing sharply and with difficult renewables integration challenges, there is a growing recognition of the need to shift away from "headstrong" (任性) expansion and toward a more rational approach.[10] (As a result of the last major round of power sector reforms, initiated in 2002, electricity generation has been unbundled from transmission. Grid companies purchase electricity from generation companies at administered on-grid prices.[11])

Good planning will be important for whatever industry model China ultimately chooses. Looking at other countries, planning is important in traditional' vertically integrated power sector models, but also in places that have liberalized or "restructured' their power sectors. In restructured markets, planning is needed to support design and periodic review and adjustment of market mechanisms. Planning is also needed to support investment in non-competitive segments, notably transmission, and to coordinate these non-competitive segments with competitive ones.[12]

China's 1995 Electricity Law (电力法) calls for "electricity development planning" to promote "rational resource use, coordinated generation and grid development, improved economic efficiency, and environmental protection". However, these broad principals have yet to translate into rigorous planning tools or processes. Before the early 2000s, national five-year plans included comprehensive plans for the electricity sector as a whole. More recently, the five-year plans have included specialized plans for various resources, including hydropower, renewable energy, nuclear, and energy efficiency, but these are developed in a largely independent fashion. (The 13th Five-Year Plan is expected to return to the practice of a comprehensive national power sector plan.) Provincial governments have continued to issue five-year plans for electricity development, but these are often quite general, lack transparency and rigor, and do not formally guide investment in a detailed way.[13]

China's State Council issued a national Air Pollution Control Action Plan issued in 2013 for the 2013–2017 period. This document directs provincial and local governments to develop air quality plans. However, so far air quality planning has not been centered on rigorous evaluation of the costs and benefits of power sector emission-control measures. Instead, the plans typically comprise lists of policies and measures, but do not quantitatively link these to air quality improvements. In these plans, power sector measures mostly focus on efficiency enhancements and end-of-pipe measures for thermal power plants, with little attention to potential emissions reductions from improvements to renewable energy and system operations efficiency.[14]

[9] Kahrl & Wang, 2015.
[10] Chen, 2016.
[11] Kahrl & Wang, 2015.
[12] Dupuy et al., 2014.
[13] Kahrl & Wang, 2015.
[14] Kahrl & Wang, 2015.

Various state-owned electricity enterprises carry out more detailed internal planning efforts for their investments in generation, transmission, and distribution assets. The broad geographic scope of the grid companies, in particular, represents an opportunity for regional planning, although, in practice, grid company planning is not very transparent and is not well linked to generation resource planning. Lack of coordination between wind generation and transmission planning, in particular, has been problematic.[15,16,17]

Project investment approval decisions are not well connected with planning. Project approval authority for most generation and transmission projects has, until recently, has been concentrated at the national level and has been subject to corruption.[18] There is currently an effort underway to decentralize project approval to provincial and municipal authorities.[19] It is unclear how more decentralized approval authority will interact with China's national industrial and environmental policies.

The results of weak and uncoordinated planning and approval procedures have included a mix of resources that is not least-cost and not supportive of system flexibility, poorly managed generation and transmission expansion, high rates of renewables curtailment, and high emissions. For example, in the northeast grid, large-scale investment in inflexible combined-heat-and-power facilities and variable wind resources has been problematic. This is a contradiction that could have been headed off by better planning.[20,21,22]

An oversupply of coal capacity has emerged. A new RAP report attempts to quantify the scale of the problem.[23] Despite slowing growth and rapid expansion of renewable capacity, coal capacity has continued to grow rapidly, with 35 GW of coal generating capacity added in 2014 compared to an end-year total system generation capacity of 1,360 GW. Meanwhile, electricity demand growth has slowed to less than one percent, down from double digit growth throughout much of the 2000s and early 2010s. The report estimates that China had significant excess generation capacity in 2014, with an average reserve margin of 25–28 percent across the country. For comparison, reserve margins in the United States are typically below 15 percent.

The reports make several recommendations centering on developing coordinated procedures for generation planning, transmission planning (particularly coordination of transmission expansion with RE investments), and environmental planning. There is also a need for transparent mechanisms to identify the least-cost mix of resources. The experience with integrated resource planning (IRP) in North America may be useful for China. Under IRP, the utility works with regulators to develop a multi-year plan identifying a least-cost combination of supply-side, demand-side, and transmission resources to meet demand for energy services. This approach can lead to increased investment in end-use efficiency by recognizing its value and by treating it as a resource like any other resource. This is an area in which there is a role for the grid company to play (see subsequent section).[24] Document #9 recognizes the problem and emphasizes the need for integrated planning, but stops short of outlining clear institutional

[15] Dupuy et al., 2013.
[16] Dupuy, Crossley, Kahrl & Porter, 2015.
[17] Kahrl & Wang, 2015.
[18] Kahrl & Wang, 2015.
[19] Chen, 2016.
[20] Dupuy et al., 2013.
[21] Dupuy, Crossley, Kahrl & Porter, 2015.
[22] Kahrl & Wang, 2015.
[23] Kahrl, 2016.
[24] Dupuy, Weston & Hove, 2015.

responsibilities and procedures.

Generator Operations and Pricing

In most countries, generator dispatch and often unit commitment are optimized based on a "merit order" approach, in which the system operator minimizes short-run marginal costs subject to transmission and reliability constraints. In contrast, in most Chinese provinces, system operators work according to principles that seek to allow each coal-fired generator to achieve a targeted number of annual operating hours, as determined in an annual generation output planning process.[25] The result is that short-run costs—chiefly those related to fuel and the external cost of emissions—are higher than necessary.

China's approach to dispatch is a major reason for the large amounts of renewable energy curtailment. China has more wind power capacity than the United States, but does not generate as much electricity as the United States from wind, partly as a result of high rates of curtailment. China's national average wind curtailment rate was 16 percent in 2012, fell to eight percent in 2014, but rebounded to 15 percent in 2015, according to the National Energy Administration.[26] Wind curtailment reached 39 percent in Gansu and 32 percent in Xinjiang, two wind-rich regions.[27] Curtailment of hydroelectric and solar output is also significant.[28] Document #9 and associated policy statements recognize these problems. In September 2015, China and the United States issued a joint presidential statement on climate change, in which China committed to a national "green dispatch" system.[29] This was followed by the announcement of pilot efforts to reduce curtailment in Gansu and Inner Mongolia—regions rich in wind and solar resources.[30] However, there is, as of yet, no clearly identified set of solutions for dispatch reform or, more broadly, renewables integration.

A major barrier to reform of generator operation is the approach to pricing. Coal and most gas generators are compensated on a per-kWh basis, at price levels intended to cover both variable and capacity costs, with the result that they are eager to reach their annual allocation of hours. As a result, thermal generators resist reductions in their operating hours that result from increased wind and solar generation. Another implication is that business models for peaking generators are very limited. In this way, dispatch practices in China also distort investment decisions, discouraging investment in flexible resources such as gas-fired power plants which would, under other pricing models, be economic as peaking capacity and useful for supporting increased penetration of variable generation.[31,32]

The reports surveyed here recommend reforming pricing for coal- and gas-fired generators.[33,34,35,36] This can be done in several ways. The first two possibilities work within China's current practices of

[25] Kahrl & Wang, 2014.
[26] National Energy Administration, 2016.
[27] National Energy Administration, 2016.
[28] Dupuy, Weston & Hove, 2015.
[29] Dupuy, 2015.
[30] Dupuy, He & Wang, 2015.
[31] Dupuy et al., 2013.
[32] Kahrl & Wang, 2014.
[33] Dupuy et al., 2013.
[34] Dupuy, Crossley, Kahrl & Porter, 2015.
[35] Dupuy, Weston & Hove, 2015.
[36] Dupuy, Kahrl & Wang, 2016.

administratively-set on-grid prices. The first option is strengthening generation rights trading, a system first implemented (on a pilot basis) in 1997 that allows various thermal generators to trade allocations of hours. In theory, the more efficient generators should be able to pay off less efficient generators. However, in practice, generation rights trading has not been fully implemented in the pilot provinces.[37] Another option is implementation of two-part pricing, comprised of a capacity price (per MW) and an energy price (per MWh). Beyond this, China could design a new set of liberalized wholesale market mechanisms. These may or may not include capacity markets. Indeed, part of the new reform efforts is to create a number of market pilot provinces. However, one of the reports surveyed in this article cautions that liberalized markets will be a difficult and high-risk model, given China's policymaking conditions and institutions.[38] The report suggests implementation of competitive contracting mechanisms, at least for acquisition of new conventional resources.

Grid Company Regulation

The roles and behavior of the two major state-owned companies have been the subject of much debate in China, with some observers decrying their political power. The reports surveyed here consider the grid companies from the point of view of incentive regulation, asking how best to align their behavior and investment decisions with the government's policy goals. Three major issues discussed in these papers are 1) grid company acquisition of energy efficiency as a resource; 2) grid company incentives vis-à-vis distributed energy resources (DERs), particularly end-use energy efficiency; and 3) grid company incentives vis-à-vis utility scale renewables.

In North America and other places around the world, policymakers have implemented regulations that encourage and support investment by utilities in end-use energy efficiency as a clean and cost-effective alternative to conventional supply-side options.[39] China has made great strides in implementing energy efficiency policy and reducing the overall energy intensity of the economy.[40] However, these policies are not yet well integrated with power sector regulations and investment decisions. Energy efficiency does not operate on a "level playing field" with other resources and, partly as a result, there is overinvestment in relatively expensive and polluting resources such as coal-fired power plants.[41,42] In 2010, the National Development and Reform Commission imposed an obligation on the grid companies to meet an annual obligation for investment in end-use energy efficiency. Although the obligation is small in percentage terms (0.3 percent of previous year's sales), it has produced large savings in absolute terms, compared to other utility efficiency obligations around the world. However, there are problems with transparency, measurement and verification, and the scope of the allowed programs. In particular, unlike in other countries, grid companies in China are allowed to satisfy a significant fraction of the annual obligation with savings within their own operations (as opposed to those of their customers), such as reductions in line losses.[43]

The grid company obligation is a requirement for investment in energy efficiency. It does not change the underlying disincentives of the grid companies with regard to end-use energy efficiency (and with regard

[37] Kahrl & Wang, 2014.
[38] Dupuy et al., 2013.
[39] Dupuy et al., 2014.
[40] Crossley, 2014.
[41] Dupuy, Weston & Hove, 2014.
[42] Crossley, 2014.
[43] Crossley & Wang, 2015.

to distributed renewables). That is, as noted, the grid companies face a traditional "throughput" incentive, which disposes the grid companies to increase kWh sales and thus oppose end-use energy efficiency.

Recommendations for improving grid company regulation include expanding the size of the obligation as well as implementation of regulatory incentive mechanisms for energy efficiency. There is currently a significant window of opportunity in China for implementation of such incentive mechanisms, as part of the Document #9 reform effort. In particular, Document #9 includes an effort to shift away from the status quo in which regulators have limited access to grid company financing and lack a transparent cost review and price-setting process. Under the new approach, grid company revenue will be subject to revenue regulation based on the basic concept that allowed revenue equals "approved costs" plus reasonable return on asset base. The revenue of the grid companies will be approved for three-year periods. This reform is primarily intended to increase transparency, improve government oversight, and reduce costs—but it also opens up the potential to change the grid companies' behavior regarding end-use energy efficiency, by diminishing the negative influence of energy efficiency on grid company revenues. The RAP reports recommend that this change in incentives be addressed more explicitly and strengthened. In particular, the reports recommend that the "approved cost" category should explicitly include expenses associated with meeting the energy efficiency obligation and other demand-side management costs.[44,45,46]

Finally, the RAP reports suggest exposing the grid company part of the cost of curtailment of renewable energy.[47,48,49] Currently, all costs associated with curtailment are borne by renewable generators. Aligning the grid company financial interest with renewable energy integration goals should motivate the grid companies to search for solutions to reduce curtailment. However, it is worth noting that reasons for curtailment are complex and that some factors are not under the grid companies' direct control. Another caveat offered in the reports is that some of the costs of curtailment should continue to fall on renewable generators in order to incentivize investment in areas with less congestion.

Conclusion

This article has synthesized several recent reports on China's power sector policy and regulation, with reference to policies and regulatory approaches from other countries that could be suitable for China. Together, these reports provide an overview of context and prospects for the current round of power sector reform in China. Information and analysis about this subject in English is very limited. Even in Chinese, there is little in the way of surveys of the various aspects of power sector reform from an international comparative perspective. In this article, we discussed three key aspects of power sector reform in China: planning, operations and pricing, and grid company regulation. The Chinese government's announcement in 2015 of a new round of power sector reform recognizes the challenges in each of these areas—the next step is to develop and implement workable policies that support the transformation of the power sector toward a clean, reliable, and cost-effective future.

[44] Dupuy, Crossley, Kahrl & Porter, 2015.
[45] Dupuy, Weston & Hove, 2015.
[46] Crossley, 2015.
[47] Dupuy et al., 2013.
[48] Dupuy, Crossley, Kahrl & Porter, 2015.
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