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Excess Capacity in China's Power Systems: A Regional Analysis

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Executive Summary

It is widely recognized that China's economy has entered a so-called economic "new normal," characterized by a lower overall economic growth rate, a structural shift toward a service economy, and widespread overcapacity in many industrial sectors.

As a consequence, China's energy consumption grew only 0.9%, and electricity consumption growth slowed to 0.5%, in 2015. Despite this downturn in electricity demand, power plant construction and permitting has continued at a rapid pace. Government agencies reported that 130 gigawatts (GW) of new generation capacity was added in 2015; other reports show that an additional 200 GW of coal-fired generation capacity is under construction, with more in the permitting process.

There are many factors that may have contributed to the overbuilding of coal power plants in China — declining coal prices, which led to higher profits for generators due to the lag in reducing their wholesale power tariff; overly optimistic expectations for economic and electricity demand growth; and local governments' preference for investment, which generates employment and tax revenues. However, there may be more fundamental issues at play. In particular, we argue that China's current planning process for the power sector is insufficient to meet emerging challenges under the economic "new normal," to address urgent air quality problems, and to support China's ambitious clean energy and climate goals.

There are three different ways to evaluate "overcapacity":

- *Reliability* — how does the current level of generation capacity compare to what is needed to meet demand under most conditions?
- *Economic* — how does the current capacity level of individual resources (e.g., baseload, peaking) compare to what would be most economic?
- *Environmental* — how does the current level of coal-, oil-, and natural gas-fired power generation compare to what is required to meet air quality and greenhouse gas emission reduction goals?

Reliability is, in many ways, the least stringent of these criteria. However, it is reasonably straightforward and offers important insights for planners and decision-makers. This paper examines China's regional electricity grids using a reliability perspective, which is commonly measured in terms of a reserve margin.

Our analysis shows that at the end of 2014, the average reserve margin for China as a whole was roughly 28%, almost twice as high as a typical planning reserve margin in the U.S. However, this national average masks huge variations in reserve margins across major regional power grid areas: the northeastern region has the highest reserve margin of over 60%, followed by the northwestern region at 49%, and the southern grid area at 35%.

In this analysis, we also examined future reserve margins for regional electricity grids in China under two scenarios: 1) a low scenario of national annual electricity consumption growth rates of 1.5% between 2015 and 2020 and 1.0% between 2020 and 2025, and 2) a high scenario of annual average growth rates of 3.0% and 2.0%, respectively. Both scenarios suggest that the northeastern, northwestern, and southern regions have significant excess generation capacity, and that this excess capacity situation will continue over the next decade without regulatory intervention. The northern and central regions could have sufficient generation capacity to 2020, but may require additional resources in a higher growth scenario. The eastern region requires new resources by 2020 in both scenarios.

The large discrepancies in reserve margins among grid regions suggests the need for greater coordination among grid regions in providing for generation adequacy across China. The eastern and central regions' potential shortfalls, for instance, could be most cost-effectively supplied by using existing resources in the southern region. The northern region's shortfalls could be supplied through imports from the northwest and northeast. Greater coordination in generation adequacy across grid regions would require mechanisms for cost allocation, such as bilateral contracts. An expansion of bilateral exchange across grid regions has been part of the National Development and Reform Commission's proposed power sector reform framework.

The results suggest that China does not need new thermal power, or at least not new baseload coal units, before 2020 and potentially not until 2025. This finding underscores the critical importance of improving investment planning processes in China to avoid making the current overcapacity problem worse, and to meet multiple policy objectives of achieving a reliable, environmentally friendly, and least-cost power system.

1. Introduction

It is widely recognized that China's 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 many industrial sectors (Gu, et al. 2014).

As a consequence, China's energy consumption grew only 0.9%, and electricity consumption growth slowed to 0.5%, in 2015 (NBS, 2016). Despite this downturn 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 (NEA, 2016a); Greenpeace estimates that an additional 200 GW of coal-fired generation capacity is under construction, with more in the permitting process (Myllyvirta and Shen, 2016).

Recently, many have posited that China's power sector likely has an excess of generation capacity, particularly coal-fired generation capacity. Average annual operating hours for thermal units, a commonly used barometer of capacity utilization, dropped to 4,329 hours in 2015 (49% capacity factor), reaching their lowest level since 1978 (NEA, 2016b). Operating hours continued to decline in the first half of 2016, falling by 194 hours compared to the fist half of 2015 (NEA, 2016c).

There are three different ways to evaluate "overcapacity":

- *Reliability* — how does the current level of generation capacity compare to what is needed to meet demand under most conditions?
- *Economic* — how does the current capacity level of individual resources (e.g., baseload, peaking) compare to what would be most economic?
- *Environmental* — how does the current level of coal-, oil-, and natural gas-fired power generation compare to what is required to meet air quality and greenhouse gas emission reduction goals?

Reliability is, in many ways, the least stringent of these criteria. However, it is reasonably straightforward and offers important insights for planners and decision-makers. This paper examines China's regional electricity grids using a reliability perspective, which is measured in terms of reserve margin.

There may be many factors that have contributed to the current situation regarding coal power plants in China — declining coal prices, which led to higher profits for generators due to the lag in reducing their wholesale power tariff; overly optimistic expectations for economic and electricity demand growth; and local governments' preference for investment, which generates employment and tax revenues (People, 2016; SEDC, 2016). However, there may also be more fundamental issues regarding overall planning for China's power sector. In particular, there are questions as to whether China's current planning process for the power sector is sufficient to meet emerging challenges under the economic "new normal," to address urgent air quality problems, and to support China's ambitious clean energy and climate goals.

2. Background

Many of the current investment and asset challenges facing China's electricity sector have their roots in an antiquated planning and project approval process. 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. Slowing 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. However, it did so without also initiating a national planning process for electricity during the 11th Five-Year Plan (2005-2010) to the 12th Five-Year Plan (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 needed to submit the entire portfolio of projects to the NEA for review and approval, using transparent criteria to evaluate different projects (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 early 2016, government agencies began to take separate steps to limit the continued development of coal-fired generating units.

In April 2016, the National Development and Reform Commission (NDRC) and the NEA issued three policies to limit the permitting and construction of new coal power plants: 1) *Announcement on Promoting Proper Development of Coal-fired Power Plants* (NDRC and NEA, 2016a), 2) *Announcement on Further Eliminating Inefficient Capacity for Coal-fired Power Plants* (NDRC and NEA, 2016b), and 3) *Announcement on Establishing Risk Warning System for Coal-fired Power Plants Planning and Construction* (NEA, 2016e).

The *Announcement on Promoting Proper Development of Coal-fired Power Plants* states that the provincial planning agencies shall temporarily postpone the permitting of coal-fired power plants for "self-use" (i.e., excluding national demonstration projects), except for "livelihood co-generation" projects in 13 provinces — Heilongjiang, Shandong, Shanxi, Inner Mongolia, Jiangsu, Anhui, Fujian, Hubei, Henan, Ningxia, Gansu, Guangdong and Yunnan — until 2017. The *Announcement* also states that provincial planning agencies should temporarily postpone construction of coal-fired power plants for self-use for those projects that were already permitted but had not started construction, except for "livelihood co-generation" projects, in 15 provinces — Heilongjiang, Liaoning, Shandong, Shanxi, Inner Mongolia, Shaanxi, Ningxia, Gansu, Hubei, Henan, Jiangsu, Guangdong, Guangxi, Guizhou and Yunnan — until 2017. For projects under construction, the *Announcement* stated that the pace of construction should be adjusted.[1]

The *Announcement on Further Eliminating Inefficient Capacity for Coal-fired Power Plants* sets standards for inefficient coal-fired power capacity that must be eliminated, and requires local governments to develop action plans for eliminating inefficient capacity for coal-fired power plants during the 13th Five Year Plan period.

The *Announcement on Establishing Risk Warning System for Coal-fired Power Plants Planning and Construction* (NEA, 2016e) recommends that local governments postpone the permitting of coal power projects and that corporations should make conservative decisions on the start of new coal projects.

In addition to policies controlling coal power plants, NEA relased a *Management Guideline for Electricity Planning* in June 2016 (NEA, 2016d), which was the first official guideline for electricity planning published by the government since 2003. The document designated NEA to develop national electricity plans, including regional electricity plans, and designated provincial energy departments to develop provical electricity plans. Plans will need to be harmonized both between national and provincial electricity plans and also 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.

3. Methodology

3.1. Planning Reserve Margin

The planning reserve margin (PRM) is defined as the percentage of available generating capacity (G) during an annual peak demand period in excess of peak demand (P)

$$PRM = \frac{G - P}{P}$$

Planning reserve margins should, in principle, be set using a loss-of-load probability (LOLP) model, which matches a desired loss-of-load expectation (LOLE) to a planning reserve margin

[1] However, it did not provide specific guidelines on "adjustments" (正在建设的，适当调整建设工期，把握好投产节奏).

level. However, in some instances, including in the U.S., planning reserve margin targets are used in lieu of more detailed LOLP analysis.

In China, it is unclear whether any formal analytical methods are used to evaluate and prescribe planning reserve margins. We use the North American Reliability Corporation's (NERC's) default reserve margin of 15% as a benchmark for an adequate planning reserve margin for this analysis (NERC, n.d.).

3.2. Regional Grids

The focus of the analysis in this paper is China's six regional electric grids. These grid regions were established in the early 2000s, with the dismantling of China's national State Power Corporation. Although accompanying power sector reforms were originally intended to culminate in regional power pools established around these regional grids, reforms ultimately stalled and were not restarted again until 2015. The regional grids have never been balancing areas, strictly defined, and balancing is still ultimately done at a provincial level (Kahrl and Wang, 2014). However, in the future, regional grids may be considered as balancing areas, as China aims to integrate more variable renewable generation resources into its electricity grids.

Figure 1. Regional Electric Grids in China[2]

Peak demand data for China is officially reported at a regional grid level, making this a convenient level of analysis. Using regional grids as the focus of a reserve margin analysis, however, requires assumptions that interprovincial transmission constraints and institutional limitations on generation capacity sharing across provinces do not exist, which is an aggressive

[2] Inner Mongolia is divided into west and east. The western part of the province operates an independent grid, although it is often included in the Northern Grid; the eastern part of the province is part of the Northeastern Grid.

assumption. For instance, an institutional limitation might be the lack of cost allocation mechanisms to ensure that an importing province pays a reasonable wholesale price to the generator in the exporting province. Interprovincial transmission and resource sharing constraints would tend to overstate regional reserve margin estimates. For instance, a regional reserve margin of 15% might correspond to provincial reserve margins of zero if provinces are completely isolated.[3]

There is, however, a significant amount of interprovincial transmission capacity in China, and these links could be expanded over the time horizons (five to ten years) analyzed in this paper. The question of institutional constraints to generation capacity sharing is, to a large extent, a question of political economy and political will. Thus, we use a regional reserve margin analysis to provide indicative results and useful insights.

3.3. Peak Electricity Demand Forecast

We forecast peak electricity demand (in gigawatts, GW) in 2020 and 2025 using a forecast of electricity (in gigawatt-hours, GWh) consumption and system load factors for China's regional grids. System load factors (SLFs) are defined as the relationship between system average load (SAL) and system peak load (SPL)

$$SLF = \frac{SAL}{SPL}$$

where average load is annual electricity consumption divided by 8,760 hours per year. Load factors are a convenient way to convert between electricity consumption and peak demand. Residential and commercial customers tend to have lower load factors, whereas industrial customers tend to have higher load factors.

Table 1 shows, load factors in 2014 varied significantly among grid regions in China, ranging from 69% in the less industrial Eastern Grid to 93% in the more industrial Northwestern Grid.[4]

Electricity consumption in China is currently difficult to forecast, given recent structural changes in the Chinese economy. Since 2010, the tertiary sector has been the primary driver of GDP growth, while the secondary sector GDP growth has fallen to its lowest level in the last two decades (Figure 2).

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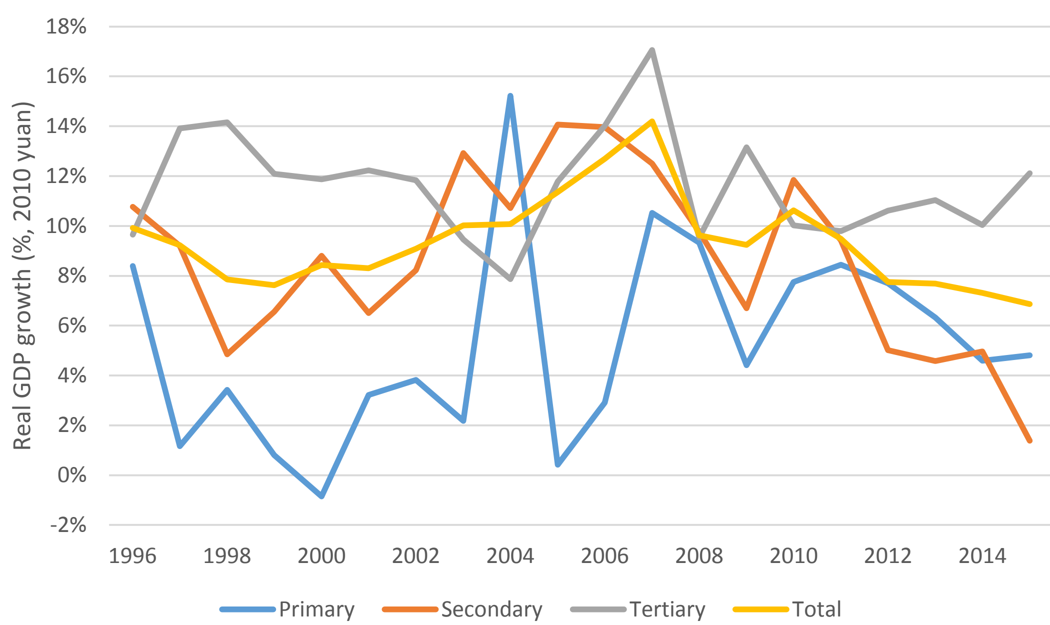
[3] For instance, consider two power systems, A and B, which have non-coincident peak demands of 10 GW (A) and 5 GW (B), and a coincident peak demand of 13 GW. A 15% reserve margin for the regional coincident peak would require 15 GW of qualified generating capacity. If A has 10 GW of generating capacity and B 5 GW, they are able to meet a 15% regional reserve margin but their individual (i.e., non-coincident) reserve margins are zero.

[4] Consumption data here, and all 2014 installed capacity by fuel type (thermal, nuclear, hydro, wind, solar, and others) for each province is from the 2015 *China Electricity Statistical Yearbook* (CEPP, 2015).

Table 1. Electricity Consumption, Peak Demand, and System Load Factors for Regional Grids in China, 2014

Grid Region	Electricity Consumption (TWh)	Peak Demand (GW)[5]	System Load Factor (%)
Central	1062.7	150.5	81%
Eastern	1332.9	220.7	69%
Northern	1305.6	192.1	78%
Northeastern	401.8	54.6	84%
Northwestern	579.3	71.5	93%
Southern	949.8	136.1	80%



[5] Here we use the CEC's "peak net generator load" (最高发受电电力) as a measure of peak within-region demand. These are "generator-side" demands, in that they already include transmission losses.

Figure 2. Real Economic Growth Rates by Sector in China, 1995 to 2015[6]

These changes in economic structure are visible in electricity consumption data. Year-on-year growth in monthly total electricity consumption fell steadily after 2010, and fell to nearly zero for most of 2015 before increasing slightly in 2016 (Figure 3). Changes in total electricity consumption were driven by the secondary sector, which experienced declining year-on-year electricity demand growth throughout much of 2015. Over the course of the year, secondary sector electricity consumption fell by 1.4% relative to 2014, with consumption by heavy industry falling by 1.9% (NEA, 2016a). Falling secondary sector GDP and electricity consumption have led to a decoupling of GDP growth and electricity consumption growth.

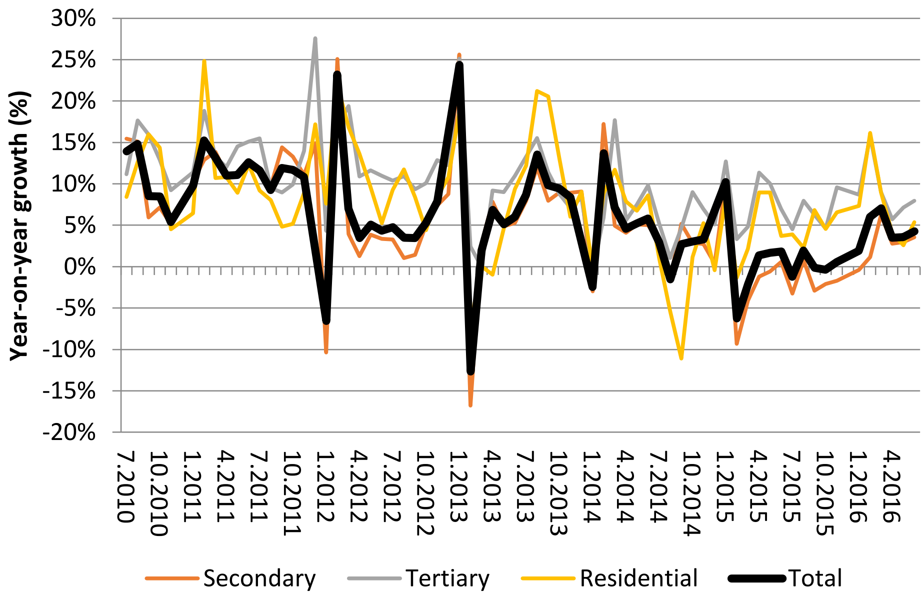


Figure 3. Year-on-Year Growth in Secondary, Tertiary, Residential, and Total Electricity Consumption, July 2010 to June 2016[7]

Changes in economic structure create a number of challenges for forecasting electricity consumption in China. Forecasts using aggregate, linear secondary and tertiary sector GDP as explanatory variables tend to overstate the individual effects of these sectors. Using non-linear explanatory variables likely provides more realistic long-term forecasts, but creates nearer-term discontinuities. Greater sectoral disaggregation could likely address these issues, but requires a larger number of assumptions about real value added growth rates by sector. For this reason, simpler regression forecasting models tend to give unsatisfactory results.

[6] Sectoral and total GDP data for year 1995 to year 2014 are from China Statistical Yearbook of Yeaar 2015. Sectoral and total GDP data for year 2015 are from Statistical Communiqué of the People's Republic of China on the 2015 National Economic and Social Development. All sectors were deflated using a national GDP deflator, from the World Bank.

[7] Data are from the CEC, http://cec.org.cn/guihuayutongji/.

For this analysis, we began with an income- and population-driven regression model of provincial electricity consumption, using real provincial GDP by aggregate sector, real household expenditure, and population as explanatory variables.[8] We aggregated these provincial electricity consumption forecasts to a regional grid level.[9] We explored a number of different functional forms.[10] However, given the difficulties described in the previous paragraph, we ultimately settled on a simpler, scenario-based approach.

In this approach, we developed scenarios of with low and high assumptions of national electricity consumption growth rates from 2015 to 2020 and 2020 to 2025, and translate these to forecasts of regional grid electricity consumption using projected regional grid shares of total consumption. These projected shares are based on our GDP-driven forecasts, described in the preceding paragraph. Interestingly, the shares do not change significantly from base year (2014) shares.

Table 2. Grid Region Shares of Total Electricity Consumption, 2014 Actual and 2020 and 2025 Projected

Grid Region	2014	2020	2025
Central	19%	20%	20%
Eastern	25%	25%	25%
Northern	23%	22%	22%
Northeastern	7%	7%	6%
Northwestern	9%	9%	9%
Southern	17%	17%	17%

For the low scenario of national electricity consumption growth rates, we assume annual average growth of 1.5% between 2015 and 2020, and 1.0% between 2020 and 2025 (Table 3). For the high scenario we assume annual average growth rates of 3.0% and 2.0%, respectively. We scale national electricity consumption to 2015 using the NEA's reported actual growth rate.

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[8] All of these data are from the China Statistical Yearbook series, accessed through China Data Online. Data for electricity consumption by sector were extracted from the Energy Balance Sheet for each province in the China Energy Statistical Yearbooks. For some provinces, electricity consumption by sector data were missing for multiple years. To fill in the gaps, we interpolated data by assuming an equal growth rate during the period of the year before the first year of missing data and the year after the last year of missing data. For one-year gaps, the growth rate was the average annual growth rate of the years immediately before and after.

[9] Inner Mongolia is a challenge in this respect because the western part of the province operates an independent grid, though it is often included in the Northern Grid; the eastern part of the province is part of the Northeastern Grid. We allocated generation capacity and demand between Western and Eastern Inner Mongolia using available historical data.

[10] More specifically, we looked at "bottom-up" specifications where we used linear and linear-log forecasts for individual sectors and then aggregated these into a regional grid total, and "top-down" specifications where we used linear and linear-log forecasts of total electricity consumption, with sectoral variables as explanatory variables.

Table 3. Low and High Scenario Assumed Annual Average Growth Rates for National Total Electricity Consumption (%/yr)

Scenario	2014-2015	2015-2020	2020-2025
Low	0.5%	1.5%	1.0%
High	0.5%	3.0%	2.0%

These assumptions lead to the 2020 and 2025 electricity consumption forecasts shown in Table 4.

Table 4. 2014 Actual and 2020 and 2025 Forecasted Electricity Consumption by Grid Region (TWh)

Grid Region	2014	Low		High	
		2020	**2025**	**2020**	**2025**
Central	1091	1204	1285	1296	1453
Eastern	1381	1536	1634	1653	1847
Northern	1311	1369	1410	1473	1594
Northeastern	397	403	411	434	464
Northwestern	520	565	592	608	669
Southern	932	1021	1076	1098	1217
National	5632	6098	6409	6562	7245

We use these consumption projections to forecast peak demand by grid region. To do so, we assume that system load factors fall by 5% (total) in each of the 2014-2020 and 2020-2025 time frames. This leads to the regional system load factors shown in Table 5.

Table 5. System Load Factors by Grid Region, Actual 2014 and Forecasted 2020 and 2025

Grid Region	2014	2020	2025
Central	81%	77%	73%
Eastern	69%	65%	62%
Northern	78%	74%	70%
Northeastern	84%	80%	76%
Northwestern	93%	88%	84%
Southern	80%	76%	72%

The values in Table 4 and Table 5 can be used to calculate regional grid peak demands, using the below equation

$$RGP = \frac{RGC}{RLF \times 8760}$$

where RGP is regional grid peak, RGC is regional grid consumption, and RLF is regional system load factor. This leads to the forecasted peak demands shown in Table 6. “National” peak demand here is the sum of regional (non-coincident) grid peak demands.

Table 6. Peak Demand by Grid Region, Actual 2014 and Forecasted 2020 and 2025 (GW)

Grid Region	2014	Low		High	
		2020	**2025**	**2020**	**2025**
Central	155	180	202	193	228
Eastern	229	268	300	288	339
Northern	193	212	230	228	260
Northeastern	54	58	62	62	70
Northwestern	64	73	81	79	91
Southern	134	154	171	166	193
National	828	944	1045	1016	1182

3.4. Effective Generation Resources

Different generation resources contribute differently to generation adequacy. Thermal (natural gas, coal, nuclear) plants, for instance, will generally be able to contribute as much as their nameplate (rated) capacity during peak system conditions. Hydropower's maximum output, and thus its contribution to generation adequacy, alternatively, will be affected by seasonal changes in precipitation, constraints imposed by water release schedules, and reservoir capacity and will be less than 100% of its rated capacity. Solar and wind generation's contribution to generation adequacy are shaped by the coincidence of incremental solar and wind generation and peak demand.

The "effective" capacity of hydro, wind, and solar power — their contribution to generation adequacy — can be assessed quantitatively using probability-based techniques. We are unaware of any such analysis for China. As a substitute, we use typical values for effective capacity of hydro, wind, and solar power in North America, shown in Table 7 (Kahrl, 2016). For simplicity, we assume that these values are constant across grid regions, which is unlikely to be the case. However, in lieu of better data, we argue that this a reasonable assumption.

Table 7. Capacity Credit Given to Hydro, Wind, and Solar Generation Resources

Region	Hydro	Wind	Solar
Central	55%	10%	30%
Eastern	55%	10%	30%
Northern	55%	10%	30%
Northeastern	55%	10%	30%
Northwestern	55%	10%	30%
Southern	55%	10%	30%

Two other adjustments to installed capacity data are necessary, to convert it to effective capacity. First, China has a significant amount of behind-the-meter thermal generation, and the extent to which this generation is able to contribute to resource adequacy is unclear. As a middle-of-the-road assumption, we assume that the share of behind-the-meter generation remains at 2014 levels (8%), that it has a load factor of 90%, and that half of it would be available to meet peak demand.[11] Second, installed capacity data in China is reported as gross, rather than net, of generator own-use, whereas effective capacity should be net of own-use. To convert gross to net generation, we use the values in Table 8.

Table 8. Generator Own-use by Resource Type[12]

Resource	Own-use
Hydro	1%
Thermal	5%
Nuclear	5%
Wind	1%
Solar	1%
Others	5%

Total effective capacity (EC) is the sum of the total gross installed capacity (IC) of each resource, multiplied by one minus its own-use (OU), multiplied by its capacity credit (CC)

$$G = \sum_i IC_i \times (1 - OU_i) \times CC_i$$

3.5. Generation Resource Forecast

Our generation resource forecast begins with 2014 generation resources by region, shown in Table 9.

Table 9. Actual Generation Resources by Grid Region in 2014 (GW)

Region	Hydro	Thermal	Nuclear	Wind	Solar	Other
Central	129.6	144.2	0	2.7	0.6	0
Eastern	26.9	221.9	10.9	6.5	3.6	0
Northern	8.1	238.6	0	34.1	4.4	0.1
Northeastern	7.7	89.9	2.0	22.5	0.5	0
Northwestern	28.3	101.7	0	23.2	14.6	0
Southern	103.5	127.0	7.2	7.7	1.0	0
National	304.0	923.2	20.1	96.6	24.7	0.2

We make two key adjustments to 2014 resources. First, we extend thermal resources to 2015, to account for the significant increase (67 GW) in online thermal generation between 2014 and

[11] 2014 values for behind the meter are based on CEC data, http://cec.org.cn/guihuayutongji/. All other values are assumed. For a more detailed discussion of these issues, see Kahrl (2016).
[12] Thermal values are based on CEC data, http://cec.org.cn/guihuayutongji/. All other values are assumed.

2015 (Table 10). We allocate these new thermal resources across grid regions using data from Myllyvirta and Shen (2016).

Table 10. Adjusted Generation Resources by Grid Region in 2014 (with Thermal Additions) (GW)

Region	Hydro	Thermal	Nuclear	Wind	Solar	Other
Central	129.6	160.5	0	2.7	0.6	0
Eastern	26.9	232.7	10.9	6.5	3.6	0
Northern	8.1	252.3	0	34.1	4.4	0.1
Northeastern	7.7	91.4	2.0	22.5	0.5	0
Northwestern	28.3	101.6	0	23.2	14.6	0
Southern	103.5	143.8	7.2	7.7	1.0	0
National	304.0	982.3	20.1	96.6	24.7	0.2

Second, we assume that current public policy goals for hydro, nuclear, solar, and wind generation capacity are met in 2020. Given the physical limitations on further hydropower development and potential social limitations on nuclear development, we assume that only solar and wind continue to expand into 2025. These values are shown in Table 11.

Table 11. Assumed Installed Capacity of Hydro, Nuclear, Solar, and Wind Generation in 2020 and 2025 (GW)

Region	2020	2025
Hydro	420	420
Nuclear	58	58
Solar	200	240
Wind	100	150

We allocate these resources to different grid regions based on each region's share of total capacity for that resource in 2014. This leads to the installed capacity forecasts for each regional grid in 2020 and 2025 shown in Table 12.

Table 12. Installed Capacity by Grid Region in 2020 and 2025 by Grid Region (GW)

2020

Region	Hydro	Thermal	Nuclear	Wind	Solar	Other
Central	179.1	160.5	0	5.5	2.4	0
Eastern	37.1	232.7	31.4	13.5	14.7	0
Northern	11.2	252.3	0	70.6	17.9	0.1
Northeastern	10.6	91.4	5.8	46.5	2.0	0
Northwestern	39.0	101.6	0	48.0	59.1	0
Southern	143.0	143.8	20.8	15.9	4.0	0
National	420.0	982.3	58.0	200.0	100.0	0.2

2025

Region	Hydro	Thermal	Nuclear	Wind	Solar	Other
Central	179.1	160.5	0	6.6	3.6	0
Eastern	37.1	232.7	31.4	16.2	22.0	0
Northern	11.2	252.3	0	84.7	26.9	0.1
Northeastern	10.6	91.4	5.8	55.9	3.0	0
Northwestern	39.0	101.6	0	57.6	88.6	0
Southern	143.0	143.8	20.8	19.1	5.9	0
National	420.0	982.3	58.0	240.0	150.0	0.2

Combining the capacity credits in Table 7, assumptions about behind-the-meter generation, own-use values from Table 8, and the installed capacity values in Table 9 and Table 12 gives the total effective capacity values shown in Table 13.

Table 13. Total Estimated Effective Capacity Values by Grid Region in 2014, 2020, and 2025 (GW)

Region	2014	2020	2025
Central	173.2	216.5	216.9
Eastern	255.1	294.4	296.8
Northern	237.2	259.6	263.6
Northeastern	89.5	99.0	100.2
Northwestern	106.5	127.9	137.6
Southern	183.8	235.9	236.8
National	1054.0	1241.9	1260.7

These values can then be directly compared against the peak demand values in Table 6.

4. Results

Our analysis shows that at the end of 2014, the reserve margin for China as a whole was roughly 28%, almost twice as high as a typical planning reserve margin in the U.S.[13] However, this national average masks huge variations in reserve margins across major regional power grid areas: the northeastern region has the highest reserve margin of over 60%, followed by the northwestern region at 49%, and the southern grid area at 35%.

[13] "National" reserve margin here refers to national resources relative to the non-coincident peaks of the grid regions, and is a useful heuristic for understanding resource adequacy across grid regions. However, "national resource adequacy" is not a meaningful concept in and of itself, given that loads and resources in China are balanced at a provincial level.

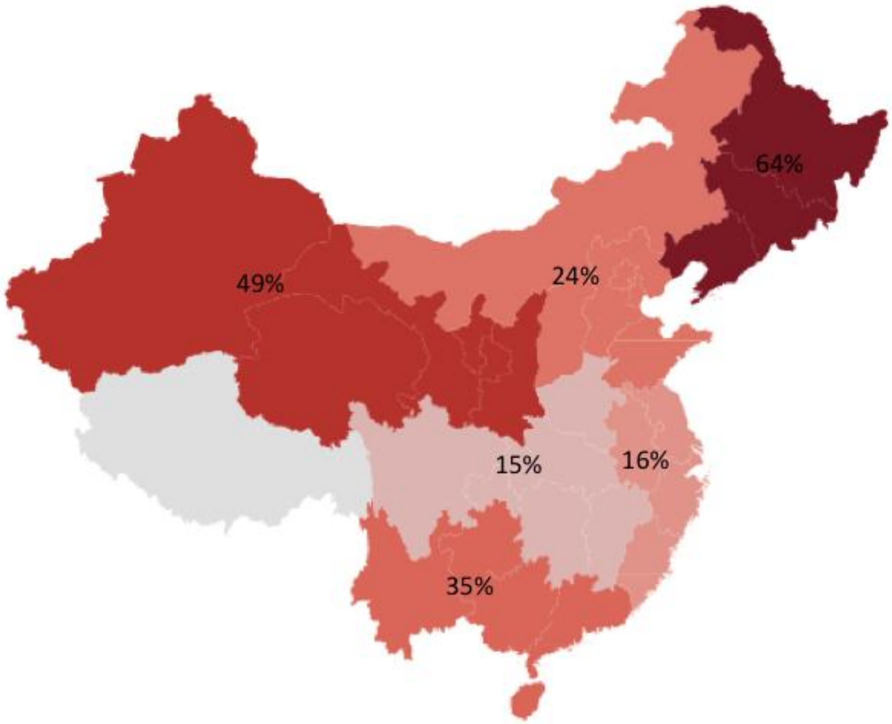

Figure 4. Actual Reserve Margin in 2014

Power generation overcapacity has increased since 2014, as China added significant new generation capacity in 2015. Based on preliminary data, the national average reserve margin increased to 38% at the end of 2015.

Based on the two scenarios of electricity demand growth described in the previous section, we calculate regional and national reserve margins for 2020 and 2025, shown in the table below by scenario.

Table 14. Planning Reserve Margins by Region, China (2020-2025)

		Low Growth Scenario		High Growth Scenario	
	2014	**2020**	**2025**	**2020**	**2025**
Central	15%	21%	8%	12%	-5%
Eastern	16%	10%	-1%	2%	-12%
Northern	24%	22%	15%	14%	1%
Northeastern	64%	72%	62%	59%	43%
Northwestern	49%	74%	70%	62%	50%
Southern	35%	53%	39%	42%	23%
National	28%	32%	21%	22%	7%

Under the high growth scenario, China's national reserve margin would fall to 22% by 2020. The northwestern, northeastern, and southern regions would continue to have large amount of overcapacity by 2020, which continues throughout 2025. However, the eastern, central, and northern regions would need additional imports from other regions or new generation capacity by 2020.

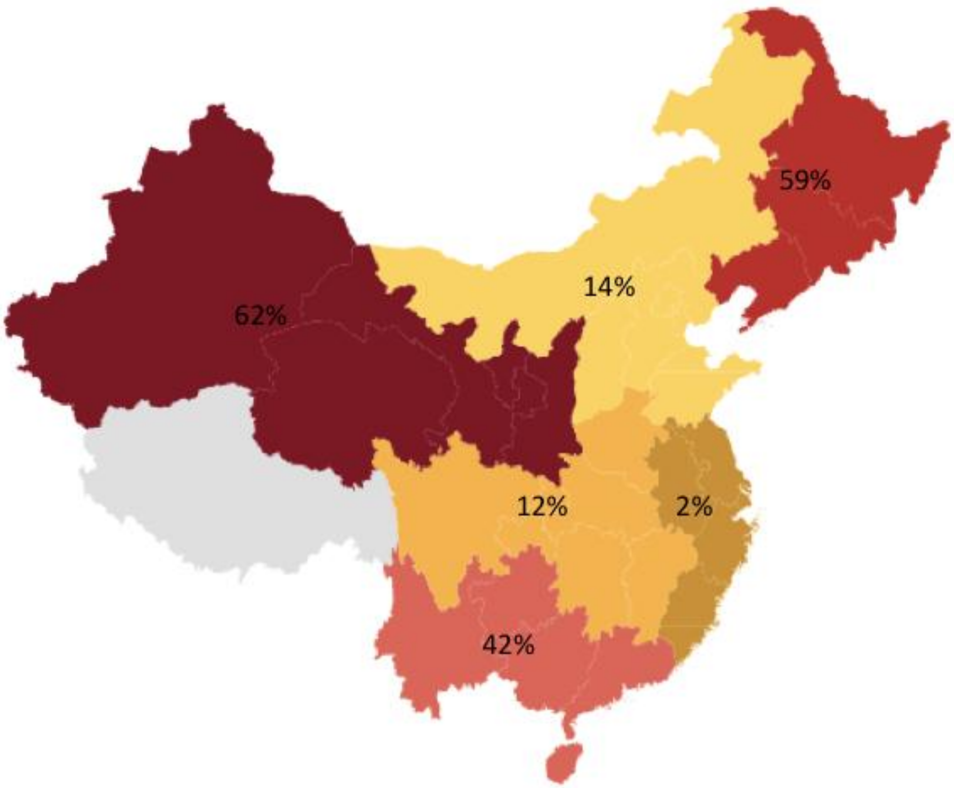

Figure 5. Planning Reserve Margin in 2020 under the High Growth Scenario

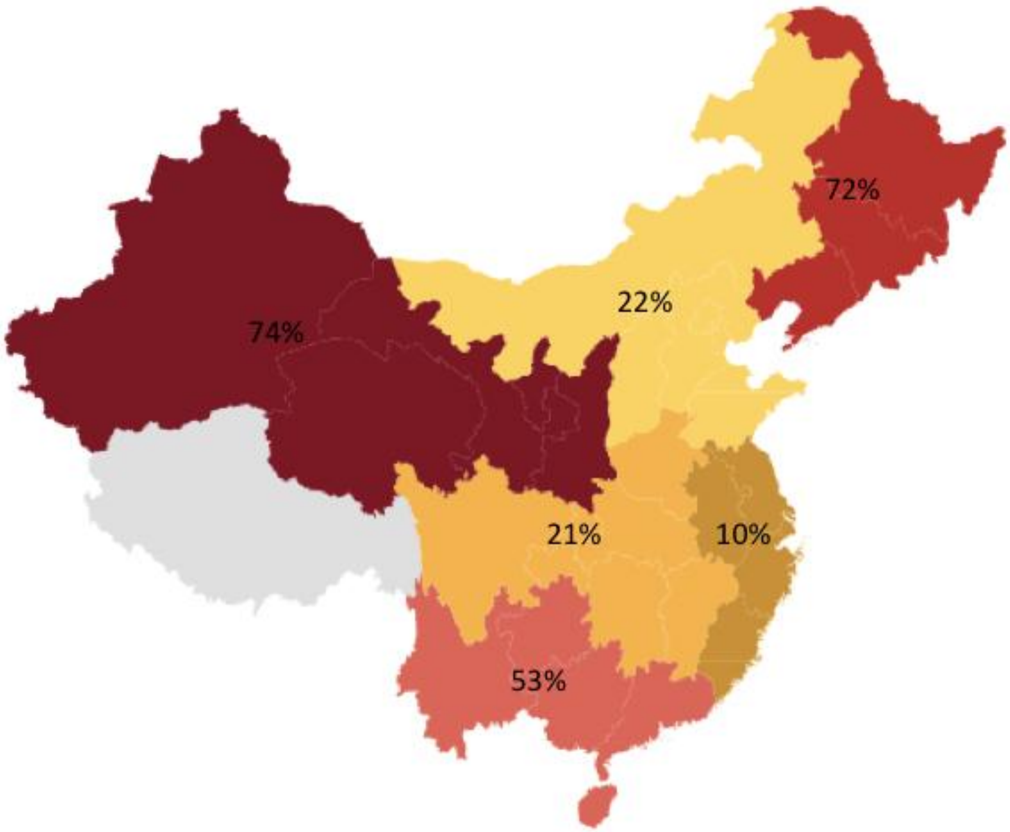

Figure 6. Planning Reserve Margin in 2020 under the Low Growth Scenario

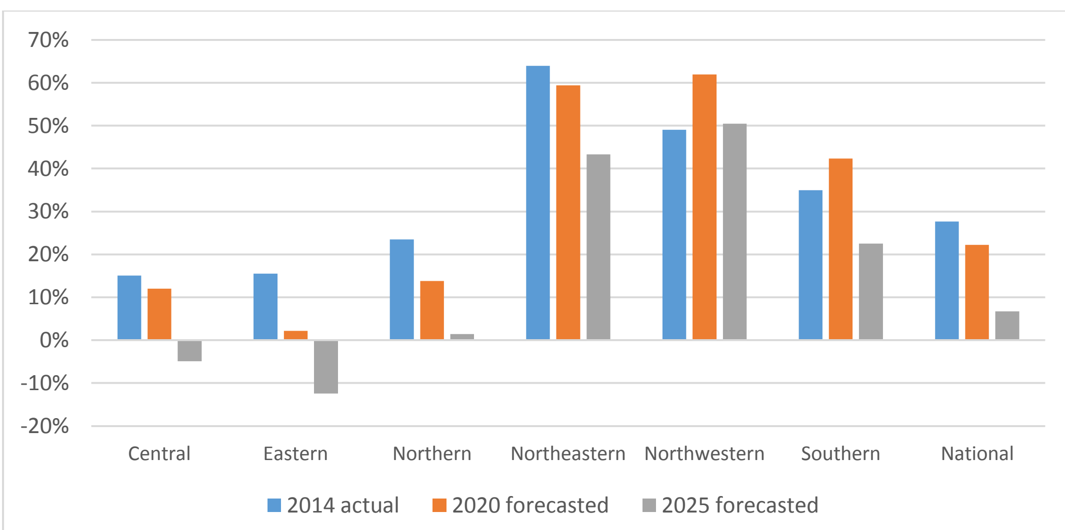

Figure 7. Regional Grids and National Average Reserve Margins under High Growth Scenario

Under the low growth scenario, the national average reserve margin would grow to 32% by 2020, and would remain at 21% by 2025. Overcapacity in the northeastern, northwest, and southern regions would be even more pronounced than in the high growth scenario, becoming a multi-decadal problem. The central and northern regions would have sufficient generation capacity through 2020, and in the northern region's case through 2025. The eastern region would need additional imports from other regions or new generation capacity by 2020.

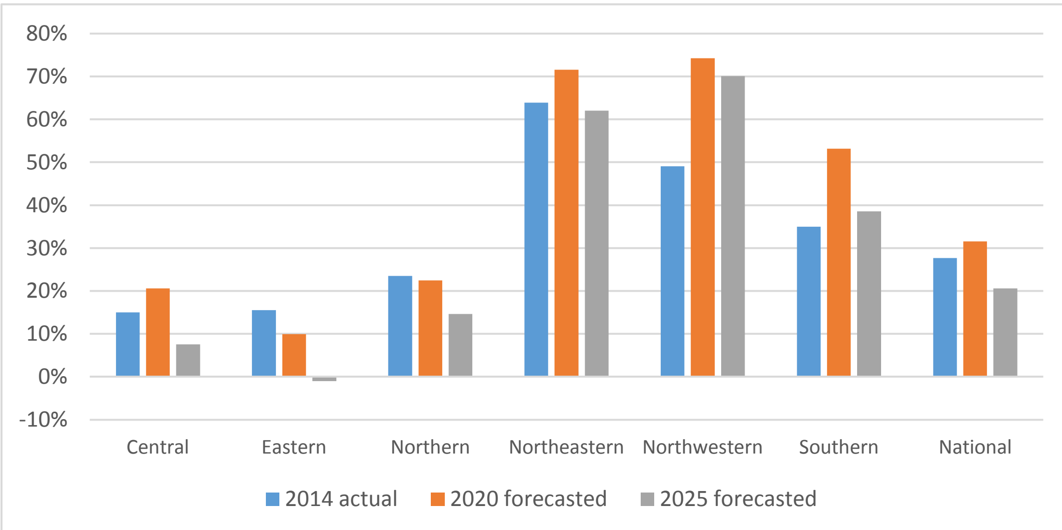

Figure 8. Regional Grids and National Average Reserve Margins under Low Growth Scenario

5. Discussion and Conclusions

In this analysis, we examined current and future reserve margins for regional electricity grids in China under two scenarios of national electricity consumption growth rates. In general, China has more than enough power plants to meet electricity demand, and does not need any new power plants for reliability purposes. China may need certain clean generation technologies, such as wind and solar, to meet its climate goals under the Paris Agreement, and domestic air quality goals. It may also need more flexible technologies to integrate more renewable power into the grid. However, in most grid regions, there is clearly an oversupply of power. Both scenarios suggest that the northeastern, northwestern, and southern regions have significant excess generation capacity, and that this situation will continue over the next decade without regulatory intervention. The northern and central regions could have sufficient generation capacity to 2020, but may require additional resources in a higher growth scenario. The eastern region requires new resources by 2020 in both scenarios.

The large discrepancies in reserve margins among grid regions suggests the importance of greater coordination among grid regions in providing for generation adequacy across China. The eastern and central regions' potential shortfalls, for instance, would be most cost-effectively supplied by using existing resources in the southern region. The northern region's shortfalls could be supplied through imports from the northwest and northeast. Greater coordination in generation adequacy across grid regions would require mechanisms for cost allocation, such as bilateral contracts. An expansion of bilateral exchange across grid regions has been part of the NDRC's proposed power sector reform framework.

The results suggest that China does not need new thermal power, or at least not new baseload coal units, before 2020 and potentially not until 2025. This finding underscores the critical importance of improving the investment planning processes in China to avoid making the current overcapacity problem worse. Although the central government has recently taken a number of steps to address overcapacity in power generation, a careful reading of the three Annoucements released in April 2016 (described in the Backgroud section of this paper) raise a number of concerns:

- First, these policies only cover a limited number of provinces, where overcapacity seems to be a more widespread phenomenon.
- Second, these policies mostly target projects that are waiting for approval or are in the pre-construction phase. No strong recommendations were made regarding projects already under construction, of which there are a significant number.
- Third, co-generation projects for "people's livelihood" (district heating) are not covered under these policies, so it is possible more plants would be built as co-generation units than neccessary.
- Fourth, and potentially more serious, is that the Annoucements only restrict the construction of coal-fired power plants for self-use. This implies that many projects associated with coal-bases that are largely built for exporting electricity to other provinces, not for self-use by provinces, are excluded from this policy. Currently, many of the proposed coal power plants are in such coal-bases.

Given the extent and potential cost of generation overcapacity, addressing these issues in the planning and project approval processes is imperative to avoid unneccessary investment on coal-fired power plants, and to minimize costs of power.

The question of what non-coal generation resources are needed by 2020 and 2025 in China is in critical need of an answer. Current levels of coal-fired generation may already be too high relative to least-cost and environmental planning goals, requiring additional investments in non-coal resources. This current window of overcapacity provides a useful respite to examine this question with greater rigor, and highlights the importance of strengthening electricity planning processes and methods in China, as well as refinement of China's regulatory governance structure and operating practices.

More specifically, in considering near-term steps to address electricity resource needs in China, we suggest that government agencies prioritize four key areas:

- More stringent policies, regulations, and mechanisms to halt the construction of new coal-fired generating units, including changes to their incentives;[14]

[14] As this paper was being finalized, the NEA issued an new guildeline to stop new coal power plant construction. In addition, NDRC (NDRC, 2016c) issued an opinion on generation planning in 2016, requiring that new coal plants

- A more scientific and workable planning process for the electricity sector that: (a) better coordinates among different geographic and administrative levels (provincial, regional, central) and across different resources (generation, demand-side, transmission), (b) uses economic evaluation methods and a scenario-based approach to forecasting and risk management, and (c) has clearer links between planning and investment decisions;
- Explicit consideration of the potential to use, and option value of using, energy efficiency and demand response to meet longer-term generation capacity needs, lengthening the window of time in which the government can design and implement reforms before new generation resources are needed; and
- The continued development of markets and regulatory institutions that facilitate economic dispatch, ideally across regions, which will in turn support longer-term resource adequacy by enabling greater sharing of generation resources across provinces.

online after March 2017 not be included in the annual operating hour planning process, which will address an important shortcoming in incentives for coal-fired generation.

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