中国电力圆桌
POWER SECTOR ROUNDTABLE

Policy Brief

Power Sector Planning:
US Experience and Recommendations for China

Power Sector Roundtable Working Group

November 2017

Power Sector Roundtable (PSR)

NRDC launched the Power Sector Roundtable (PSR) in 2015, aiming at addressing climate change and supporting China's efforts in power sector low-carbon transition. PSR provides an open platform for dialogues within a diverse group of policymakers, industry experts, researchers, and NGO representatives. As the current round of Chinese power sector reform involves a wide spectrum of stakeholders representing a multitude of perspectives and interests, the Power Sector Roundtable was designed from its inception as a forum and an ongoing channel for discussion of critical and contentious reform issues. These exchanges and analyses will inform policymakers with an on-the-ground picture of the effects of the reform across industrial sectors, and in turn, support policy implementation.

Power Sector Roundtable Working Group

NRDC

The Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 3 million members and online supporters. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC works in countries and regions including the United States, China, India, Canada, Mexico, Chile, Costa Rica, and the European Union.

RAP®

The Regulatory Assistance Project (RAP)® is an independent, non-partisan, non-governmental organization dedicated to accelerating the transition to a clean, reliable, and efficient energy future. We help energy and air quality regulators and NGOs navigate the complexities of power sector policy, regulation, and markets and develop innovative and practical solutions designed to meet local conditions. We focus on the world's four largest power markets: China, Europe, India, and the United States. Visit our website at www.raponline.org to learn more about our work.

1 Introduction

Institutions and practices for power sector planning are the foundation for cost-effective investment and environmental sustainability. Indeed, Document #9 emphasizes the importance of reform planning. The main challenge is to shift the Chinese power sector away from the old model, in which meeting rapid demand growth was the prime consideration, and toward a model that gives careful consideration of complex trade-offs and multiple targets, including China's goals for renewable energy, environmental quality, affordability, and reliability. The National Energy Agency's (NEA) June 2016 Power Sector Planning Regulation is a very good step toward this framework.[1]

The challenge now is to flesh out this new framework—and ensure that planning is well coordinated with markets and other aspects of power sector reform, particularly China's new electricity markets. To this end, the NEA regulation includes the principle that "market mechanisms" are to be used to procure the resources, in line with "guidance" provided by the plan.[2] This is certainly in line with the broad experience in other countries. For example, even in parts of the United States that have implemented electricity markets, planning still plays an essential role in evaluating resource adequacy, informing the need for adjustments to market design, and helping to coordinate investments in generation with those in transmission and demand-side resources.

Looking more closely at China's current situation, we see four major interrelated challenges that improvements in planning can help resolve:

- Generation overcapacity. Most provinces in China currently have excess generation capacity relative to electricity demand; most regions currently have between 10% and 40% more generation capacity than what is needed to meet peak electricity demand (including a reasonable reliability margin).[3]
- Achieving air quality goals. By 2030, all cities in China will be required to meet a national PM2.5 standard of 35 micrograms per cubic meter (annual average). Ozone regulation and control will also be an increasingly important consideration for urban areas. The electricity sector can play a significant role in reducing these pollutants.

1 National Energy Agency (2016). Power Sector Planning Regulation, Document 139. Retrieved from: http://zfxxgk.nea.gov.cn/auto84/201606/t20160606_2258.htm.

2 See Article 38 of NEA Document 139.

3 Lin, J., et al. (2016). Excess Capacity in China's Power Systems: A Regional Analysis. Ernest Orlando Lawrence Berkeley National Laboratory. Retrieved from: https://eta.lbl.gov/sites/all/files/publications/lbnl1006638.pdf. Also see: Kahrl, F. (2016) Coal Fired Generation Overcapacity in China, Quantifying the Scale of the Problem: A Discussion Draft. Regulatory Assistance Project. Retrieved from: http://www.raponline.org/wp-content/uploads/2016/05/rap-coalcapacitychina-2016-feb.pdf.

- Meeting greenhouse gas targets. The 13th Five-Year Plan establishes a goal of reducing the CO_2 intensity of China's economy by 18% below 2015 levels by 2020. By 2030, China has committed to achieve a peak in total CO_2 emissions. Achieving the latter goal will require expanding non-fossil fuel generation to around 40% of total generation (from 29% in 2015) by 2030.[4]

- Integrating variable renewable generation. Rising penetrations of wind and solar generation have strained provincial grids in China, contributing to levels of wind and solar curtailment that are much higher than those found in other countries. Wind curtailment exceeds 20% in five of China's six largest wind generating provinces, compared to a typical rate of less than 5% in the United States.[5]

Based on a review of experiences in the United States, we suggest five areas of planning that would benefit from attention in China: (1) clarification of planning roles and responsibilities among government agencies and between government agencies, grid companies, generating companies, and other entities; (2) clarification of the role of planning in investment decision-making; (3) mechanisms for coordinating various investment options (demand-side resources, generation, storage, and transmission) in order to identify least-cost resources; (4) continued development and application of quantitative modeling tools; and (5) the incorporation of risk management into planning analysis and investment decision-making.

4 See, for instance, Liu, Q., et al. (2015). Peaking China's CO2 Emissions: Trends and Mitigation Potential. Open Climate Network Working Paper. Retrieved from: http://www.wri.org/sites/default/files/uploads/WRI15_OCN_Peaking_Emissions_v4.pdf. Data on the share of non-fossil fuel generation are from the China Electricity Council (CEC), retrieved from: http://www.cec.org.cn/.

5 Wind curtailment data for China are from: National Energy Administration (NEA). (2015). Development of the Wind Industry. (2015年风电产业发展情况). Retrieved from: http://www.nea.gov.cn/2016-02/02/c_135066586.htm. "Largest wind generating provinces" here is measured as a percentage of total generation. For more on wind curtailment in the US, see: US Department of Energy (DOE). (2015). 2014 Wind Technologies Market Report. Retrieved from: http://energy.gov/sites/prod/files/2015/08/f25/2014-Wind-Technologies-Market-Report-8.7.pdf. For more on the drivers of curtailment in China, see Kahrl, F., and Wang, X. (2014). Integrating Renewable Energy into Power Systems in China: A Technical Primer—Power System Operations. RAP White Paper. Beijing, China: The Regulatory Assistance Project. Available at: http://www.raponline.org/wp-content/uploads/2016/05/rap-e3chinapowersystemoperations-final-2014-dec-24.pdf

2 US Experience with Electricity Planning

Parts of the United States are facing challenges that have some similarities to those in China: overcapacity, achieving environmental goals, and integrating variable renewable generation.[6] The US experience with electricity planning processes and economic methods could provide a useful reference for China.

2.1 Electricity Planning Processes in the US

The US experience has found that well-functioning planning processes are essential to addressing many of the kinds of planning challenges that are being faced in China. The development of these processes for electricity planning in the United States has involved identifying:

- How to integrate environmental targets and other public policy goals into the planning process.
- Which organizations are responsible for developing different kinds of plans.
- How local and regional planning should interact.
- When, how, and which stakeholders will be able to participate in the planning process.
- How state and federal regulators oversee plans produced by regulated entities.
- How different regulators—for instance electricity and air quality—coordinate within the planning process.
- How plans will affect investment, retirement, and approval decisions.

Table 1 outlines the kinds of questions addressed by planning processes in the United States. The institutions involved in planning vary across different regions, depending in part on whether the region[7] is part of an ISO/RTO market.[8] Coordinating among these different planning processes is a "best practice" in the United States—for instance, the inputs used in resource, transmission, and distribution planning should be consistent to ensure that planning outcomes are consistent.

6 For an overview of emerging electricity planning challenges in the US, see Kahrl, F., Mills, A., Lavin, L., Ryan, N., and Olson, A. (2016). The Future of Electricity Resource Planning. US Department of Energy Future Electric Utility Regulation Series. Retrieved from: https://emp.lbl.gov/sites/all/files/lbnl-1006269.pdf

7 "Region" here refers to either a state or a utility service territory.

8 ISO/RTO refers to "regional transmission organization and independent system operator." See article on "Electricity Wholesale Markets" in this series for a description of ISOs/RTOs and their significance.

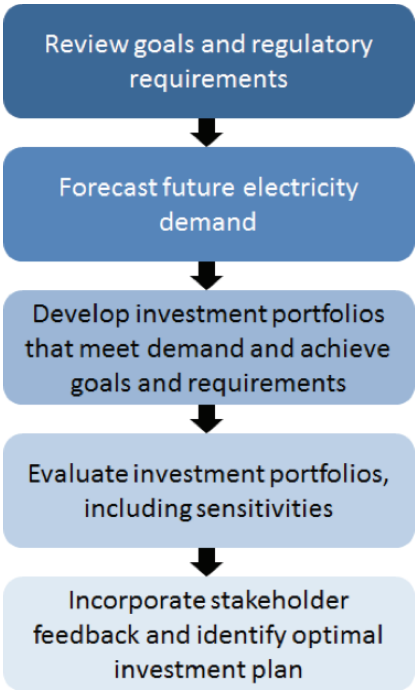
Table 1. Questions Addressed and Key Participants in the United States

Question Type	Questions Addressed	Key Participants	
		Non-ISO/RTO	ISO/RTO
Distributed energy resource (DER)	What level of DER investment is cost-effective, relative to investments in other resources? Which kinds of DER resources are most cost-effective?	Utility, state agencies	State agencies, utilities
Resource adequacy and resource investment	How much generation capacity and demand-side resources are needed to maintain future grid reliability, given forecasted electricity demand? What portfolio of resources best balances costs and risks? How should market mechanisms design be adjusted to ensure needed capacity materializes and unneeded capacity is retired in a rational manner?	Utility, state agencies	System operator, state agencies, utilities
Wind and solar integration	What operational changes, operating costs, and transmission investments will be needed to accommodate different penetrations of wind and solar generation?	Utility, state agencies	System operator, utilities
Transmission	How much transmission capacity is needed—and where—to maintain grid reliability, minimize generation costs, and meet public policy goals, including goals associated with renewable energy?	Utility, state agencies	System operator, utilities
Distribution	When and where are investments needed in the distribution system to maintain operating margins; where can investments be deferred?	Utility, state agencies	Utilities, state agencies, system operator
Environmental	How to meet targets for air quality, including integrated consideration of multiple pollutants, in an integrated and least-cost fashion?	Utility, state agencies	State agencies

Figure 1 offers a conceptual outline of the approach to planning in the United States. This process begins with a load forecast and an evaluation of regulatory requirements (e.g., reliability standards, emissions standards) and public policy goals (e.g., energy efficiency and renewable energy goals) that will affect plans. Based on that foundation, planners then develop and evaluate the economics of potential investment portfolios, often subjecting them to sensitivity analysis. The ensuing plan—which identifies new investment projects and sometimes retirement decisions—seeks to meet reliability and environmental objectives at least-cost and, in the best-practice cases, least-risk. Plans are typically released to stakeholders for comment before being finalized.

This concept of "least-risk" is worth emphasizing. Ideally, planning should include careful assessment of uncertainty and risk when comparing investment options. Sources of uncertainty and risk in the United States include: demand forecasts, fuel costs, investment costs, construction delays, changes in regulation, and emissions (SO_2, NOX, CO_2) prices. Additionally, planners may consider changes in policy or regulation that have yet to be decided or implemented—for example, foreseeable tightening of emission regulations.[9]

Figure 1. Typical Process for Electricity Investment Planning



Planners and regulators coordinate among the different types of planning. For instance, utility energy efficiency plans are often required to incorporate up-to-date information on generation, transmission, and distribution costs, so that utilities and regulators can identify cost-effective levels of energy efficiency investments. RTO transmission plans attempt to incorporate the most up-to-date information on proposed generation investments, retirements, and demand in order to identify transmission upgrades that incrementally improve reliability or reduce costs. Ensuring this kind of integrated planning requires a significant amount of effort, but can help to identify lower-cost options for meeting electricity demand and environmental goals. [10]

---

9 See Binz, R., Sedano, R., Furey, D., and Mullen, D. (2012). Practicing Risk-Aware Regulation: What Every State Regulator Needs to Know. Retrieved from: http://www.raponline.org/knowledge-center/practicing-risk-aware-electricity-regulation-what-every-state-regulator-needs-to-know/

10 See Wilson, R., and Biewald, B. (2013). Best Practices in Electric Utility Integrated Resource Planning. Montpelier, VT: The Regulatory Assistance Project. Retrieved from: http://www.raponline.org/document/download/id/6608/ and also Section 2.3 of the following, (available in English): Dupuy, M., Allen, R., Crossley, D., Kahrl, F., Porter, K., Weston, R., and James, C. (2014). Low-Carbon Power Sector Regulation: International Experience from Brazil, Europe, and the United States. Beijing, China: The Regulatory Assistance Project. Retrieved from http://raponline.org/document/download/id/7432 and Chinese: http://www.raponline.org/document/download/id/7482

Planning frequency and time horizons vary across different types of plans and industry structures. Table 2 shows the examples of California and the PJM region. In California, the state regulator—the California Public Utilities Commission (CPUC)—has jurisdiction over resource adequacy, and coordinates an investment planning process across the state's investor-owned utilities to identify long-term resource needs. The utilities are then required to procure new resources, subject to further approval, in accordance with the long-term procurement plan. The California Independent System Operator (CAISO) oversees a separate transmission planning process.

PJM undertakes resource adequacy and transmission planning processes for its member load serving entities,[11] but these load serving entities vary significantly in the additional planning they do and the time horizons for this additional planning. All of the plans in Table 2 are undertaken by regulated entities and subject to either federal or state regulatory oversight.

Table 2. Planning Organizations and Planning Characteristics in PJM and CAISO Planning in PJM[12]

Organization	Plan	Coverage	Organization Type	Frequency of Update	Planning Horizon
Dominion Power	Integrated Resource Plan	Virginia only	Vertically integrated utility	Annual	25 years
PECO Energy Company	Default Service Program Petition [13]	Pennsylvania only	Default service provider	Annual	2 years
PJM	Regional Transmission Expansion Plan	PJM region-wide	System operator	Annual	10 years
	Resource Adequacy Plan	PJM region-wide	System operator	Annual	3 years

Planning in California

Organization	Plan	Organization Type	Frequency of Update	Planning Horizon
CPUC	Long-term Procurement Plan	State regulator	Biennial	10 years
	Resource Adequacy	State regulator	Annual	1 year
PG&E	Bundled Procurement Plan [14]	Utility	Biennial	10 years
California Independent System Operator	Transmission Plan	System operator	Annual	10 years

11 PJM's member load-serving entities include vertically integrated utilities and default service utilities in states within PJM that have retail competition.

12 Virginia and Pennsylvania are two of the states within the PJM region and are offered here as examples of the variation within the PJM region.

13 This petition is for approval of PECO Energy Company's retail tariff for its default service customers. As part of the petition, PECO provides an overview of its procurement strategy.

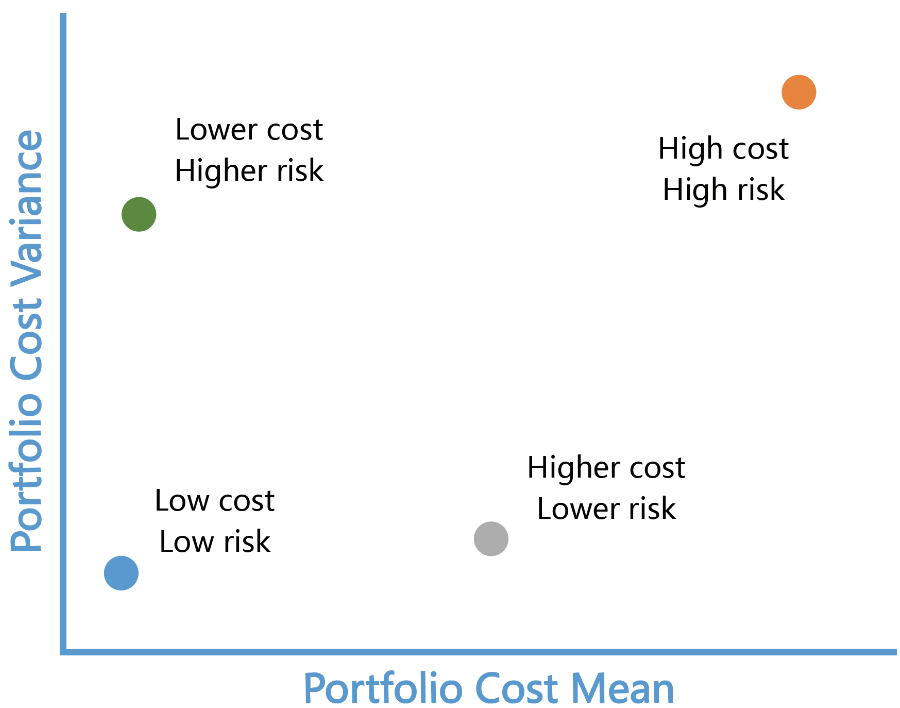
14 This "bundled procurement plan" is an overview of investor-owned utilities' strategy for procuring energy and managing energy-related risk. By approving the strategy, the CPUC effectively approves the procurement plan.

2.2 Quantitative Planning Methods in the US

Quantitative analyses used in planning processes in the United States include the following:

- Reliability models, which are used to estimate system-wide and local planning reserve margins corresponding to a desired loss-of-load-expectation (LOLE) target, and to determine capacity credits for wind, solar, and run-of-river hydropower resources. Planning reserve margins are then used to determine the total amount of installed capacity needed to meet this target.
- Capacity expansion models, which are used to determine least-cost portfolios of generation, demand-side, and transmission resources needed to meet future planning reserve margins and plant-level or regional air quality and CO_2 emissions standards.
- Production simulation models, which are used to examine the economic and physical performance of different resource portfolios.
- Some utilities use capacity expansion and production simulation models in tandem to conduct sophisticated risk analysis. These utilities use capacity expansion models to identify least-cost portfolios that meet reliability and environmental constraints under a range of scenarios that feature varying assumptions regarding demand growth, regulatory requirements, and fuel costs. These portfolios are then subjected to more detailed production simulation modeling, using sensitivity (Monte Carlo) analysis to generate a distribution of possible costs.

Figure 2. Visualization of Results from Resource Portfolio Risk Analysis



This resource portfolio risk analysis generates an expected (mean) cost and variance for each portfolio, which enables an evaluation of portfolio risk. Figure 2 visualizes potential results from this analysis. Portfolios that have low expected costs but high variance may be too risky, whereas portfolios that have low variance but high expected costs may be too expensive. Through this process, planners seek to identify portfolios that have low expected costs (low-cost) and low variance (low-risk).

Use of quantitative analysis can provide important insights and guide decision-making, but it does not replace the role of judgment in planning and always requires a clear process for how the results will be used.

3 Conclusions and Questions for Further Research and Discussion

The importance of electricity planning has long been recognized in China. Planning was given a central role in the 1995 Electricity Law. More recently, the National Energy Administration's (NEA's) 2016 Methods for the Management of Electricity Planning (电力规划管理办法) emphasizes the importance of electricity planning for supporting science-based decision-making and prescribes new planning processes, roles, and responsibilities.[15] However, many important details have yet to be decided. The diversity of planning processes in the US electricity sector could provide a useful reference for China.

Quantitative tools could play a more important role in supporting scientific decision-making in China's electricity sector, particularly through more rigorous economic assessment. An important consideration is how these tools are used in decision-making processes. The United States has a long history of developing and using economic analysis tools in electricity planning processes, and the design and use of these tools could be a useful reference for China.

We suggest five areas that would benefit from attention in China:

- Clarification of planning roles and responsibilities, including the roles and responsibilities of different government agencies (e.g., energy, electricity, environment, industry, housing) and the roles of different electricity suppliers (e.g., grid companies, generating companies, retail providers).
- Clarification of the role of planning in investment decision-making, in particular how the results from planning processes are used in decision-making about investments and retirements.
- Mechanisms for coordinating across different electricity planning processes, to ensure that different planning processes are identifying least-cost portfolios of generation, DER, transmission, bulk storage, and distribution resources.
- Continued development of quantitative modeling tools, increasing the rigor and authoritativeness of planning analysis, while at the same time promoting transparency.
- Incorporation of uncertainty analysis and risk management into planning analysis and investment decision-making, to manage the considerable uncertainty in, and risks associated with, variation in electricity demand, coal and natural gas fuel costs, renewable generation costs, and transmission capacity availability.

15 National Energy Administration (2016).

4 References and Further Reading

Clean Air Alliance of China (CAAC). (2016a). How to Achieve the Air Quality Attainment in the Beijing, Tianjin and Hebei Region? Studies on Reaching PM2.5 Standard in the Beijing-Tianjin-Hebei Region Based on Scenario Analysis. Retrieved from: http://en.cleanairchina.org/product/7695.html

Clean Air Alliance of China (CAAC). (2016b). How to Achieve the Air Quality Attainment in the Yangtze River Delta Region? Scenario Analysis for Reaching PM2.5 Standard in Shanghai, Jiangsu and Zhejiang. Retrieved from: http://en.cleanairchina.org/product/7759.html

US Department of Energy (DOE). (2015). 2014 Wind Technologies Market Report. Retrieved from: http://energy.gov/sites/prod/files/2015/08/f25/2014-Wind-Technologies-Market-Report-8.7.pdf

Kahrl, F. (2016). Coal-Fired Generation Overcapacity in China: Quantifying the Scale of the Problem. Discussion Draft. Retrieved from: http://www.raponline.org/knowledge-center/coal-fired-generation-overcapacity-in-china/

Kahrl, F., Mills, A., Lavin, L., Ryan, N., and Olson, A. (2016). The Future of Electricity Resource Planning. US Department of Energy Future Electric Utility Regulation Series. Retrieved from: https://emp.lbl.gov/sites/all/files/lbnl-1006269.pdf

Kahrl, F., and Xuan, W. (2014). Integrating Renewable Energy into Power Systems in China: A Technical Primer—Power System Operations. Beijing, China: The Regulatory Assistance Project. Retrieved from: http://www.raponline.org/wp-content/uploads/2016/05/rap-e3chinapowersystemoperations-final-2014-dec-24.pdf

Kahn, E. (1988). Electric Utility Planning & Regulation. American Council for an Energy Efficient Economy.

Lin, J., Liu, X., and Kahrl, F. (2016). Excess Capacity in China's Power Systems: A Regional Analysis. Lawrence Berkeley National Laboratory. Retrieved from: https://china.lbl.gov/sites/all/files/lbnl1006638.pdf

Liu, Q., Chen, Y., Zheng, C. T. X., Teng, F., Gu, A., Yang, X., Wang, X., Matthews, E., and Song, R. (2015). Peaking China's CO2 Emissions: Trends and Mitigation Potential. Open Climate Network Working Paper. Retrieved from: http://www.wri.org/sites/default/files/uploads/WRI15_OCN_Peaking_Emissions_v4.pdf

National Energy Administration (NEA). Methods for the Management of Electricity Planning 《电力规划管理办法》. Retrieved from: http://zfxxgk.nea.gov.cn/auto84/201606/P020160606511645707541.pdf

US Environmental Protection Agency. (2015). Energy and Environment Guide to Action: State Policies and Best Practices for Advancing Energy Efficiency, Renewable Energy, and Combined Heat and Power, 2015 Edition. Retrieved from: https://www.epa.gov/sites/production/files/2015-08/documents/guide_action_full.pdf

Wilson, R., and Biewald, B. (2013). Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans. Montpelier, VT: The Regulatory Assistance Project. Retrieved from: http://www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf

Recycled paper.

中国电力圆桌
POWER SECTOR ROUNDTABLE

Natural Resources Protection Association
Taikang finance building, No. 38, East sanhuan North Road,
Chaoyang District, China, 1706
P.C. :100026
Tel. :+86-10-5927 0688
www.nrdc.cn