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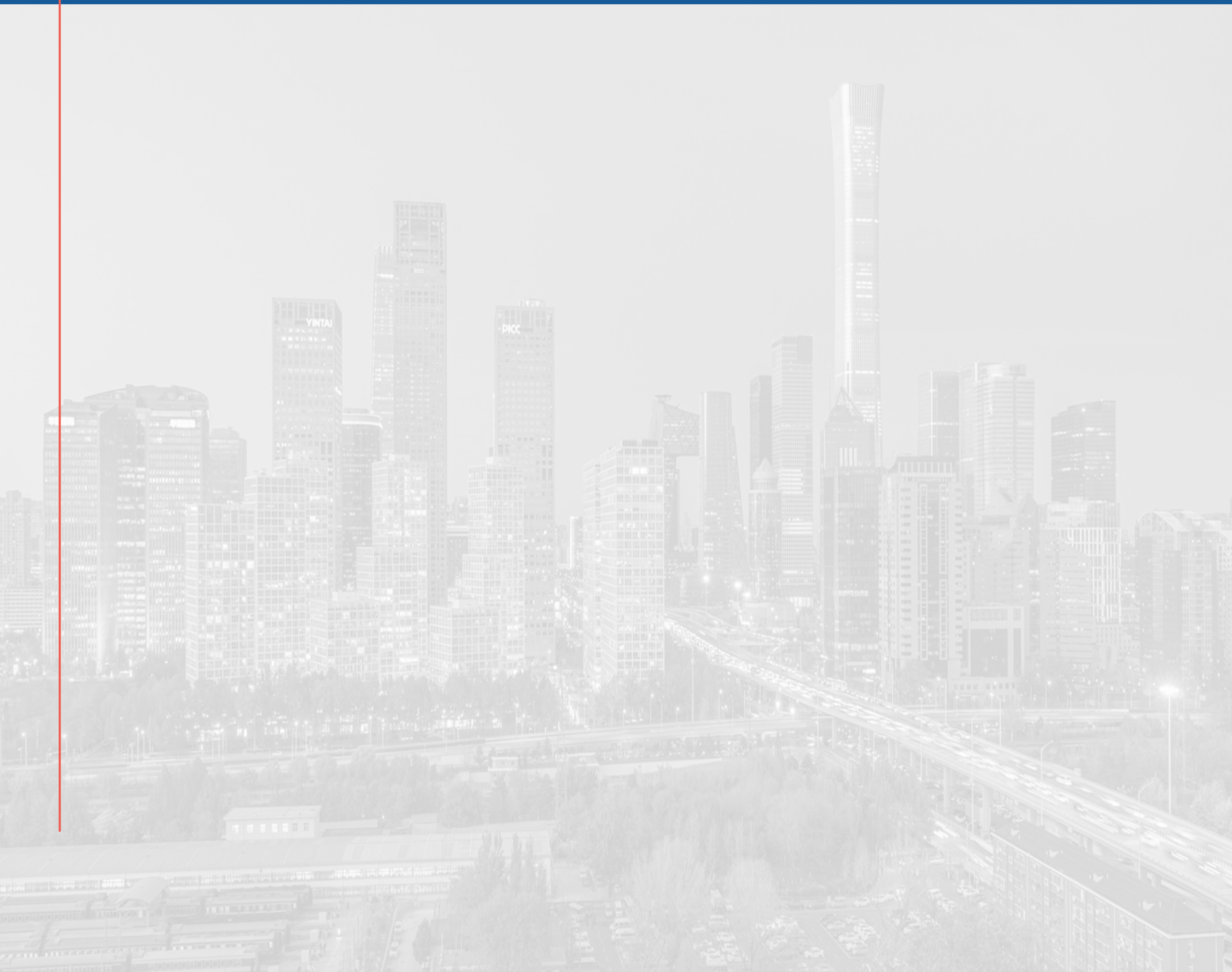
Practical Power Sector Reforms To Boost Reliability, Reduce Risk and Accelerate Carbon Peaking

Regulatory Assistance Project



Section 1: Overview[1]

Introduction

In 2021, the Chinese government declared its intention to issue a "1+N" policy framework for carbon peak and carbon neutrality. The two initial documents in the 1+N series, which follow China's landmark dual carbon pledges, established high-level directives for the power sector, including requirements to "speed up the development of the new electric power system" with "optimized clean energy generation."[2] This paper offers recommendations for fleshing out these directives in the form of power sector reforms for the near term (i.e., the 14th Five-Year Plan period) to support the 1+N documents. Our selection of recommendations is based on guiding principles from the 1+N and related policy statements, including:

- "Pursue progress step by step" in a practical manner that fits China's conditions and reform path.
- Ensure reliability and energy security and "guard against risks."

Our recommendations offer practical ways to follow these principles and build on China's world-leading renewable energy investment — while containing costs and accelerating progress toward the dual carbon targets. The recommendations are based on our global team's analysis of what works and what doesn't in other parts of the world combined with our understanding of China's policies and institutions based on decades of discussion and cooperation with policymakers and partners in China.

Some recent policy statements issued by stakeholders in China imply that there is a perceived trade-off between 1) an optimized new electric power system based on clean energy and 2) other goals such as power sector reliability and energy security. The experience of other countries — and of various pilot reforms in China — suggests, in contrast, that power sector reforms, such as those recommended in this section, can improve energy security and power sector reliability while also bringing forward the date of China's carbon peak.

This first section provides an overview of each power sector reform recommendation. Our practical recommendations cover the following areas, which will each be elucidated in a separate section:

- Setting next steps for implementing a national unified electricity market system.
- Implementing transparent power sector planning to support reliability during the transition.
- Unlocking low-cost options to support system flexibility and renewable energy integration.
- Integrating the pledge to "give first priority to the conservation of energy" with power sector reform.

[1] This report was circulated as a discussion paper in July 2022 and was updated and revised in April 2023. Max Dupuy led the writing and development of this report and was the co-author with Wang Xuan. We would like to thank Rick Weston for his support in writing Section 5, Gao Chi for his revisions to this edition, and Helen He for her expert editing. We also thank RAP's Richard Sedano, experts from Ea Energy Analyses who provided contributions and comments, and experts at research institutions in China for their comments on the draft.

[2] 中共中央 国务院.(2021). 中共中央 国务院关于完整准确全面贯彻新发展理念做好碳达峰碳中和工作的意见. http://www.gov.cn/zhengce/2021-10/24/content_5644613.htm; 国务院. (2021). "国务院关于印发2030年前碳达峰行动方案的通知". http://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm

International perspectives on power sector reform and the clean energy opportunity

Around the world, policymakers are grappling with the challenge of decarbonizing the power grid. Where this was once seen as a costly burden, it is now increasingly recognized as an opportunity. Solar and wind generation costs have declined dramatically over the past decade, creating new benefits for electricity providers and their customers. In many places, the levelized cost of solar and wind generation is now near or below the *fuel cost* of coal-fired and gas-fired power plants, meaning that it can be less expensive to construct new solar and wind generators than it is to operate existing thermal plants.[3] Meanwhile, the falling cost of battery storage and increasing recognition of the value that demand-side resources can provide mean that there are new clean energy options to play flexibility, peaking and firm capacity roles.

To get the most out of the clean energy opportunities and meet decarbonization goals, policymakers in the U.S., EU, China and other places are considering a broadly similar set of power sector issues, centered on ensuring a reliable grid with high levels of wind and solar generation. Fortunately, this challenge and its corresponding solutions are increasingly well understood.[4] With a well-designed policy, market and regulatory framework, one can expect a very reliable power sector, even at very high penetrations of wind and solar generation. There is a growing body of international experience — including within China — that bears this out.[5] The details of reform, however, require careful attention. In this paper we discuss the ways in which these discussions are evolving in different countries and offer recommendations for next steps in China.

The Chinese government's current power sector reform effort, launched in 2015, has made important progress.[6] This includes the piloting and development of new power sector market mechanisms, an overhaul of regulation of grid companies, ongoing demand-side management work, new approaches to renewable energy resource compensation and efforts to revamp power sector planning. This has been complemented by measures that are, within China, sometimes considered outside of power sector reform but nevertheless are important building blocks for power sector transformation, including a new carbon trading mechanism and tightened air quality measures.

The "energy revolution" effort in China has had impressive success, including strong investment in wind and solar generation and improvements in the average efficiency of coal generation. There are, however, gaps remaining in power sector reform, and the

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[3] For relative costs in the U.S., see Gimon, E. et al. (2021). *The Coal Cost Crossover 2.0*. Energy Innovation. https://energyinnovation.org/publication/the-coal-cost-crossover-2021/. Also see Runyon, J. (2021). *New solar is cheaper to build than to run existing coal plants in China, India and most of Europe*. Renewable Energy World. https://www.renewableenergyworld.com/solar/report-its-now-cheaper-to-build-new-solar-than-to-run-existing-coal-plants-in-china-india-and-most-of-europe/#gref

[4] A growing number of detailed analyses for China show how reliability can be maintained with much higher levels of penetration of wind and solar generation. For example, regarding China, see Chinese Energy Research Institute. (2021). *China energy transformation outlook 2021*. https://ens.dk/sites/ens.dk/files/Globalcooperation/2021-11-04_ceto21_summary_en-final_0.pdf and Abhyankar et al. (Forthcoming). *Achieving an 80% carbon free electricity system in China by 2035*.

[5] For international case studies, see Lew, D. et al. (2020, December 28). *Getting to 100% renewables: operating experiences with very high penetrations of variable energy resources. IET Renewable Power Generation, 14*(19), 3899–3907. https://www.esig.energy/wp-content/uploads/2021/03/Getting-to-100-Renewables-Operating-Experiences-with-Very-High-Penetrations-of-Variage-Energy-Resources.pdf

[6] 中共中央 国务院. (2015). 关于进一步深化电力体制改革的若干意见(即"9号文"）. https://www.ne21.com/news/show-64821.html

debate regarding next steps is increasingly complex. The good news is that there are ways to accelerate power sector reform while sidestepping some of this complexity. The key is to choose relatively simple reforms that can be refined later. In this regard, it is important to recognize that there is no "out-of-the-box" set of solutions from countries and that it is necessary to consider practical measures that suit China's social and institutional conditions. Accordingly, the power sector reforms recommended in this paper are based on our understanding of China's conditions, as well as the principles of "applying systems thinking" and "pursuing progress while ensuring stability step by step."[7]

Recommendations for power sector reform in China

This section provides an overview of the recommendations we discuss in this paper. More details on each area can be found in each section, as numbered below.

Set next steps for implementing a "National Unified Electricity Market System" (Section 2)

Well-designed electricity markets can help optimize demand and supply on the grid in real time across a large geographic area. This can be a very effective and low-cost way to boost system reliability and support integration of wind and solar generation. Policymakers in China have been moving in this direction. The recent statement by the National Development and Reform Commission (NDRC) and National Energy Administration (NEA) on a "National Unified Electricity Market System" (hereafter referred to as Document 118) is a very important step forward, although there are several areas where the vision could be improved — and pitfalls that should be avoided in implementation.

- We suggest focusing effort on rapid development and coordination of unified regional spot markets. That is, unified spot markets with geographic footprints that are much broader than a single province.[8] Meanwhile, we recommend that the medium- and long-term (MLT) contracts should be financialized as contracts for differences, linked to the spot price.
- These unified regional spot markets need not be as complex as the provincial pilot spot markets that have been under development. To start, the dispatch and trading centers could be tasked with 1) implementing a single unified economic dispatch procedure for each multiprovince region and 2) creating a spot market energy price based on estimated system marginal cost. In a step-by-step fashion, while ensuring stability, this could be refined into a more competitive system over time as regions become confident with regional market operations.
- Once a basic spot market mechanism is in place, the existing compensation mechanism for thermal power plants based on the administratively determined benchmark on-grid price should be eliminated. The recent expansion of the price fluctuation range for MLT contracts around the benchmark price was an important step in the right direction, but we recommend the next step should be to eliminate the benchmark on-grid coal price mechanism in favor of a compensation model

[7] 新华社. (2022). 习近平参加内蒙古代表团审议 . http://www.xinhuanet.com/english/20220306/c69a07272af64d949eb7f601bc9c3097/c.html

[8] We use the term "unified regional spot markets" here because multiprovince regional markets may be a more practical near-term goal, although a single unified national spot market would be an excellent outcome.

centered on the spot market. As in other countries with spot markets, market participants will be able to hedge against price fluctuations in the spot market through financial contracts for difference (CFDs).

- We suggest revisiting and clarifying the statement in Document 118 that all regions should establish a "generation capacity cost recovery mechanism" to "guarantee electric resource fixed cost recovery (保障电源固定成本回收)." In particular, it would be useful to clarify that, in a situation of overcapacity and given the pressing need to retire inefficient and carbon-intensive resources, some resources should not be guaranteed fixed cost recovery. Instead, only resources that are needed (and available) for reliability (as identified in a scientific planning process) and that meet policy criteria (including air quality standards) should be allowed to recover any fixed costs.

Implement transparent power-sector planning to support reliability during the transition (Section 3)

"Scientific," transparent and rolling planning processes, with detailed published reports, can be very useful to reassure officials and other stakeholders that reliability will be maintained at desired levels during the transition. Various organizations in China, including grid companies and research institutions, already carry out detailed planning processes. Our emphasis is on filling two gaps and bringing about the level of transparency that is necessary to support an increasingly marketized power sector. An improved process can help with:

- Monitoring reliability concerns during the transformation of the power sector.[9]
- Avoiding and managing power sector crises, such as those seen in 2021.
- Identifying problems with power sector policy, market rules and market design.
- Increasing public awareness of market opportunities, thus increasing opportunities for social capital.

We recommend updating NEA's 2016 planning regulation to create three closely interlinked types of planning processes, each with published reports and data releases:

1. A seasonal planning process to assess and manage near-term risks. This would have a rolling one-year time horizon and twice-yearly reports.
2. A medium-term, least-cost resource planning process to identify the least-cost mix of new resources needed to meet policy objectives. This would help test whether market mechanisms are sending rational signals for investment. It would have a rolling time horizon of five to 10 years, with yearly reports.
3. A long-term transmission system planning process to examine different long-run pathways for the clean energy transition. The rolling time horizon would be 20 years or more, with reports every two years.

Ideally, processes should be organized on a regional basis, matching the spot market regions described above.

[9] Resource adequacy planning should ideally be done in a manner that takes building heating into consideration. Combined heat and power, particularly in northeast China, has been a longstanding issue for system flexibility.

Unlock low-cost options to support system flexibility and renewable energy integration (Section 4)

Integrating large amounts of wind and solar generation into the grid is an ongoing challenge around the world. Maintaining reliability requires managing increased variability at various time scales. This includes short-term (seconds, minutes and hours) to long-term (e.g., weeks) fluctuations in supply and demand. Managing this variability requires the identification, construction and orchestration of a cost-effective portfolio of resources with the right characteristics to support a clean energy grid. In turn, this requires a well-designed set of policies — and associated market mechanisms, planning processes and regulations. Previous sections discussed relevant aspects of planning and markets. This section builds on that discussion and offers additional recommendations for supporting integration of variable renewable generation.

There is a very welcome emphasis in the first two documents in the 1+N series on developing flexible resources. What can be done to ensure the identification of least-cost options for flexibility and orchestration in a low-cost, reliable manner? We emphasize two points:

- Recent efforts in China to expand the scope of time-of-use (TOU) retail electricity pricing promises to put the country at the forefront of this effort internationally. We offer suggestions for refining the implementation of this policy at the provincial level. This includes ensuring that all system costs, including transmission and distribution costs, are reflected in the design of TOU rates.
- The 1+N documents commit to supporting virtual power plants (VPPs), which are aggregations of distributed and demand-side resources. We offer suggestions for developing participation models for VPPs to participate directly in the new spot electricity markets in a way that identifies and compensates these resources for the full value of various services that they can provide to the system.

Integrate the pledge to “give first priority to the conservation of energy” with power sector reform (Section 5)

The initial 1+N statements commit to “give first priority to the conservation of energy.” This is a very important pledge that promises to support several key policy objectives: It has the potential to boost reliability by managing demand growth, improve energy security by reducing energy imports, and reduce system costs and emissions. We offer the following recommendations regarding integrating the pledge with power sector reform:

- Expand the target, under the NDRC’s “Demand-Side Management Rule,” for grid company annual energy savings.
- Create detailed rules requiring grid companies to evaluate and invest in energy conservation and other demand-side resources as a “non-wires alternative.” Alternatively, this concept could be framed as “virtual transmission and distribution assets.”

- Under the ongoing effort to eliminate coal as a fuel in buildings, we suggest ramping up efforts to replace direct coal consumption with electric heating. This will free up limited gas supplies for more valuable uses, including as fuel for flexible gas-fired generation plants.
- Create a framework for energy efficiency to be included as a component of virtual power plants.
- Implement closer central government (NEA) review, with published regional reports on the energy-intensity and carbon-intensity targets to evaluate whether they are being met and whether they can be adjusted. This should be coordinated with the medium-term planning process recommended in Section 3.

Additional policy topics related to power sector reform

There are several additional topics that will be important for the power sector's clean energy transition, which we briefly address here. These topics are often not considered to be part of the scope of power sector reform in China — as they were not addressed in detail in the guiding 2015 power sector reform policy statement — but we recommend they should be increasingly integrated with power sector reform discussions.

Emissions standards for power plants: In 2015, the Ministry of Ecology and Environment (MEE) issued a standard that required all coal units to meet "super low" emissions standards for sulfur dioxide (SO_2), nitrogen oxides (NO_X) and particulate matter by 2020.[10] Coal generators subsequently made significant investments in pollution-control equipment, but some analysis indicates there may have been problems of inaccurate reporting of results.[11]

Carbon trading: A new carbon trading mechanism is now in place for the power sector in China. This is a very important step forward. Next steps could include shifting to a mass-based cap on emissions and moving to auctioning for carbon allowances.[12]

Renewable energy curtailment targets and renewable energy quotas: The curtailment (waste) of wind, solar and hydroelectric energy declined substantially in China starting late in the last decade, due in part to a policy that set targets for the grid companies to facilitate curtailment reductions.[13] Given the ongoing challenges of integrating renewable energy generation, it would be useful to continue to have such performance targets for the grid companies as well as strengthening targets associated with the renewable energy quota policy.[14]

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[10] According to the MEE policy, retrofittable (具备改造条件) units should meet emissions standards of 10, 35 and 50 mg per cubic meter for particulate matter, SO_2 and NO_x. See 生态环境部. (2015). 全面实施燃煤电厂超低排放和节能改造工作方案. http://www.mee.gov.cn/gkml/hbb/bwj/201512/t20151215_319170.htm. However, meeting these standards, which are comparable to levels for natural gas units, requires pollution removal efficiencies that are much higher than what has been commercially available in other parts of the word, including the U.S.

[11] Karplus, V., Zhang, S., & Almond, D. (2018). Quantifying coal power plant responses to tighter SO_2 emissions standards in China. *Proceedings of the National Academy of Sciences*, *115*, 7004–7009. https://www.pnas.org/content/pnas/115/27/7004.full.pdf

[12] Energy Innovation. (2022). *China's emission trading system report series*. https://energyinnovation.org/publication/chinas-emission-trading-system-report-series/. For discussion of integration of the design of carbon trading and electricity markets, see Regulatory Assistance Project. (2020). *Designing power markets to maximize the effectiveness of carbon pricing*. https://www.raponline.org/knowledge-center/designing-power-markets-maximize-effectiveness-carbon-pricing/

[13] The clean energy consumption target was an annual indicator for the wind power, photovoltaic and hydropower utilization rate and electricity curtailment rate formulated for each province. See 国家发展和改革委员会、国家能源局. (2018). 清洁能源消纳行动计划 (2018–2020 年). https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/201812/W020190905495739358481.pdf

[14] The quota policy has a role in driving wind and solar investment but can be very important as a mechanism to support renewable integration and control of renewable curtailment.

Section 2: Next steps for implementing a "National Unified Electricity Market System"

Introduction and overview

Optimizing demand and supply on the grid in real time across a large geographic area is a very effective and low-cost way to boost system reliability. Unified electricity markets with broad geographic footprints help manage variability and uncertainty about the output from wind and solar generation as well as fluctuations in demand, thermal plant outages, hydro supply and other factors.[15] In short, such markets are an important strategy to boost reliability, reduce risk and accelerate carbon peaking. The challenge, around the world, is to overcome the problems posed by political boundaries (e.g., provincial) that are too small from the perspective of renewable integration.

Since the launch of the current power sector reform effort in 2015, which included market reform (市场化改革) as a basic principle, Chinese policymakers have made important strides in developing new power market mechanisms. These have helped to raise efficiency and reduce emissions. In January 2022, the National Development and Reform Commission (NDRC) and National Energy Administration (NEA) issued an important vision for continued market reform, "On Forming a National Unified Electricity Market System" (hereafter referred to as Document 118).[16] It includes requirements for:

- "Optimizing the overall design of the power market" [优化电力市场总体设计].
- "Developing a unified power market system" that "harmonizes transaction rules and technical standards" [统一电力市场体系，统一交易规则和技术标准].
- "Eliminating market barriers."
- Creating power market mechanisms that "give play to the supporting role of the electricity market in the clean and low-carbon transformation of energy."

The document sets the ambitious target that, by 2025, a national electricity market, together with regional and provincial markets, will "operate in a coordinated fashion" and "mid- and long-term, spot, and auxiliary service markets for electricity will be designed and operating together." However, there are many details to be decided and there will be numerous implementation challenges.

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[15] See Lin, J. et al. (2022, January 7). *Large balancing areas and dispersed renewable investment enhance grid flexibility in a renewable-dominant power system in China*. *iScience*, *25*(2). https://doi.org/10.1016/j.isci.2022.103749 . See also NRDC and RAP. (2017). *Renewable energy integration: U.S. experience and recommendations for China*. https://www.raponline.org/knowledge-center/renewable-energy-integration-us-experience-and-recommendations-for-china/. For a case study of the benefits of creating a regional market in the U.S. context, see Energy Innovation. (2020). *Economic and clean energy benefits of establishing a southeast U.S. competitive wholesale electricity market*. https://energyinnovation.org/publication/economic-and-clean-energy-benefits-of-establishing-a-southeast-u-s-competitive-wholesale-electricity-market/

[16] 国家发展和改革委员会、国家能源局. (2022). 关于加快建设全国统一电力市场体系的指导意见. 发改体改〔2022〕118号. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202201/t20220128_1313653.html

This section offers analysis and recommendations regarding ways to strengthen the vision set out in Document 118 while filling gaps and avoiding implementation pitfalls. We emphasize five points:

1. There are now several types of overlapping electricity market mechanisms under development in China, with different rules in different provinces. We suggest simplifying this complex patchwork by prioritizing implementation of unified regional spot markets. This can start with designs that are simpler than the provincial spot markets that have been piloted so far. (We use the term "unified regional spot markets" because this may be a more practical near-term goal, although a single unified national spot market would be an excellent outcome.[17]) The spot market price should replace the coal-power-benchmark on-grid price mechanism and become the main power generation compensation mechanism. Market participants can manage the impact of spot market price volatility (at least in part) by hedging prices through financial medium- and long-term contracts.

2. Spot markets are likely to be susceptible to manipulation and distortion by market participants or other interested parties. There are also likely to be market design mistakes in the early stages. These problems may undermine a core function of electricity markets: to reveal underlying resource costs and underpin economic dispatch. We recommend tasking the dispatch centers, under supervision of regional energy bureaus, with estimating the operating costs of each generating unit and ensuring that dispatch is optimized around true operating costs.[18]

3. Document 118 suggests that "capacity cost recovery mechanisms" should "guarantee electric resource fixed cost recovery (保障电源固定成本回收)." We recommend clarifying this statement. It is important that only resources that are needed for reliability (as identified in a scientific planning process) and that meet policy criteria (including air quality standards) should be allowed to recover any fixed costs. An approach based on scarcity pricing is likely to be the best option.

4. The medium- and long-term (MLT) contract markets have been a major part of post-2015 reforms and were a reasonable step to promote competition among coal-fired generators. However, as currently structured, the approach to MLT contracts impinges on flexibility. We recommend shifting to a financial (contracts for differences) model for MLT contracts. The spot market operation rules of several provincial spot markets — including Guangdong, Zhejiang, Shandong, Sichuan, Hubei and Liaoning — have clearly stated that MLT contracts that are to be financial in nature are not to be used by dispatch centers as grounds for deviating from economic dispatch. This is a very important development. The financialization of medium- and long-term contracts can maximize the ability of

[17] This section is focused on the benefits of implementing unified spot markets with footprints that are significantly wider than a single province. For that reason, having several unified regional spot markets or a single unified national spot market would both be beneficial and, for the purposes of the present section, given the early stages of the policy discussion about unified markets, we do not attempt to differentiate the merits of these two outcomes. For more discussion of the challenges of coordinating neighboring regional spot markets, see Regulatory Assistance Project. (2021). 区域电力市场的形成和协调. https://www.raponline.org/blog/rap-regional-market-coordination/

[18] For many years, analysts in China have discussed the issue of whether dispatch centers should be independent from the grid company. The key principle is to create an institutional structure where the dispatch center supports policy objectives, including economic dispatch and renewable energy integration. In our view, either an independent or nonindependent model could work well, as long as good oversight and regulation are in place. For more discussion, see Dupuy, M. et al. (2017). *Power consumption, demand and competition cooperation: Recommendations for the pilots in Guangdong, Jilin, Jiangsu, and Shanghai*. Ea Energy Analyses. https://www.ea-energianalyse.dk/en/publications/1649-power-consumption-demand-and-competition-cooperation-recommendations-for-the-pilots-in-guangdong-jilin-jiangsu-and-shanghai/

the spot market to conduct dispatch in an economic and flexible manner, supporting renewable energy integration.

5. The current approach to interprovincial transmission pricing in China is a barrier to cross-provincial trading and to unlocking the benefits of unified regional spot markets. We recommend moving away from the flat per-kilowatt-hour transmission price, which discourages efficient interprovincial trade, toward an approach that encourages efficient use of interprovincial transmission lines.

Our discussion draws on international experience, tailored to address the immediate challenges in China. Market design and implementation is a multifaceted topic, and here, we discuss only a selection of priority issues.[19]

1. Prioritize implementation of regional spot markets with a simple initial design

Document 118 discusses several market mechanisms that have been under development in different parts of the country, including the medium- and long-term (MLT) contract markets, peaking ancillary service markets, provincial pilot spot markets and interprovincial market mechanisms. In addition, there is an effort to develop cross-regional mechanisms, such as the "cross-regional spot trading" proposal issued by the State Grid in 2021. While each of these mechanisms can be viewed, individually, as a step in the right direction, the proliferation of different mechanisms threatens to create a patchwork that will be difficult to coordinate, rationalize and unify — with the result that the benefits of broad geographic markets may remain out of reach. In our understanding, much of the discussion of unified regional and national markets in Document 118 references the MLT markets, as opposed to spot markets. Unfortunately, the MLT markets in current form impinge on system flexibility (as discussed in the subsequent section).

We recommend focusing effort on rapid development of unified regional spot markets — that is, unified spot markets with geographic footprints that are much broader than a single province. Spot markets can promote flexible use of resources across wide geographic regions in real time. It is better to focus now on establishing practical footprints for unified multiprovince spot markets, rather than designing complex spot markets in individual provinces and then attempting to coordinate these disparate provincial markets later. The Southern Power Grid regional spot market is now in trial operation, and this will be an important test case.[20] In December 2022, NEA released "Basic Rules for the Electricity Spot Market (Draft for Comments)" and "Measures for the Supervision of the Electricity Spot Market (Draft for Comments)." These two

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[19] For a perspective on market design issues in the U.S., see Aggarwal et al. (2019). *Wholesale market design for rapid decarbonization*. Energy Innovation. https://energyinnovation.org/wp-content/uploads/2019/07/Wholesale-Electricity-Market-Design-For-Rapid-Decarbonization.pdf. For more detailed discussion of the application of international experience to spot market design in China, see Regulatory Assistance Project. (2020). *'Energy revolution' and power sector reform*. https://www.raponline.org/knowledge-center/energy-revolution-power-sector-reform-insights-challenges-china-southern-grid-region-from-comparative-international-perspective/.

[20] 南方能源监管局会同云南、贵州能源监管办.(2022). 2022年南方区域电力市场监管工作要点. https://shoudian.bjx.com.cn/html/20220311/1209550.shtml. For a positive assessment of Southern Grid's current status, see Guo, B., & Tang, Y. (2023). 全国统一电力市场体系率先在南方区域落地的意义何在. https://www.21jingji.com/article/20230327/herald/07c24801d41feb6be2b70a81b1d678ee.html

Regional markets are also being developed in the Jing-Jin-Ji region, centered on Beijing and the Yangtze River region. See Sohu. (2021). 两部委发文扩大电力现货试点范围，引导新能源项目. https://www.sohu.com/a/465511973_441315 and Hu, X. (2023). 扎实推进长三角区域电力市场建设. https://news.bjx.com.cn/html/20230317/1295214.shtml documents include measures for market monitoring and regulation as well as financial contracting.[21]

These unified regional (or national) spot markets need not be as complex as the provincial pilot spot markets that have been under development, which have drawn on international electricity market examples, particularly from the U.S. and Europe. These international electricity market examples may be unnecessarily complex and may reflect the historical and institutional circumstances of the countries that are implementing the markets. In addition, these markets began developing at a time before decarbonization came to the fore as a major policy objective. There are certainly very valuable lessons and principles to be drawn from these markets but it is important to be very selective, while designing China's markets to suit China's characteristics and objectives. We suggest, to start, the dispatch centers and trading centers could together be tasked with 1) implementing a single unified economic dispatch procedure for each multiprovince region and 2) creating a spot market energy price based on estimated system marginal cost. (See the discussion regarding reference levels in the following section.) By operating in a "step-by-step" fashion while ensuring stability, this arrangement could be refined into a more competitive system over time as regions become confident with the concepts. The subsequent section discusses an important element: ensuring the markets work well in the case where there is weak competition.

2. Ensure that spot markets reveal the true marginal cost of various resources

Around the world, one of the key reasons to implement electricity markets is to ensure that resource costs are reflected in day-to-day and hour-by-hour operational decisions. This is very important for integrating renewable energy while reducing costs and maintaining reliability. In theory, spot markets with high levels of competition give generators incentives to make market bids at the level of their true operating cost, thus revealing important information about operating costs. This information can then be used by dispatch centers to guide economic dispatch — that is, to ensure that the least-cost units are dispatched first.

In practice, however, spot markets are vulnerable to episodes of weak competition and market manipulation. This vulnerability may be particularly acute in the early stages of China's spot markets. Although static measures of concentration of ownership (e.g., Herfindahl-Hirschman index estimates) may indicate a reasonable degree of competition for most provinces and regions, there are likely to be recurring transmission constraints that constrain competition in geographic pockets, allowing a given generation company to manipulate the market and distort dispatch decisions. The efforts of the State-owned Assets Supervision and Administration Commission to consolidate ownership of generation assets in the northwest and possibly other regions elevate the importance of this issue.[22]

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[21] The two draft NEA regulations are available here: http://www.nea.gov.cn/2022- 11/25/c_1310679693.htm. Also see RAP's comments: Regulatory Assistance Project. (2022). 国际视野：对电力现货市场基本规则的建议. https://www.raponline.org/knowledge-center/rap-suggestions-to-spot-market-rule/

[22] For more discussion of coal ownership consolidation issues in the northwest and State Administration for Asset Supervision policy, see Regulatory Assistance Project. (2021). *Road map for power sector transition and coal generation retirement in northwest China: policy and regulatory strategies*. https://www.raponline.org/knowledge-center/road-map-power-sector-transition-coal-generation-retirement-northwest-china/.

To ensure that electricity markets are doing a good job in supporting economic dispatch, international experience suggests that it will be necessary to implement measures to monitor and mitigate the exercise of market power, including a structure for collecting information on generator operating costs. This will be particularly important for parts of China that have high concentrations of generation ownership.

Document 118 calls for strengthened regulation and "scientific monitoring" of electricity markets as well as the establishment of an information disclosure system. We suggest that the NDRC or NEA should clarify what measures are needed in this regard. These national authorities could set out guidelines for monitoring systems that the regional authorities would then design and implement. Alternatively, the national authorities could take a more direct role and provide uniform, detailed rules to be applied across the country. More specifically, based on U.S. and EU experience, we recommend that the NDRC and NEA issue guidelines that do the following:

- Outline methodology and criteria for estimating "reference cost" levels for each generation unit that reflect that unit's estimated operating cost.
- Establish an annual or biannual administrative process that preconditions a generation company's ability to freely offer into a given electricity spot market, based on the company's ability to pass a structural market power assessment. If the generation company is not able to pass the assessment in any given year, then it must subsequently bid at levels tied to the estimated reference cost for each of its units.
- Require detailed, automated market power screening and mitigation mechanisms. If a generation unit's bid fails the automated market power screen, then the system automatically adjusts the bid to a level related to its unit's reference cost. In an initial "simple" design for regional spot markets, all generation units could be required to bid at a level tied to the estimated reference cost.[23]
- Require each electricity spot market to establish an independent market-monitoring body with clear responsibilities and roles.
- Establish a governance system with regional scope for monitoring transactions and ensuring transparency, in which roles and responsibilities are clearly shared and established.

Additional explanation and technical information regarding the above recommendations are available in publications on these subjects.[24]

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[23] For discussion of a cost-based market and the recommendation that it be maintained in the early stages of Peru's market reform effort, see Wolak, F. (2021). *Transformation of the Peruvian wholesale electricity market*. Stanford University. https://web.stanford.edu/group/fwolak/cgi-bin/sites/default/files/report_wolak_June_2021_draft_0.pdf . For a critical view of cost-based markets, see Munoz, F. et al. (2018). Economic inefficiencies of cost-based electricity market designs. *The Energy Journal.* https://www.iaee.org/en/publications/ejarticle.aspx?id=3077. Note that, as the Munoz paper points out, there are difficulties in accurately estimating operating costs. However, U.S. experience indicates that it is possible to create a framework to do so and, in China, there are existing policies that have laid groundwork for such a structure.

[24] See Regulatory Assistance Project. (2021). 电力现货市场风险管理备忘录: 发电运行成本分析、电力现货市场监测、市场力筛选和减缓. https://www.raponline.org/knowledge-center/rap-spot-market-risk-management-final/. Also see Regulatory Assistance Project. (2020). *Regulating electricity markets: Experience from the United States and perspectives for China.* https://www.raponline.org/knowledge-center/regulating-electricity-markets-experience-from-the-united-states-and-perspectives-for-china/

3. Strictly limit any measures to support generator fixed cost recovery

Document 118 requires "all regions to establish a market-oriented power generation capacity cost recovery mechanism" and allows for several options, including a "capacity compensation mechanism, capacity market or scarcity electricity price." Internationally, capacity payments and capacity markets have been problematic and have supported high-emitting and inflexible generation resources in a manner that diminishes market efficiency and raises environmental costs for both consumers and society. A new energy system dominated by clean energy requires the support of a range of resources, each with its own ability to provide tailored flexibility services (see Section 4). An approach based on scarcity pricing is more suitable for such a new energy system. That is, prices that fluctuate by time and location, in response to demand and supply conditions, are better suited to reward the right resources with the right ability at the right time.

For these reasons, internationally, capacity payments are coming under increasing criticism and falling out of favor and scarcity pricing is receiving more attention. In Europe, the Clean Energy for All Europeans energy policy package, adopted in 2019, requires any capacity payment mechanisms to be temporary. In addition, the policy sets out a series of restrictive requirements that must be fulfilled before such a mechanism is implemented. Meanwhile, the policy package puts a renewed focus on scarcity pricing and emphasizes its significance for achieving reliability. According to the policy, "To support this shift to variable and distributed generation, and to ensure that energy market principles are the basis for the Union's electricity markets of the future, a renewed focus on short-term markets and scarcity pricing is essential." [25]

An approach based on scarcity pricing is also likely to be the best option in China, for similar reasons.[26] However, if capacity payments or a capacity market are used, we suggest clarity, caution and restrictive conditions for the design of these capacity mechanisms. We suggest that it is important to be cautious about the statement in Document 118 that capacity cost recovery mechanisms should "guarantee electric resource fixed cost recovery (保障电源固定成本回收)." In a situation of generation overcapacity and given the pressing need to retire inefficient and carbon-intensive resources, excess and relatively inefficient resources should not be guaranteed fixed cost recovery. Only generators that are economic, meet environmental standards, are needed for reliability or flexibility services (as identified by the type of "process 2" planning described in Section 3) and consistently demonstrate availability when needed[27] should receive any capacity payment. Only resources that meet all these criteria should be allowed to recover any fixed costs. A notice from NDRC and NEA published in May 2022 recognizes these principles and appears to restrict the scope of

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[25] The policy goes on to say that any price caps should be raised to allow for the formation of scarcity pricing. European Commission. (2019). *Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast).* https://eur-lex.europa.eu/eli/reg/2019/943/oj

[26] For discussion of the theory and international practice of scarcity pricing and the ways it could be applied to a regional spot market in the Southern Grid region, see Section 2a *Improving spot market price signals with scarcity pricing* of this paper.

[27] In 2022, NDRC issued new rules specifying that power generation enterprises may not conceal reasons for suspending operation. 国家发改委 (2022). 电力可靠性管理办法 (暂行). http://www.gov.cn/zhengce/zhengceku/2022-04/25/content_5687101.htm

resources that are eligible for capacity payments.[28] We suggest it would be useful for NDRC and NEA to further clarify and reinforce these principles.

A well-designed spot market is likely to reveal certain generation units as uneconomic. This is an important step forward and one of the main goals of implementing markets. Uneconomic assets should be allowed to retire according to market forces as soon as possible (subject to short-term orderly-retirement reliability considerations). The owners of the uneconomic asset may try to argue for some compensation on "stranded assets" grounds. The appropriate official reaction to this argument will vary across countries, according to institutional and historical context, and is beyond the scope of this section. We emphasize, however, that shielding uneconomic resources from market competition and allowing them to continue operation is a very costly (and environmentally harmful) way of resolving the question of who pays for the remaining accounting value of an asset. It is best to let these uneconomic units retire as soon as possible in an orderly fashion, subject to reasonable reliability considerations. Any compensation offered to these generation units that retire before the end of their normal accounting life should be designed in a way that does not unnecessarily prolong the operational life of the generation unit and does not encourage investment in new, unneeded resources.

In a mature spot market, there is no reason to continue using the administratively guided benchmark on-grid electricity prices as a compensation mechanism for thermal power plants. Expanding the price fluctuation range of benchmark on-grid electricity prices is an important step in the right direction, but we recommend abolishing the coal-fired on-grid electricity pricing mechanism and adopting the spot market instead. Although on-grid electricity prices play a certain role in controlling large fluctuations in electricity prices, the power crisis in some regions (such as the Northeast) in 2021 revealed that this price adjustment mechanism leads to conflicts between market and planned prices, which can damage system reliability and the market's ability to generate rational investment signals. As in other countries, market participants, including retailers, can use medium- and long-term contracts to mitigate the impact of price fluctuations and hedge risks. In this way, smaller end users can be insulated from the impact of fluctuations in the electricity wholesale market prices.

In addition, in many countries, governments have concerns about the workers at retiring generation plants. A detailed discussion of this topic is also beyond the scope of this section, although we note that the principle here, as well, should be to help the workers with direct support and retraining instead of unnecessarily prolonging the life of the uneconomic power plant.[29]

4. Transform medium- and long-term contracts, which in current form impinge on flexibility

The current approach in China to MLT contracting sometimes impinges on system flexibility and reduces the system's day-to-day and hour-to-hour operational (dispatch) efficiency. This is due to the practice under which physical contracts are signed often a

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[28] "By the end of 2022, could establish a capacity compensation mechanism for some of the resources that are needed for the safe and stable operation of the power system". 国家发改委、国家能源局 (2022). 关于加快推进电力现货市场建设工作的通知. https://www.163.com/dy/article/H6M5OPSC05509P99.html

[29] For discussion of labor issues and estimates of employment effects from the power sector transition, see Abhyankar, N. et al. (Forthcoming). Achieving an 80% carbon free electricity system in China by 2035.

month or year in advance, with limited scope for adjustment closer to the hour of operation. This kind of rigid physical MLT contracting limits the short-term optimization of transmission capacity, which is vital for integration of variable renewable generation. It constrains use of this transmission capacity, which otherwise could take advantage of real-time conditions, including real-time fluctuations in weather conditions. Our understanding is that dispatch centers track MLT contracts and sometimes take action to satisfy the monthly or annual operating hours specified in the MLT contracts signed by individual thermal-generation units. Such actions may result in deviations from economic dispatch, which otherwise would be the least-cost dispatch based on the conditions (such as weather) that appear in any given hour.

Annual allocations of hours were historically made under annual generation output planning and then were reformed to become competitive monthly or annual MLT contracts. The introduction of competition was a positive development that helped improve the average efficiency of the fleet of thermal generators. However, the continued practice by dispatch centers of adjusting some dispatch decisions to satisfy MLT contracts is likely inefficient and hinders integration of renewable energy.

National policy[30] and rules in some provincial spot market pilots[31] have said that the existing physical approach to MLT contracting will transition to financial contracts for differences. However, it appears this transition has yet to be fleshed out and implemented. Unfortunately, Document 118 does not directly address this issue of financialization.[32]

We suggest the best way to coordinate MLT contracts and spot markets is to shift to a financial model for the contracts, while relying on the spot market to provide price signals for operational decisions.[33] How might this financialization of MLT contracts work? In parts of the country that already have spot markets, MLT contracts could be transformed into financial hedges against spot market prices (e.g., contracts for differences). MLT contracts would no longer have priority for a specific transaction path and would not reserve physical transmission capacity at the time of the signing of the contract. In other parts of the country that may take longer to implement spot markets, MLT contracts could, in the meantime, be transformed into financial contracts that reference an administrative, on-grid, time-varying spot price that could be implemented based on estimated operating costs of available resources.[34]

30 国家能源局. (2019). 关于进一步推进电力现货市场建设试点工作的意见（征求意见稿）. http://www.nea.gov.cn/2019-03/08/c_137878845.htm

31 For example, see the case of Guangdong's spot market pilot. National Energy Board Southern Authority. (2018). *Notice of the Southern Energy Regulatory Bureau, Guangdong Provincial Economic and Information Technology Commission, Guangdong Provincial Development and Reform Commission on soliciting opinions on the southern (starting from Guangdong) electricity spot market series rules.* South China Energy Regulatory Office of the National Energy Administration. http://nfj.nea.gov.cn/adminContent/initViewContent.do?pk=402881e56579be6301658d7123c2001a

32 Document 118 does mention the possibility of improving the "coordination" of MLT contracts and spot markets.

33 Some provinces are developing the practice of 带曲线的中长期交易. This may be able to alleviate the problems discussed in this section by allowing adjustments to generators' positions closer to real time. However, this may be an unnecessarily complex approach.

34 For more discussion of how an administered spot on-grid price could work, see Regulatory Assistance Project. (2021, October 21). 分时上网电价：无现货市场省份的一种选择. https://www.raponline.org/blog/implementing-time-differentiated-pricing-for-generation-in-chinas-provinces-without-spot-markets/

5. Reform transmission pricing to support unified regional markets and unified regional dispatch

A basic principle for transmission pricing is that it should support efficient use of the transmission network as conditions on the grid change due to weather, congestion and other factors. According to our understanding, in China, in most cases, importing provinces pay a flat (i.e., not time-varying) yuan/kWh transmission price for each kWh imported. This transmission price is intended to cover the full cost (or most of the cost) of interprovincial transmission lines. This approach does not reflect the fluctuating underlying costs of transmission utilization and can create a barrier to electricity trade between market participants, thus blocking some of the benefits of unified regional markets.

To understand why it can be inefficient to recover the cost of interprovincial transmission lines from a flat price for each kWh transmitted, consider an example of two neighboring provinces: Province A, with ample wind-generation capacity, and its neighbor, Province B, with mostly thermal capacity. Imagine a specific hour when the wind conditions strengthen in Province A, demand surges in Province B and ample transmission capacity is available to facilitate increased power flows from Province A to Province B. In this case, reducing production from the Province B thermal generators in favor of the Province A wind generators would provide positive net benefits (system cost savings) for the two provinces overall. However, a flat per-kWh interprovincial transmission charge can make the operating cost of wind power (which is near zero) from Province A *appear* more expensive than the operating cost of the thermal power in Province B, even when there is plenty of transmission capacity available that is sitting unused in that hour. This misrepresentation can cause the thermal generators to be dispatched and wind generation to be curtailed, leaving transmission capacity underutilized. This goes against the principle of economic dispatch, which suggests that, in this case, the thermal generators should not be dispatched and the wind generation should not be curtailed.

A new approach to cost recovery for interprovincial transmission lines would help unlock the benefits of unified regional (or national) markets. We suggest, as a reasonably easy-to-implement approach, allocating the cost of interprovincial regional transmission lines to each of the provincial grid companies within the region on a monthly basis, calculated according to each company's share of the peak level of regional electricity consumption for that month.[35] Each provincial grid company would then recoup these costs as part of the electricity prices that the provincial grid company applies to its customers (i.e., ideally as a component of retail time-of-use prices, as discussed in Section 4). This is an approach similar to that used to pay for regional transmission costs in the U.S.[36]

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[35] As an extension to this approach, large end users could be separated out and given responsibility for a share of interprovincial transmission line costs according to each large end user's contribution to regional system peak demand.

[36] Spot market pricing mechanisms to manage transmission congestion can also be an important part of rationalizing transmission utilization and transmission cost allocation. The key idea is that transmission capacity is intermittently congested. It is economically rational to implement transmission congestion pricing so that there is a fluctuating per-kWh grid congestion cost at different locations (nodes) on the regional grid. However, revenue from congestion pricing will not typically be sufficient to recover all transmission costs. See Madrigal, M., & Stoft, S. (2011). *Transmission expansion for renewable energy scale-up: Emerging lessons and recommendations.* World Bank Group. https://www.esmap.org/sites/default/files/esmap- files/Transmission-Expansion-and-RE_0.pdf

Section 3: Transparent power sector planning to support reliability during the transition

Introduction and overview

"Scientific," transparent and rolling planning processes, with detailed published reports, can be very useful to assure officials and other stakeholders that reliability will be maintained at desired levels during the clean energy transition. Such planning processes can serve as a foundation for a check-and-adjust mechanism to ensure an electricity system is reliable. Various organizations in China, including grid companies and research institutions, already carry out detailed planning processes. Our emphasis in this section is on filling two gaps. First, we recommend the 2016 planning policy issued by the National Energy Administration (NEA) should be revised and updated to rationalize and unify various planning processes, roles and responsibilities.[37] Second, the power sector planning processes that do exist in China do not have sufficiently detailed (or, in some cases, any) published reports. Improving these planning processes can help with:

- Assessing reliability concerns during the transformation of the power sector.
- Identifying problems with market rules and market design.
- Monitoring to ensure that various power sector institutions and firms follow policy directives and market rules.
- Supporting the State Council and Central Committee's objective of "creating a good ecology for various market players to invest and start businesses according to local conditions."[38]

More specifically, we recommend updating and revising NEA's 2016 planning regulatory framework to specify three closely interlinked types of planning processes:

- *Process 1:* A **short-term resource-adequacy assessment** process for each region (i.e., spot market region or grid region) will help manage seasonal risks and manage debates about the impact of the clean energy transition on reliability.
    - Rolling time horizon: one year.
    - Published report frequency: quarterly or twice-yearly.
- *Process 2:* An improved **medium-term process to identify a least-cost mix** of new resources needed to meet growth. This can be built from the existing five-year power sector planning process and can serve as a test on whether the new market mechanisms are sending rational signals for investment.
    - Rolling time horizon: five to 10 years.
    - Published report frequency: every year.

[37] 国家能源局. (2016). 电力规划管理办法. http://www.gov.cn/gongbao/content/2016/content_5145577.htm.

[38] 中共中央、国务院 (2022). 关于加快建设全国统一大市场的意见. http://www.gov.cn/zhengce/2022-04/10/content_5684385.htm.

- *Process 3:* An improved **transmission planning process** with a long horizon and scenarios that examine different long-run pathways for the clean energy transition.
    - Rolling time horizon: 20 years or more.
    - Published report frequency: every two years.

We recommend basing the three planning processes on the following guiding principles:

- Publication of reports with detailed information on assumptions and inputs, including provision of detailed data sets for public download. This will facilitate additional analysis by market participants and support evaluation of planning scenarios by stakeholders.
- A rolling time horizon. For example, Process 2 could look forward five years and be updated every year. This would mean that the 2023 report would consider the period from 2023 to 2028 and the 2024 report would consider the period from 2024 to 2029.
- Presentation of scenarios that illuminate policy and market design options, including alternative measures for meeting the dual carbon targets.
- Analysis and presentation of probabilistic results rather than simple point estimates. This will support better understanding (on the part of policymakers, market participants and the public) about the range of likely outcomes for key variables, such as demand and wind generation output.
- All power sector resources, including distributed generation and demand-side resources (including demand response, virtual power plants, energy efficiency measures and heating demand management) should be assessed in planning on an "even playing field" basis, according to the full value that these resources can provide.
- Regions (not provinces) should be the main geographic subdivision for planning and reports, mirroring the spot market regions (see Section 2 in this paper). National reports can be based on coordination of regional elements.
- Review and approval of reports and methodology by NEA. This agency should require revisions when reports or underlying processes are deemed to be inadequate relative to requirements set out in the revision of NEA's 2016 document.

In the remainder of this section, we describe recommendations for how NEA might define and coordinate each of the planning processes in a revised planning regulation — with discussion of international examples. We emphasize the experience of the European Association for the Cooperation of Transmission System Operators for Electricity (ENTSO-E), which serves as a continentwide planning authority and conducts resource adequacy analysis with different time horizons. ENTSO-E's planning processes have been developing to better support a clean energy grid. We also discuss U.S. experience with planning, which varies in quality and comprehensiveness across states and regions, but nevertheless has some useful examples that could inform national-scale processes in China.

Process 1: Short-term resource-adequacy assessment (quarterly or biannual reports)

As the power sector undergoes rapid and dramatic transition, policymakers and stakeholders are likely to continue to have questions and concerns about maintaining reliability.[39] There is a history of difficulty and contention (in China as well as other countries) about managing periods of system "tightness" and "looseness," which sometimes become headline news. In addition, there is the challenge of coordinating detailed decisions about these topics among various policymaking agencies. This was seen in China during the 2021 power sector crises. Although a transparent resource adequacy assessment process might not have entirely avoided the 2021 crises, it would have been very useful to help coordinate and rationalize quick-response measures, including demand-side management and "orderly use" of electricity. It would have also been useful in the aftermath, for assessing the lessons and policy implications of the crises. For example, a published set of regional projections of expected wind performance under different weather scenarios would have been very useful in assessing public claims that wind resources "underperformed" during the crises.[40] In short, a planning process of the type described in this section can give policymakers, market participants and other stakeholders greatly increased confidence in their understanding of the state of the power system, preparedness for upcoming seasonal challenges and policy options to manage risks.

In February 2023, NEA issued a policy titled "Power System Operation Risk Management," which requires that provincial-level grid company subsidiaries should regularly report summer peak and winter peak analyses.[41]

In the U.S., the organizations known as regional transmission organizations (RTOs) that manage the regional markets, roughly analogous to the spot markets under development in China, are responsible for conducting regional load forecasts and conducting resource adequacy assessments.[42] Currently, these assessments are based on reserve margin studies. These typically include quarterly or biannual analyses and public reports on three topics: 1) estimates of current reserve margins, 2) forecast reserve margins for the region and 3) the setting of target reserve levels based on a reliability target.[43] These practices are under scrutiny and are evolving in light of the clean energy transition, the need to better assess the full value of various clean energy resources, changing weather conditions and other factors.[44] The Federal Energy Regulatory Commission (FERC) oversees RTO load forecasting and resource adequacy planning; and FERC authorizes the North American Electric Reliability Corporation

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[39] For more discussion of the topics in this section and more details on U.S. practices, see Regulatory Assistance Project. (2021). 电力现货市场风险管理–资源充足性规划. https://www.raponline.org/knowledge-center/rap-resource-adequacy-planning-memo/.

[40] For example, after the 2021 crisis in Texas, much of the discussion and analysis focused on the seasonal scenarios issued by the system operator as part of resource adequacy reports published before the crisis. This helped focus discussion on how well various resources, including wind, performed relative to expectations. See, for example, Regulatory Assistance Project. (2021). '得州大停电' 凸显了能源政策不同方面相互关联的属性. https://mp.weixin.qq.com/s/tfq0OS95NKm498g7qJQHmQ

[41] 国家能源局.(2022). 国家能源局综合司关于完善电力系统运行方式分析制度 强化电力系统运行安全风险管控的通知. http://zfxxgk.nea.gov.cn/2023-02/17/c_1310700939.htm

[42] Because the terms Independent System Operators (ISO) and Regional Transmission Organizations (RTO) are nearly synonymous in the U.S., we will simply refer to RTOs in the text of this paper when describing these U.S. ISO/RTO markets as a category.

[43] This reliability target could be a loss-of-load expectation target but could also include other metrics.

[44] For a review of current issues with resource adequacy planning, focusing on the United States, see Stenclik, D. (2021). *Redefining resource adequacy for modern power systems*. Energy Systems Integration Group. https://www.esig.energy/reports-briefs.

(NERC) to develop electric reliability standards. For example, NERC conducts audits and investigations of RTO load forecasts.

In the EU, ENTSO-E has, since 2020, significantly upgraded its methodology for assessing short-term resource adequacy (i.e., seasonal time horizons).[45] Most notably, the seasonal adequacy assessment has shifted from a weekly snapshot based on a deterministic approach to a state-of-the-art, sequential, hourly Monte Carlo probabilistic approach. Outlook reports are prepared for summer and winter seasons (i.e., two times a year) and are based on detailed data input from the transmission system operators (analogous to the dispatch centers in China) and from ENTSO-E's own Pan-European Climate Database, which includes detailed hourly information on photovoltaic and wind output across the continent.[46] Each seasonal outlook report is accompanied by a retrospective analysis of the previous season. In addition, with each seasonal report, ENTSO-E's website provides detailed data sets regarding hourly system demand, transmission transfer capacities, hydro conditions, wind generation and other inputs.[47]

We suggest NEA build on its 2016 planning policy and its 2023 Operation Risk Management policy by requiring creation of this kind of regional resource-adequacy planning processes, ideally matching the geographic scope of regional spot markets (see Section 2). In such a revised framework, regional grid companies, power generation companies and research institutions would be tasked to collaborate, collect and analyze data and write planning reports, which then would be subject to review and approval by NEA and published online. The NEA and regional energy bureaus would guide the process and ensure high-quality implementation. If done well, this process would provide early warnings regarding seasonal problems, thereby allowing policymakers to take quick-response measures (including adjusting regulations and market rules). In this way, a short-term resource-adequacy assessment process would be very useful to help support the regional transition toward the 2030 and 2060 goals.

Process 2: Least-cost planning for new resources (annual or biannual reports)

All countries face a challenge of creating a framework for rational power sector investment decision-making, such that investors choose the right mix of new energy resources to meet needs and satisfy policy objectives at least cost. A careful planning process will be useful to help identify the mix of new resources needed as the transition unfolds. Such a planning process should evaluate not only central generation resources but also distributed energy resources, including demand response and energy efficiency — all on an even playing field. This process should also consider the retirement of fossil-fueled resources to meet decarbonization goals.[48]

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[45] The methodology was developed by ENTSO-E in line with the Clean Energy for all Europeans package, particularly the regulation on risk preparedness in the electricity sector (EU 2019/941) and has received formal approval from the Agency for the Cooperation of Energy Regulators (ACER).

[46] Marinelli, M. et al. (2014). *Pan European Climate Data*. DTU Orbit. https://orbit.dtu.dk/en/projects/pan-european-climate-data.

[47] For seasonal reports and data, see ENTSO-E. (2022). https://www.entsoe.eu/outlooks/seasonal/.

[48] For discussion of methods to identify coal-fired units for retirement, see Cui, R. et al. (2022). *A decade of action: A strategic approach to coal phase-down for China*. Center for Global Sustainability, University of Maryland, College Park, Maryland and California-China Climate Institute, Berkeley, California. https://ccci.berkeley.edu/publications. Also see "Recommendation 7: Rationalize the process for identifying specific coal generation units for retirement" in Regulatory Assistance Project. (2021). *Road map for power sector transition and coal generation retirement in Northwest China: policy and regulatory strategies*. https://www.raponline.org/knowledge-center/road-map-power-sector-transition-coal-generation-retirement-northwest-china/.

The five-year-plan process in China has long played the central role of providing high-level guidance for the amount and type of investment (and retirement) in various resources. The challenge will be to continue improving the power sector component of the five-year-plan process and to coordinate between that process, with resource-specific market mechanisms, and incentive policies that directly motivate specific investment decisions. Fortunately, NEA's 2016 planning policy sets out some useful principles that serve as an excellent basis for these tasks. Bolstering the existing power sector component of the five-year plan with a more transparent, detailed and rolling process would be very useful. This, again, should be conducted on a region-by-region basis. It should focus on the following question: What is the overall least-cost (including external costs associated with emissions) portfolio of resources on a regional level, considering all resources? "All resources" means not just generation resource options but also storage, demand response and energy savings investments.

This type of resource planning will still be useful, even as marketization of the power sector proceeds and market pricing plays an increasing role in guiding resource investment decisions. In an increasingly marketized system, resource planning would help to set longer-term expectations for the various market participants and investors, including on the demand side. Market mechanisms could play the leading role in incentivizing investment (and retirement) while the resource-planning process helps policymakers assess whether various market mechanisms (including the electricity markets but also any resource-specific support mechanisms, such as for storage resources and demand-side resources) are functioning in a unified rational manner and whether adequate investment in the right type of resources, including flexible resources to support wind and solar generation, are forthcoming. (Flexible resources are essential to support a power sector dominated by renewable energy. See Section 4.) ENTSO-E's annual report is subject to review by the EU's Agency for the Cooperation of Energy Regulators (ACER). ACER rejected ENTSO-E's first annual report, due, in part, to ACER's assessment that the report's methodology "does not recognize the value of demand-side response sufficiently." ENTSO-E addresses these shortcomings in its 2022 report.[49]

The type of resource-planning process described in this section would likely judge investments in new coal generation to fill resource-adequacy needs as relatively expensive — that is, expensive relative to other options that might include a mix of variable renewables, storage resources, demand response and targeted energy savings measures — even without considering full emissions externality costs. (See the text box in Section 4 for more discussion of these factors.)

In the EU, the 2019 Clean Energy for all Europeans package (an energy policy framework enshrined in law) requires and outlines a process for medium- and long-term resource planning. The new process features annual published reports and published data setss. It has a 10-year horizon, with detailed results published for each of the 10 years out to that horizon. The ENTSO-E process considers detailed data, which is also published.[50]

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[49] ACER. (2022). *ACER decides not to approve ENTSO-E's first pan-European resource adequacy assessment due to shortcomings.* https://www.acer.europa.eu/news-and-events/news/acer-decides-not-approve-entso-es-first-pan-european-resource-adequacy-assessment-due-shortcomings

[50] ENTSO-E. (2021). *European resource adequacy assessment 2021*. https://www.entsoe.eu/outlooks/eraa/2021/eraa-downloads/

Under this framework, scenario development is a key feature. As ENTSO-E puts it, "A scenario is the outcome of a specific set of assumptions and data, applied to a target year, and run through a set of models (methodologies) to give a picture of the future. By using these different scenarios, we can gauge the impact of certain policy, regulatory or economic measures…"[51] All scenarios are required to be consistent with EU climate targets.[52] In this way, the scenarios facilitate consideration of alternative pathways to meet the climate targets.

The scenarios are based on an integrated picture of the energy sector, including integrated analysis of the electric and gas sectors. The rules governing the development of trans-European energy infrastructure require that ENTSO-E and its gas sector counterpart, ENTSO-G, develop and coordinate scenarios.[53] The scenarios provide evaluation of alternative futures, based on a quantitative analysis. For example, the 2021 report considers scenarios in which EU electricity market design includes or does not include a generator capacity-payment mechanism, with future reliability assessed and compared under both scenarios. Other scenario evaluations include the impact of accelerated thermal power plant retirement. These scenarios also constitute the analytical foundation for the long-term planning process, as described in the following section. The analysis underlying the scenarios is based on a probabilistic assessment of wind, solar and hydro generation patterns (including forced outages) and climate-dependent consumption patterns incorporated into several alternative scenarios. Rather than calculating point estimates for resource adequacy measures, the framework calculates probabilities and thus explicitly accounts for risk and uncertainty.[54]

The experience of state-level integrated resource planning (IRP) in the U.S. can also provide useful case studies for the type of planning process recommended in this section. Under an IRP, the utility develops, under the guidance of the state regulatory commission, a multiyear plan identifying a least-cost combination of supply-side, demand-side and transmission resources to meet demand for energy services.[55] 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. For China, experience from parts of the U.S. with both statewide IRP and RTO-style electricity markets, such as California, may be a useful reference.[56]

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[51] ENTSO-E, 2021.

[52] A fundamental feature of the framework is that it is performed in a coordinated and consistent manner. Each Member State both establishes a reliability standard and performs a national assessment. The reliability standard is expressed in terms of a nationally approved value of lost load estimation. At the EU level, it is the responsibility of the European Association of TSOs (ENTSO-E) to prepare the adequacy assessment report, while it is the duty of the EU's Agency for the Cooperation of Energy Regulators (ACER) to approve or request amendments.

[53] In this way, the process includes integrated analysis of building heating.

[54] These measures are expected energy not served and loss of load probability.

[55] For more detail on U.S. IRPs, see RAP and NRDC. (2017). *Power sector planning: US experience and recommendations for China*. https://www.raponline.org/knowledge-center/power-sector-planning-us-experience-and- recommendations-for-china/. Also see Section 2.3 of Regulatory Assistance Project. (2014). 低碳电力行业监管：巴西，欧盟和美国的国际经验, 2.3节: 电力行业规划. https://www.raponline.org/wp-content/uploads/2016/05/rap-lowcarbonpowersectorregulation-cn-2015-jan-12.pdf

[56] For details on California's statewide IRP, see California Public Utilities Commission. (n.d.) *Integrated Resource Plan and Long Term Procurement Plan*. https://www.cpuc.ca.gov/irp/.

Process 3: Transmission planning process (reports every two years)

Grid planners in China, the EU and the U.S. face similar needs for coordinated grid planning across a very large system in support of a clean energy transition. NEA has stated goals of "increasing cross-provincial transmission and regionalization in support of clean energy" and "improving utilization of existing transmission capacity."[57] As discussed in Section 2, transmission infrastructure facilitates system balancing across large regional and national scopes. Rational planning of transmission can help support the development of renewable energy on the grid at regional and continental scales.

In the EU, ENTSO-E is responsible for a process that has emerged as a leading international example of continental-scale grid planning.[58] This grid planning process seeks to select the right grid investments to achieve decarbonization objectives and energy transition, at least cost and in coordination with electricity markets.[59] ENTSO-E uses a coordinated and comprehensive transmission grid planning approach, which includes development of scenarios, screening of potential new transmission projects and combined cost-benefit analysis for proposed new transmission assets. The aim is to ensure system reliability, guarantee power supply and integrate more renewable energy at lowest possible cost. The time horizon for the planning is 20–30 years.

The ENTSO-E process results in a public plan that lays out the transmission development in Europe for the coming 10 to 20 years. The plan is conducted every second year in an open process with stakeholders and public hearings. The final plan must be approved by ACER and the European Commission. As with other ENTSO-E planning processes, detailed reports (regarding scenarios, results and methodology) and data sets are published online.[60]

EU rules specify that the Ten-Year Network Development Plan (TYNDP) should help identify infrastructure projects that are key to the EU achieving its climate and energy objectives. Such projects, known as European projects of common interest (PCI), are selected from the TYNDP's overall list of possible investments. TYNDP 2020, for example, contains 58 PCI projects. The European Commission is responsible for selecting the PCI list. From the moment a TYNDP project becomes a PCI, it may benefit from favorable treatment, such as access to a European coordinator and speeding up of permitting processes and possible obtaining of financial support from EU funding.[61]

In the U.S., transmission planning suffers from lack of continental scope, and regional planning processes are not well integrated. Efforts are currently underway to address these shortcomings. In addition, in April 2022, FERC issued draft requirements for

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57 国家能源局.(2021).国家能源局公开第二轮中央生态环境保护督察整改方案.. http://www.nea.gov.cn/2021-08/31/c_1310159647.htm

58 For ENTSO-E's 2022 report, see https://2022.entsos-tyndp-scenarios.eu/#download. For detailed discussion of the ENTSO-E pan-European transmission process, with discussion of relevance to the Chinese context, see EU-China Energy Cooperation Platform. (2021). ENTSO-E 电网规划模型中国演示. http://www.ececp.eu/zh/entso-e-cn/ .

59 The ENTSO-E approach seeks to optimize pan-European grid planning for overall social benefits. A key aspect of the ENTSO-E methodology is the recognition from the transmission grid planning perspective that the market will determine the use of the grid. The main processes in the ENTSO-E approach are scenario building, screening and cost-benefit-analysis project assessments.

60 See ENTSO-E TYNDP. https://tyndp.entsoe.eu/.

61 For discussion of the need for a national transmission planning process in the U.S., see ESIG. (2021). *Transmission planning for 100% clean electricity*. https://www.esig.energy/wp-content/uploads/2021/02/Transmission-Planning-White-Paper.pdf. For an example of a U.S. RTO plan, see ISO New England. (n.d.) *Regional system plan*. https://www.iso-ne.com/system-planning/system-plans-studies/rsp/.

improved regional and interregional transmission planning that include several similarities with the EU process. The FERC draft requirements include requirements for RTOs to produce improved long-term transmission plans, subject to FERC oversight, with:

- Rolling planning horizons of at least 20 years, with revised reports at least once every three years.
- Evaluation of multiple planning scenarios, based on factors including federal and state energy, climate and electrification objectives.
- Coordination across regions.
- Increased transparency, including publication of additional information regarding modeling methodology, assumptions and data.[62]

In addition, the U.S. Department of Energy recently announced it will develop and oversee a "national transmission planning study."[63] Finally, existing regional transmission planning processes conducted by U.S. RTOs can also be useful references, particularly regarding details of methodology.[64]

We recommend NEA update its 2016 regulation with new requirements for a unified national-transmission-planning process. We recommend a planning horizon of 20 years or more and a requirement for development of scenarios that examine different long-run pathways for the clean energy transition, including high-electrification scenarios. We suggest the reports and scenarios should be updated every other year in detailed published reports, along with detailed data sets, similar to the ENTSO-E practices. This transparent process would significantly improve the present grid planning in China achieve the dual carbon goals, supporting further integration of renewables in the power system, while maintaining reliability.

Conclusion

We have discussed several recommendations that could be included in a revision of NEA's 2016 framework planning regulation. Such an updated regulation would play an important role in setting out the nature of and requirements for the various planning processes. Given the complexity of executing regularly updated planning reports, we recommend NEA should delegate responsibility for many of the details of undertaking the various planning studies. However, we suggest NEA should retain responsibility for approving planning methodologies and reviewing the periodic regional and national reports. NEA can and should reject reports and require revisions if standards set out in the planning process are not met or if underlying assumptions and inputs are not justified or well explained, ideally in a public statement with detailed responses to the report in question.

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62 FERC. (2022, April 21). *Building for the future through electric regional transmission planning and cost allocation and generator interconnection*. Notice of proposed rulemaking. https://www.federalregister.gov/documents/2022/05/04/2022-08973/building-for-the-future-through-electric-regional-transmission-planning-and-cost-allocation-and

63 See https://www.energy.gov/oe/national-transmission-planning-study (https://www.energy.gov/gdo/national-transmission-planning-study) and U.S. Department of Energy. (2021, December 6). *National transmission planning study introduction letter*. NorthernGrid. https://www.northerngrid.net/private-media/documents/NTP-Intro-Letter_12-06-21_DOE.pdf. For discussion of the need for a national transmission planning process in the U.S., see ESIG. (2021). *Transmission planning for 100% clean electricity*. https://www.esig.energy/wp-content/uploads/2021/02/Transmission-Planning-White-Paper.pdf

64 FERC, 2022 provides examples and discussion of existing RTO planning processes. In addition, see Pfeifenberger et al. (2021). *Transmission planning for the 21st century: Proven practices that increase value and reduce costs*. The Brattle Group. https://www.brattle.com/wp-content/uploads/2021/10/2021-10-12-Brattle-GridStrategies-Transmission-Planning-Report_v2.pdf.

Section 4: Unlock resources to support power system flexibility and renewable energy integration

Introduction

Integrating large amounts of wind and solar generation into the grid is an ongoing challenge around the world. Maintaining reliability requires managing increased variability at various time scales. This includes short-term (seconds, minutes and hours) to long-term (e.g., weeks) fluctuations in supply and demand. Managing this variability requires the identification, construction and orchestration of a cost-effective portfolio of resources with the right characteristics to support a clean energy grid. In turn, this requires a well-designed set of policies — and associated market mechanisms, planning processes and regulations. We have already looked at various aspects of planning and markets in previous sections. In this section, we consider more closely how the various parts of the puzzle fit together to support the integration of large amounts of variable renewable generation.

China's power system has made world-leading strides in absorbing fast-growing amounts of wind and solar into the grid so far. As in other countries, however, there is still a large mountain to climb to get to a decarbonized grid. The 1+N series of documents recognize the importance of these issues. The two initial 1+N documents include high-level calls for "the construction and operation of a new power system ... [with] improved comprehensive flexibility." The documents briefly mention the need for work in the following areas:[65]

- Top-level design of new power systems.
- A power grid that adapts to the local utilization and wide-area transmission of renewable energy.
- Market mechanisms to support the new power system.
- Mechanisms for construction and operation of flexible resources.
- Demand response mechanisms.
- Regional energy trading.

As in other countries, there is much work to be done to flesh out these work areas and decide on implementation details. This section builds on the previous sections in this paper and offers additional recommendations for supporting integration of variable renewable generation. As before, our discussion is based on our understanding of China's existing policies, combined with our analysis of international experience.

Background: Considering flexible resources in a systematic and holistic manner

To ensure the reliability of the power system while absorbing high penetrations of wind and solar generation, innovative power sector structures and policies are needed. These structures and policies should not be designed individually but should be planned and coordinated according to systematic thinking. System operation needs to

[65] In March 2022, China's National Development and Reform Commission and National Energy Administration issued the 14th Five-Year Plan for modern energy system, which once again emphasized the importance of flexible resources at a high level.

ensure a real-time balance of supply and demand — and the growth of intermittent renewable energy sources increases the need for flexibility in the power system. This requires a wide range of flexibility over various time spans from short-term (seconds, minutes and hours) to long-term (weeks or longer) to deal with changes and uncertainties in the power system. How to best coordinate a flexible system to accommodate renewable energy at the lowest cost while maintaining system stability requires comprehensive consideration of the overall system.

In Section 2, we discussed streamlining electricity market development, with a focus on practical regional spot market designs, which is very important from a renewable energy integration point of view. Regional spot markets across multiple provinces support renewable energy consumption on a larger scale. In addition, the real-time spot prices that change with time and geographical location also provide a scarcity price signal for the available resources of the power system, to incentivize the flexible operation of resources.

Influenced by China's planned-economy system, power generation resources were traditionally compensated based on fixed benchmark feed-in tariffs set by the government. Under this regime, power generation companies strive to increase operating hours instead of operating at critical moments when system supply and demand is tight. In a new power system dominated by renewable energy, a well-designed unified spot market can optimize and coordinate a variety of flexible resources across wide geographic areas. It can also help provide incentives for flexible resources, including energy storage and demand response. In this way, it can contribute to reductions in the use of traditional fossil-fuel power generation resources, increase the integration of renewable energy into the grid and support system reliability.

In Section 3, we discussed recommendations for improving power system planning, in particular the need for periodic resource adequacy analysis, least-cost resource expansion planning and improved transmission planning. We emphasized the importance of publishing detailed planning reports to augment planning transparency and public confidence in the energy transition. Rationalized planning for flexibility will help reduce the risk of system emergencies. It will also help avoid costly, polluting and inefficient ways to provide flexibility (see box on next page). The key is to 1) assess the gap between the existing flexibility that can support the integration of renewable energy into the grid and the flexibility required to accommodate a higher penetration of renewable energy under the current system structure and operating mode and 2) identify the solution for unlocking flexibility at the lowest cost in the future and acquiring new flexibility resources.[66]

In the remainder of this section, we build on the previous sections and make complementary recommendations to support the integration of high penetrations of renewable energy.

[66] International Renewable Energy Agency. (2018). *Power system flexibility for the energy transition* (pp. 35–41). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Nov/IRENA_Power_system_flexibility_1_2018.pdf?la=en&hash=72EC26336F127C7D51DF798CE19F477557CE9A82

New coal-fired generation capacity to support renewables?

Internationally, there are several reasons why markets and planning mechanisms no longer choose new coal generation capacity to meet power system needs.

1. The capital cost of solar and wind generation has fallen dramatically, and it is now near or below the **fuel cost** of coal-fired and gas-fired power plants, meaning that it is cheaper to construct new solar and wind generators than operate existing thermal plants.[67] Once built, using power from wind and solar capacity eliminates fuel, emissions and other operating costs that would otherwise be caused by operating existing thermal plants.

2. Even the most flexible coal plants are constrained in their ability to provide short-term flexibility (e.g., minute-by-minute and hour-by-hour) due to constraints on minimum output levels, ramp rates and startup and shutdown processes. Demand response, storage resources and gas-fired generation are typically better able to provide these services and at lower cost. Demand response can be highly cost-effective if the right incentive mechanisms are in place.

3. Existing resources are shifting roles to support renewables. Existing gas-fired generation is moving toward playing a supporting role in providing flexibility in many countries. This business model can continue in the case of high gas prices because gas generators operate for a few hours a year only when needed. Some decarbonization scenarios for the U.S. see gas-fired generation playing a continued role in this manner over the next couple of decades, but little capacity is expected to be added. In these decarbonization scenarios, existing gas-fired power plants steadily reduce annual gas use, sipping fuel very sparingly in support of a renewable-dominated system.[68]

4. In power systems with very high degrees of renewable energy penetration, there will ultimately be a need for moderate amounts of "clean firm" resources that can support system reliability during longer-term lulls in the weather. There is still debate about the most cost effective resources to play this role. Thermal resources fitted with carbon capture equipment or fired with green hydrogen may play a limited part. In any case, it is clear there is no need for an immediate large-scale build-out of thermal resources to address this need.[69]

5. The external costs associated with climate change and air pollution are increasingly internalized by mechanisms, from emissions markets to regulatory measures, to varying degrees across countries.

Continued on next page…

[67] For relative costs in the U.S., see Gimon, E. et al. (2021). *The coal cost crossover 2.0*. Energy Innovation. https://energyinnovation.org/publication/the-coal-cost-crossover-2021/ and Bolinger et al. (2021). *Utility-scale solar, 2021 edition*. Lawrence Berkely National Laboratory. https://emp.lbl.gov/utility-scale-solar/. For international estimates, see Runyon, J. (2021). *New solar is cheaper to build than to run existing coal plants in China, India and most of Europe*. Renewable Energy World. https://www.renewableenergyworld.com/solar/report-its-now-cheaper-to-build-new-solar-than-to-run-existing-coal-plants-in-china-india-and-most-of-europe/#gref

[68] For example, in one high-profile set of 2050 net-zero pathway scenarios for the U.S., most net-zero scenarios see gas-fired capacity staying approximately constant but fuel use declining because this capacity is used sparingly to support wind and solar. One scenario expects gas-fired capacity to expand by about 580 gigawatts by 2050 but nevertheless projects gas consumption by these power plants to steadily decline. In all net-zero scenarios, the remaining amounts of gas-fuel use in the power sector in 2050 are either hydrogen gas or accompanied by carbon capture and sequestration equipment. Larson, E. et al. (2021). *Net-zero America: Potential pathways, infrastructure, and impacts*. "Pillar 2: Clean electricity" on pp. 87–88, "Clean firm resources and thermal plant retirements" on pp. 150–152 and hydrogen uses on p. 178. Princeton University. https://netzeroamerica.princeton.edu.

[69] Long, J. et al. (2021). *California needs clean firm power, and so does the rest of the world.* Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/SB100%20clean%20firm%20power%20report%20plus%20SI.pdf

New coal-fired generation capacity to support renewables? Continued.

In the case of China, many and possibly all of these factors are also relevant. Accordingly, the power sector reforms discussed in this paper are likely to identify better solutions than new coal-power capacity to support a power grid with increasing amounts of renewables. That is, it is likely the recommended market and planning mechanisms described in sections 2 and 3 would judge investments in new coal generation as expensive —relative to other options that might include a mix of variable renewables, storage resources, demand response and targeted energy-saving measures — even without considering full emissions costs.[70] These mechanisms would also likely reject the proposition of "cut and replace" of old coal plants with new, more efficient coal plants. Some existing studies by teams of international and Chinese analysts have found that new coal-fired generation is unlikely to be the best solution to meet system needs in China.[71] A good way to test these findings would be to conduct and publish official least-cost (Process 2) resource planning studies under the assumption of functional unified regional (or national) spot markets.

Implementation and refinement of time-of-use retail electricity tariffs

A well-designed time-of-use (TOU) pricing structure can motivate users to provide flexibility to the power system and reduce electricity costs by adjusting the load. In July 2021, the National Development and Reform Commission (NDRC) launched a landmark policy which promises to put China in the forefront of countries implementing TOU electricity pricing. The "Notice on Further Improving Time-of-Use Tariffs"[72] requires a dramatic increase in the scope of TOU pricing, requiring mandatory TOU pricing for nearly all customers in the country. As of the time of this writing, 30 provinces have issued new time-of-use tariff policies. It would now be useful to undertake a careful review and refinement of these provincial policies.

In addition, we recommend that NDRC and the National Energy Administration (NEA) could consider offering additional national guidance regarding TOU rate design and implementation. Based on our understanding of the emerging provincial TOU policies that are being issued in response to the July 2021 policy, we make the following suggestions for NDRC and NEA to clarify TOU design and implementation:[73]

- Ensure that all system costs, including transmission and distribution costs, are reflected in the design of TOU rates. Our understanding is that some provincial policies are not considering transmission and distribution costs in TOU rates. Ideally, electricity prices should reflect the various cost components related to the user's electricity consumption, including generation, transmission, and

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[70] For a quantitative analysis that supports this proposition, see Abhyankar, N. et al. (forthcoming). *Achieving an 80% carbon free electricity system in China by 2035.*

[71] See Lin, J. et al. (2022). Large balancing areas and dispersed renewable investment enhance grid flexibility in a renewable-dominant power system in China. *iScience, 25*(2). https://doi.org/10.1016/j.isci.2022.103749. See also Lu, H. et al. (2019). Reducing wind power curtailment in China: comparing the roles of coal power flexibility and improved dispatch. *Climate Policy, 19*(5), 623–635. https://doi.org/10.1080/14693062.2018.1546164

[72] NDRC. (2021). *Notice on further improving the time-of-use electricity price mechanism (No. 1093)*. http://www.gov.cn/zhengce/zhengceku/2021-07/29/content_5628297.htm

[73] For additional discussion, see Regulatory Assistance Project. (2021). *International perspective and several suggestions for the implementation of time-of-use retail electricity prices for power users.* https://www.raponline.org/knowledge-center/rap_time-varying-pricing_cn/

distribution and emissions costs. The July 2021 policy does not specifically address this issue. It would be useful to issue a clarification requiring that all these cost components should be reflected in TOU rates and specify a methodology for doing so.

- Clarify the approach to implementation of TOU rates in the context of retail competition. Retail competition has developed with different characteristics and to different degrees, in various provinces. This has raised some challenging issues regarding how to promote TOU pricing. It would be useful for NDRC and NEA to provide more guidance on this topic. For example, it may be useful to specify that all retailers are required to meet a target for the percentage of customers on TOU plans, with the quality and design of these plans subject to review by provincial authorities. EU Member States, some of whom have high degrees of retail competition, are currently developing regulations to require larger retailers to offer high-quality TOU plans. This experience may be useful for policymakers in China.[74]
- Develop pilot programs to test more dynamic time-varying electricity pricing models. While TOU rates can be very helpful for flexibility, critical peak pricing and real-time pricing have the potential to further exploit the operational flexibility of the demand side.

Participation of demand-side resources in the electricity spot markets

With the electrification of buildings, transport and industry, demand-side resources in various forms can provide excellent sources of flexibility at low cost. If managed well, these flexible electrified end uses can provide capacity, energy and ancillary services to the power system, like conventional power plants but at lower cost and zero emissions. Indeed the 1+N documents commit to developing virtual power plants (VPPs), which we understand will be combinations of distributed and demand-side resources. The key will be to develop participation models for VPPs and any other distributed resource aggregations to participate directly in the new spot electricity markets in a way that identifies and compensates these resources for the full value of various services that they can provide to the system. In addition to its traditional role of shedding load – that is, the curtailment of loads, typically in emergency situations – demand response and VPPs are capable of modifying the daily pattern of energy uses at different time scales, including small, second-by-second adjustments to support grid stability.[75]

At present in China, some provincial policies are in place to support participation of demand-side resources, energy storage, distributed generation and electric vehicles in the new spot market trading. However, in practice, there are still problems, including high market-access thresholds and barriers to fair competition with traditional power generation resources. In and outside of the spot market context, demand response resources are still mainly used to manage summer or winter peak, chiefly on an occasional emergency basis, and do not yet have opportunities to receive compensation for the full value of services provided to the system. In addition, some end users in new

[74] Regulatory Assistance Project. (2022). “制定配电系统分时电价：支持系统灵活性，实现低成本电气化”. https://www.raponline.org/knowledge-center/implementation-and-refinement-of-tou-electricity-pricing/

[75] One nomenclature refers to this range of services as “shedding, shifting, shaping, and shimmying.” Lawrence Berkeley National Laboratory. (2017). *2025 California demand response potential study — charting California's demand response future: Final report on phase 2 results*. https://buildings.lbl.gov/publications/2025-california-demand-response

spot markets complain that the opportunities to participate in spot markets are "not worth it (划不来)."[76] This may be partly a result of imperfections in the design of the way prices are formed in spot markets, as discussed in Section 2. These price-formation problems include restrictive price caps that dampen the incentive to provide flexibility services at the times and places when these services would be most valuable to the grid – and thus should be the most lucrative for the resource.[77] This is another reason why, as noted in Section 2, the scarcity price approach to spot market design is important to pursue.

There is also much discussion in other countries regarding these issues. For example:

- In 2020, the U.S. Federal Energy Regulatory Commission issued a requirement for the U.S. regional electricity markets to develop participation models to allow distributed energy resources (DERs), including demand response, to participate as aggregations.[78]
- Similarly, EU law enacted in 2019 requires regulatory authorities to facilitate access of demand response to electricity markets as part of efforts to "ensure the supply of electricity at the most competitive price."[79]
- In 2019, the Australian Energy Market Operator began to develop VPP demonstration projects and, as of 2022, has sufficient VPP capacity available to serve about 30% of the country's needs for short-term flexibility services.

In these countries, however, the implementation details are still under development and there is work to be done to ensure that the full value of DERs is recognized and fairly compensated in market and planning processes. Doing so will allow DERs to lower system costs where they provide cost-effective alternatives to traditional centralized resources.

Improve energy-storage-supporting policies

Energy storage can be highly valuable in supporting the energy transition to meet dual carbon goals. In China, existing rules and policies have been successful in motivating the energy storage industry to reduce costs and improve operational performance. We hope that policymakers will continue to build on this success. The ongoing efforts to implement new spot electricity markets will be very important for this (see Section 2). NEA's May 2022 storage policy clearly entitled energy storage to participate in any MLT market, spot market or ancillary service market, whether combined with conventional generators or as a standalone entity.[80] For next steps, many technical details need to be fleshed out regarding how spot markets can recognize the technical characteristics of various storage resources and reward these resources for the value of

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[76] Guangdong Province has been a leader in developing spot market participation models for distributed resources, including VPPs, and has recently issued a revised policy on this topic. https://mp.weixin.qq.com/s/Djg9HA_e01Kk-gV0_wwHDQ

[77] Price caps can be a reasonable policy in the face of insufficient competition, as may be the case in many provinces. However, market monitoring and market power mitigation regulations are likely to be a better way to deal with insufficient competition and would allow for clearer scarcity price signals. See Section 2 and the references cited there.

[78] FERC. (2022). Order No. 2222 fact sheet. https://ferc.gov/media/ferc-order-no-2222-fact-sheet

[79] Article 13 of European Directive 2019/944. For additional discussion, see Meus, L., & Nouicer, A. (2018). *The EU clean energy package*. http://cadmus.eui.eu/bitstream/handle/1814/57264/RSCAS_2018_TechnicalReport.pdf?sequence=1 and European Commission. (2016). *Demand response for Europe*. https://dr4eu.org/memos/

[80] 国家发展和改革委员会、国家能源局. (2022). 关于进一步推动新型储能参与市场和调度运用的通知. https://www.ndrc.gov.cn/xxgk/zcfb/tz/202206/t20220607_1326854.html?code=&state=123

the services that they can provide to the system. NEA has already tasked local authorities to come up with implementation plans that may specify requirements such as minimum threshold, state of charge and discharging/charging limits. The U.S. RTO markets, under the supervision of FERC, have been engaged in a similar effort since 2018, and that process may be a useful reference point for policymakers in China.[81] Ultimately, the market-driven approach could be the ideal way to orchestrate and incentivize various resources to provide the most valuable system services. In the meantime, we still suggest carefully designing the supporting measures and coordinating them with other market mechanisms in place.[82]

- The central government is exploring allowing the cost of new energy storage facilities, as alternatives to traditional transmission and distribution (T&D) assets, to be recovered through T&D pricing.[83] We recommend that a scientific assessment based on technical, economic and environmental criteria should be implemented (see sections 2 and 3 on planning). Only capable and cost-effective energy storage can fully recover its cost.
- Any capacity payment to any resource (whether storage, traditional generation or anything else) should be given to the resources that are needed to meet reliability or flexibility purposes, identified through the least-cost resource planning process.
- The regional spot market and ancillary service market need to be coordinated and co-optimized. In principle, the market design should allow fair competition between all capable resources and the benefit/cost should be shared among all the participants.

Conclusion

Power system flexibility is critical for new power systems dominated by renewable energy. All countries with decarbonization goals are facing the challenge of orchestrating a portfolio of reliable and cost-effective resources to support a decarbonized grid. Controlling the cost of electrification and supporting the integration of renewable energy into the power system will depend on whether power sector reforms can unlock the cost-effective flexibility of electrified end uses. China has emerged as a world leader in various aspects of electrification — notably, uptake of electrified transportation, but also, increasingly, the electrification of buildings. Now there is potential for China to become a world leader in terms of the power sector reforms needed to revamp the way that electrified end uses interact with the power grid. Recent policy statements, including regarding the commitment to expand TOU pricing and develop VPPs, are very promising. We suggest next steps will involve refining TOU pricing and extracting more value, beyond emergency situations, from the flexibility services that demand response and VPPs can provide to the grid. In addition, it is necessary to coordinate various supporting policies to energy storage

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[81] Dupuy, M., & Porter, K. (2018). *Leveling the playing field for storage resources in China's electricity markets: A view from the U.S.* Regulatory Assistance Project. https://www.raponline.org/blog/leveling-the-playing-field-for-storage-resources-in-chinas-electricity-markets-a- view-from-the-u-s/

[82] For more discussion of related storage issues see Regulatory Assistance Project. (2020). *Energy revolution and power sector reform*. Section 2b. https://www.raponline.org/knowledge-center/energy-revolution-power-sector-reform-insights-challenges-china-southern-grid-region-from-comparative-international-perspective/

[83]国家发展和改革委员会、国家能源局.(2022). 关于印发《"十四五"新型储能发展实施方案》的通知. https://www.ndrc.gov.cn/xwdt/tzgg/202203/t20220321_1319773.html?code=&state=123

with existing market rules and structures to ensure a level playing field for all flexible resources.

Part of the challenge will be to promote rational formation of prices at the wholesale spot market level, as discussed in Section 2. As noted in that discussion, spot markets that are designed according to the scarcity pricing principle will offer better signals and compensation to flexible resources, such as demand response, energy storage and VPPs, to operate where and when they are most needed. Tight price caps and capacity payments for traditional thermal generators will work at cross-purposes with this effort to unlock demand-side flexibility. Similarly, planning processes will need to carefully analyze the value and cost of distributed resources, as discussed in Section 3.

Section 5: "Give first priority to the conservation of energy": Making it work for the power sector

Introduction

The initial 1+N statements commit to "give first priority to the conservation of energy." This is a very important pledge and has the promise to support several key power sector objectives: It has the potential to boost reliability by managing demand growth, improve energy security by reducing energy imports and reduce system costs and emissions. If conservation is truly to be given first priority, then conservation must be carefully considered when designing the market, planning and other mechanisms that affect resource investments in the power sector.[84] A major question will be how to integrate this pledge with the details of power sector planning, markets and other aspects of power sector reform. There is a parallel with the EU, which issued a landmark Efficiency First principle in 2015 (see box on next page). That EU directive has been successful in motivating renewed conservation efforts in the EU, although there are several ways in which China could surpass the EU in ensuring that the high-level objective is implemented in a highly effective manner within the power sector. In this section, we offer several recommendations for policymakers in China on creating a "give first priority to the conservation of energy" power sector policy framework to ensure the principle applies in a comprehensive fashion within the power sector.

84 End-use energy efficiency is a resource of enormous potential, and one of the things that is most remarkable about it is that, even as it is acquired in ever-increasing amounts, its cost remains low. This is because the reservoir of efficiency constantly refills because of technological advances and reductions in manufacturing costs. This phenomenon has been identified numerous times by analysts over the past several decades. See, for example, Neme, C. et al. (2016). *The next quantum leap in efficiency: 30 percent electric savings in ten years.* Appendix A. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/the-next-quantum-leap-in-efficiency-30-percent-electric-savings-in-ten-years/

Eu efficiency first principle and the EU power sector

The European Union adopted the Efficiency First principle in 2015.[85] The principle builds on existing EU policy and gives energy efficiency the emphasis that its economic and environmental benefits justify. [86] Analysis shows that there is a vast amount of cost-effective energy efficiency to be tapped and, as a result, the least-cost pathway meeting the EU's greenhouse gas emissions reduction target of 80% by midcentury includes a decrease in primary energy demand of 35% between 2005 and 2050.[87]

The savings achievements of the EU Member States have varied. Additional steps to give the directive teeth have been, and are being, taken. In 2018, the EU agreed on an economy-wide energy efficiency target for 2030.[88] Currently, the EU, which, like China, has committed to a climate neutrality target, is in the process of revamping its energy efficiency legislation, with a more ambitious target for 2030, including a doubling of the energy savings targets for individual Member States.[89]

What does the Efficiency First principle mean for the EU power sector? There are several key policies under development, including 1) rules requiring that grid companies look for opportunities to displace traditional network investments with end-use energy efficiency investments and 2) rules allowing aggregations of end-use energy efficiency resources (similar to what have sometimes been called "efficiency power plants" in China) to participate in electricity markets. Meanwhile, several Member States have implemented and gradually increased the size of "energy efficiency obligations" for grid companies. These give grid companies mandatory annual targets for investing in end-use energy savings. [90] There still is much work to be done to implement these policies and ensure that efficiency is truly the priority resource in the EU power sector.

Expand the grid companies' demand-side management regulation targets

In the U.S., EU and other places, there is decades of experience with requiring electricity utilities (电网公司) to invest in end-use energy efficiency.[91] The key idea is that energy efficiency is a power sector resource that can be a highly cost-effective alternative to investing in supply-side resources, such as building power plants and expanding the electricity grid.[92]

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[85]European Commission. *Energy efficiency first principle*. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-first-principle_en

[86] Economidou, M. et al. (2020, October 15). "Review of 50 years of EU energy efficiency policies for buildings." *Energy and Buildings*, *225*. https://www.sciencedirect.com/science/article/pii/S0378778820317229.

[87] European Climate Foundation. (2016, June 14.) *Efficiency first: A new paradigm for the European energy system.* https://www.raponline.org/knowledge-center/efficiency-first-new-paradigm-european-energy-system/.

[88] Text of the energy efficiency directive, as revised in 2018: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018L2002&from=EN.

[89] More information on the European Commission's website: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en.

[90] Santini, M., & Thomas, S. (2020). *Article 7 of the energy efficiency directive 3.0*. Text box "About article 7." https://www.raponline.org/wp-content/uploads/2020/11/rap-Article7_policy_brief_251120.pdf.

[91] In this section, we use the terms "conservation of energy," "energy efficiency" and "energy savings" as roughly synonymous.

[92] Regulatory Assistance Project. (2014). *Energy efficiency as a resource for the power sector in China.* https://www.raponline.org/knowledge-center/energy-efficiency-as-a-resource-for-the-power-sector-in-china/.

In China, the central government issued a document on *Electricity Demand-Side Management Regulations* (发改运行[2010] 2643号) in 2010.[93] This document, for the first time, placed an obligation on the grid companies that required them to achieve energy savings of at least 0.3% in sales volumes and 0.3% in maximum load compared with the previous year.[94] Internationally, leading jurisdictions have grid-company energy efficiency obligations equal to 2.5% or more of annual sales volumes. For example, in the U.S., Massachusetts has set (and achieved) targets of approximately 2.7% annual savings in recent years.[95] We suggest expanding the grid companies' targets in the 2010 regulations in order to build on the success of the policy to date. It could be linked to efforts of the grid companies to support transportation and building electrification. For this reason, allowing grid companies to count savings from displacement of natural gas and other fuels would be useful.

Create requirements and rules for grid company uptake of "non-wires alternatives"

Non-wires alternatives (NWAs) are technologies and other interventions that can displace or reduce the need, in certain cases, for traditional investments in transmission and distribution networks. Energy conservation investments can act as NWAs, for example, by targeting inefficient sources of peak demand in a locality that would otherwise require network upgrades to meet peak demand. Several governments around the world have developed frameworks to identify and exploit cost-saving NWA opportunities.[96]

In the EU, the Electricity Directive requires that distribution network plans "provide transparency on the medium- and long-term flexibility services needed ... [and also] include the use of demand response, energy efficiency, energy storage facilities, or other resources that the distribution system operator is using **as an alternative to system expansion**" (Art 32[3]; emphasis added).[97]

In China, the National Development and Reform Commission (NDRC) and National Energy Administration (NEA) could consider issuing a policy that similarly requires grid companies to explicitly and transparently consider NWAs, ideally as part of the Process 2 planning described in Section 3. Given the official support for virtual power plants (VPPs; further discussed below) in China, we suggest this policy might be framed as "virtual transmission and distribution assets." The policy could require the grid company to consider NWAs in a routine, transparent and evenhanded way when creating planning scenarios and when making incremental decisions about new investments. Such an NWA framework would provide a level playing field for all

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93 NDRC. (2010). *Guidance on electricity demand-side management regulations No. 2643.* 关于印发《电力需求侧管理办法》的通知 (发改运行 [2010] 2643). This was followed by a statement on the same topic in 2017, although that statement did not increase the targets. 发改运行规〔2017〕1690 号《关于深入推进供给侧 结构性改革做好新形势下电力需求侧管理工作的通知》. https://www.waizi.org.cn/doc/24839.html

94 Regulatory Assistance Project. (2014). *Energy efficiency as a resource for the power sector in China.* https://www.raponline.org/knowledge-center/energy-efficiency-as-a-resource-for-the-power-sector-in-china/

95 ACEEE. (2019, May). *State energy efficiency resource standards.* https://www.aceee.org/sites/default/files/pdfs/u2201.pdf.

96 For an international survey, see Regulatory Assistance Project. (2020). *Rewarding energy efficiency for energy system services through markets: Opportunities and challenges in Europe.* https://www.researchgate.net/publication/339032491_Rewarding_energy_efficiency_for_energy_system_services_through_markets_Opportunities_and_challenges_in_Europe

97 EU Electricity Directive. (2019). http://publications.europa.eu/resource/cellar/8594f013-8e7c-11e9-9369-01aa75ed71a1.0006.03/DOC_1

options. It should consider the total societal costs of different options, including costs associated with greenhouse gas emissions and health impacts. The framework should be detailed enough that the grid company can use it to guide routine decision-making. The framework should detail a methodology for cost-benefit analysis, including which costs and benefits to include. Each demand-side measure should receive credit for the benefits that accrue over the entire life of the measure. Ideally, this should include avoided emissions costs and avoided health costs associated with air pollution.

Clarify that "coal-to-electricity" is the focus of building-retrofit efforts

Around the world, electrification is closely related to energy conservation. Electrifying end uses that previously consumed fossil fuels often — particularly in the transportation and building sectors — significantly reduces overall energy consumption, costs and emissions. Electrified end uses will enable demand flexibility that is vital in a system with high penetration of variable renewable generations. China has emerged as a world leader in certain aspects of electrification — particularly electrified transportation. In part, this transportation electrification effort has been supported by the investment of the country's grid companies in electric vehicle charging infrastructure.

The electrification potential of buildings is also enormous. We suggest that replacement of coal heating with natural gas heating is not the best use of scarce natural gas — and is not consistent with decarbonization goals. The priority should be on coal-to-electricity conversion. Indeed, the 1+N documents appear to emphasize coal-to-electricity. A clarification that electrification is now the focus of heating policy would be useful. In addition to the significant emissions reductions this will produce, it has the added benefit of making China's limited gas resources available for more valuable uses — in particular, for the flexible gas-fired generation needed now to integrate renewables into the system, before there are sufficient clean energy alternatives (or carbon capture) to serve this need.

Coordinate investment in virtual power plants and efficiency power plants

As discussed in Section 4, the 1+N documents commit to developing VPPs, which we understand will be, as in other countries, aggregations of demand-side and other distributed resources. The 14th Five-Year Plan's Energy System Plan includes a target to increase demand response capacity to 3% to 5% of the maximum load by 2025.[98]

While the VPP concept is centered on providing system flexibility, energy conservation can complement VPPs by cost-effectively *reducing* the need for flexibility. That is, in a manner similar to the NWA concept, energy conservation can help avoid the need for additional flexible resources through investment in targeted end-use energy efficiency. The Chinese power sector has already had success in developing a kind of VPP that acquires energy savings through efficiency. These have been called "efficiency power plants" (EPPs) — energy efficiency programs whose savings mirrored, and could replace, the output of conventional power sector resources. EPPs were first "built" in

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98 国家发展改革委员会、国家能源局.(2022). 关于印发《"十四五"现代能源体系规划》的通知. https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220322_1320016.html?code=&state=123

Guangzhou in the mid- and late 2000s.[99] Joint consideration of VPPs and EPPs — or even merging the two concepts — would be a useful policy to support the principle of "priority to energy conservation" in the power sector.

Update intensity targets during the Five-Year Plan period

The 1+N commitments and the 14th Five-Year Plan set out aggressive national targets for reductions in energy intensity, carbon emissions intensity and peaking carbon emissions by 2030. First are an 18% reduction in carbon intensity (tons CO_2e/unit of GDP) and 13.5% reduction in energy intensity between 2020 and 2025. Second is that the nonfossil share of energy consumption in 2025 will be 20%. Third is the goal of nonfossil energy consumption of 25% by 2030.[100] If achieved, energy intensity (Btus/unit of GDP) in 2030 will be 65% lower than that in 2005. Meanwhile, there is a 2030 subtarget for renewable energy to have 1200 GW of total installed capacity.[101, 102] Together these aims constitute a comprehensive approach to energy use and management whose efficacy will be, in meaningful measure, a function of how the intensity targets interact — with each other and with related mandates — to drive behavior.

The emissions- and energy-intensity targets are aggressive, but they shouldn't be regarded as etched in stone. It is reasonable to keep an eye out for opportunities to surpass the targets. For example, the current pace of investment in wind and solar resources appears to be surpassing the official objectives.[103] This is good news and is consistent with international experience. More often than not, targets are exceeded. Those who are subject to them find creative and lower-cost ways of meeting them than the program designers expected. This calls, therefore, for regular review and adjustment of the targets. Where they can be tightened, they should be.

The example of the Regional Greenhouse Gas Initiative (RGGI) in the northeast United States is instructive. RGGI is a cooperative effort among states to reduce carbon dioxide (CO_2) emissions from power plants within each participating state. Together, the participating states have established a regional cap on CO_2 emissions from regulated power plants within the RGGI states. Over time, according to an agreed-on trajectory, the regional cap declines, so that CO_2 emissions decrease in a planned and predictable way.[104]

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[99] Regulatory Assistance Project. (2010). *The Guangdong efficiency power plant: An assessment of progress*. https://www.raponline.org/knowledge-center/the-guangdong-efficiency-power-plant-an-assessment-of-progress/.

[100] NDRC. (2021, October 27). *Action plan for carbon dioxide peaking before 2030*. https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html

[101] See Kahrl et al. (2021). *Peaking by 2025: Aligning climate and energy goals in China's 14th five-year plan*. California-China Climate Institute. https://ccci.berkeley.edu/sites/default/files/CCCI_Dec2021_Energy_and_Climate_Alignment_in_China.pdf.

[102] 国家发改委等多部委.(2022年). "十四五"可再生能源发展规划. https://www.ndrc.gov.cn/xwdt/tzgg/202206/t20220601_1326720.html?code=&state=123

[103] 中国证券报.(2022)."十四五"装机约2亿千瓦 第二批风光大基地规划落地. http://www.xinhuanet.com/energy/20220228/bb053b31da024e859e35bb123ecc290f/c.html

[104] RGGI is a market-based "cap-and-invest" initiative. The affected power plants must acquire one RGGI CO_2 allowance (or permit) for every short ton of CO_2 they emit. The RGGI states distribute allowances through quarterly auctions, where they can be purchased by power plants and other entities. The revenues from the auctions are invested in clean energy resources—primarily end-use energy efficiency—in the states. See https://www.rggi.org/.

A key element of the program is its program reviews, which are conducted periodically to examine the successes, impacts and design of the program, including whether the emissions "budget" should be changed. During the first two program reviews, the states implemented changes that improved program design and reduced the overall emissions cap and the trajectory it will follow. The consequence is that, since its inception in 2009, carbon emissions from power plants in the RGGI region have fallen more than 50%.

We recommend NEA and the other relevant government agencies in China put into place a mandatory annual review of China's energy-intensity and carbon-intensity targets at the regional level, to evaluate whether they are being met and can be strengthened (tightened). Yearly updates can be integrated with the least-cost planning process (Process 2) described in Section 3.

Conclusion

The pledge to "give first priority to the conservation of energy" puts China in the forefront of global efforts to promote energy efficiency. Given the focus of this paper on power sector policy, we have looked at the ways in which this pledge can be operationalized and integrated with power sector reform. Our recommendations can be summarized as follows:

- Expand the target, under the NDRC's "Demand-Side Management Rule," for grid company annual energy savings.
- Create detailed rules requiring grid companies to evaluate and invest in energy conservation and other demand-side resources as a "non-wires alternative." Alternatively, this concept could be framed as "virtual transmission and distribution assets."
- Under the ongoing effort to eliminate coal as a fuel in buildings, emphasize coal-to-electricity and gas-to-electricity conversion and end coal-to-gas conversion. This will free up limited gas supplies for more valuable uses, including as fuel for flexible gas-fired generation plants.
- Create a framework for energy efficiency to be included as a component of virtual power plants.
- Implement a mandatory review with published reports, conducted by NEA, of the energy-intensity and carbon-intensity targets at regional level, to evaluate whether they are being met and whether they can be adjusted. This should be coordinated with the medium-term planning process recommended in Section 3.

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