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# Low-Carbon Power Sector Regulation: Options for China

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# Table of Contents

## Executive Summary

**The Chinese government has set a number of goals to reduce carbon emissions and coal consumption, and also has set closely related goals to improve air quality.** These are outlined in the 12th Five-Year Plan (2011–2015) and the *Air Pollution Prevention and Control Action Plan (2013–2017)*. In addition, many provinces and municipalities have set very ambitious 2017 goals for coal consumption reduction and air quality improvement.

**The power sector will be central to any attempt to meet these goals in a cost-effective manner.** However, the Chinese authorities have yet to set out a clear and comprehensive agenda for the power sector's role in meeting emissions and environmental goals. The *Air Pollution Action Plan* and the associated local plans largely omit power sector policy and regulatory issues. More importantly, a major once-in-a-decade "power sector reform" guidance document is expected to be issued by the government soon – but, as of the time of this writing, media reports about the content of the document suggest that the draft reform plan has not been explicitly designed to help meet the government's carbon emissions, coal cap, and air quality goals.

This paper offers concrete options for framing power sector reforms to support carbon emissions reduction in a cost-effective, low-risk manner. Our recommendations are based on international experience and analysis of China's conditions. This paper is a companion to the report *Low-Carbon Power Sector Regulation: International Experience from Brazil, Europe, and the United States*. We do not address all issues related to power sector reform, but instead focus on the most important topics for achieving carbon reduction goals. We offer recommendations for meeting carbon goals while providing reliable and affordable electricity services to a growing economy.[1]

**This paper is focused on carbon reduction goals, but it is important to recognize that there is not a clear dividing line between carbon emissions reduction policy and policies to improve air quality.** Air quality objectives are currently motivating much of the effort on emissions reduction in China and air quality efforts will have significant implications for carbon emissions. If policymakers integrate the design and implementation of three areas of policy – power sector policy, air quality policy, and low-carbon policy – this will allow for more rapid, less expensive, and smoother reductions of both "conventional" pollutants and carbon emissions.

Our recommendations are organized as they relate to six key areas that are relevant to emissions reduction: planning, end-use energy efficiency, generation operations and pricing, renewable resources, retail pricing, and emissions pricing. In brief, they are as follows:

**Power Sector Planning**

Internationally, the goal of electricity planning is to facilitate least-cost investment in demand-side, generation, and transmission resources while meeting reliability and environmental goals. This requires a minimum of three elements: (*1*) planning processes that identify resource needs, oriented around policy goals; (*2*) coordination among planning processes for different resources that ensures comparability among demand-side, generation, and transmission resource investments; and (*3*) explicit links between planning processes and resource investment. Even in places with competitive retail and wholesale markets, such as parts of the United States and the European Union (an approach that, in any case, is unlikely to be fully implemented in China in the near-term), careful attention to planning is important for meeting emissions reduction and reliability goals for the entire power sector, including

[1] The term "electricity services" refers to services, such as lighting or cooling, provided by the use of electricity, as distinct from physical sales of electrical energy. A given amount of electricity service can be delivered using varying amounts of energy, depending on the level of energy efficiency.

roles for resources that are typically not guided primarily by market mechanisms – notably, transmission resources and end-use energy efficiency.

In China, the term "planning" is sometimes judged to have a negative connotation because it conjures up notions of "central planning." However, old-style central planning is not what we have in mind. Just as in other countries, good planning practices are essential for China's power sector, especially given ambitious emissions reduction targets. Planning processes for demand-side, generation, and transmission resources lack coordination and are not adequately focused on meeting policy goals. In addition, planning is not well connected with actual resource investment. Instead, investment is driven by an opaque project approval process in which generation and grid companies appear to have been able to circumvent, distort, or undermine planning processes. Reaching the government's goals for the power sector – including goals for emissions reduction – at reasonable cost will require new approaches to electricity planning.

***Recommendations:***

- **Clarify planning roles, responsibilities, and functions and ensure that these roles are coordinated.** There are a number of possible options for how planning responsibility could be allocated. Government agencies could take a more active role in demand forecasting and identifying resource needs, or power sector companies could do so with government oversight. Planning processes could be national or regional in scope.
- **Integrate environmental goals into planning processes.** Environmental goals should be well integrated into electricity planning so that the electricity sector contributes an appropriate amount to overall emissions reductions.
- **Implement transparent and accurate valuation of different resource options, including the full social cost of emissions.** Within planning processes, it is important to accurately value different kinds of resources and technologies, based on their function in the power system and their contribution to air quality and carbon dioxide ($CO_2$) goals. In general, developing analytical tools to support more transparent and accurate valuation of different resources should be a priority for Chinese planners. For generation resources, it is important to accurately value different kinds of technologies, based on their function in the power system and their contribution to air quality and $CO_2$ goals. For transmission, it is important to have greater regulatory oversight of grid company transmission plans, with these transmission plans evaluated on the basis of their impact on reliability, cost-effectiveness, and emissions. For demand-side resources, we recommend better efforts to evaluate the costs of demand response and energy efficiency, particularly the costs of investments made by the grid company under the efficiency obligation. For all resources, valuation should take into account the need for flexible resources to support the significant planned scale-up of wind, solar, and nuclear generation in China.
- **Establish a level playing field for different resources options.** To achieve a least-cost resource mix, demand-side, generation, and transmission resources should be able to "compete" against each other, based on their different emissions, costs, and other characteristics. Planning should allow for comparison across different resource options. This will require more coordinated planning processes, so that, for instance, the generation planning process incorporates information on potential demand-side and transmission investments.
- **Ensure that planning is connected to investment.** The desired resource mix identified in power sector plans should guide investment decisions. Carefully designed mechanisms – including competitive mechanisms, where appropriate – are needed to mobilize investment in a cost-effective, timely, and reliable manner.

### Energy Efficiency as a Power Sector Resource

China has made important strides in improving the efficiency with which energy is used in the economy. The overall energy intensity of the economy has fallen significantly in recent years. However, energy efficiency policy is still not well integrated with power sector policy. There are likely large remaining opportunities to displace conventional, high-emissions supply-side generation resources with clean and cost-effective investments in *end-use* energy efficiency. These opportunities for energy savings are available across all sectors of the economy (industrial, commercial, residential, and agricultural). In China, this concept is sometimes referred to as investing in "efficiency power plants" (EPPs). That is, end-use energy efficiency investments can be organized into bundles that are comparable to a conventional power plant in the ability to meet demand for energy services.

Policymakers in many countries treat end-use energy efficiency as a power sector resource and have placed obligations on electric utilities to deliver end-use energy efficiency. These utility energy efficiency programs have delivered verified, reliable, and highly cost-effective resources, displacing the need for investment in supply-side generation, transmission, and distribution resources. They have also been well documented to inexpensively and reliably reduce the deleterious impacts of electricity production on air, water, land, and climate.

In January 2011, the central government of China for the first time placed an energy efficiency obligation (EEO) on grid companies.[2] The obligation requires the grid companies to achieve modest targets for end-use energy savings. However, regulatory mechanisms to align the grid company's incentives with this obligation – with which there have been many years of experience in North America – have yet to be implemented in China. Currently the grid companies face two types of disincentives to change their business models to achieve the EEO energy savings and load reduction targets. First, the grid companies face significant costs in investing in energy efficiency that are not assured full recovery under current regulatory rules and practices. Second, grid company revenues are reduced by end-use energy efficiency because the increased efficiency means that the grid companies sell less electricity. Our main recommendations involve implementation of regulatory mechanisms to align gridco incentives with investment in end-use energy efficiency. The idea is to change the business model of the grid companies to one in which they are adequately motivated to invest in end-use energy efficiency.

***Recommendations:***

- **Expand and strengthen the grid company EEO.** There is likely significant room to expand the EEO targets, guided by the type of power sector planning described previously. The levels of the EEO targets in China are low compared with leading examples of utility delivery of energy efficiency in other countries. For example, a number of US states have EEOs at 2.5 percent of sales or above, compared to 0.3 percent in China. We also suggest strengthening evaluation, measurement, and verification of the grid company's efforts, drawing on well-developed methods used in the United States and elsewhere.
- **Change the metrics that the State-Owned Assets Supervision and Administration Commission uses for evaluating grid company performance to include end-use energy efficiency**. The grid companies are state-owned enterprises and are motivated not just by profits but also the methods the government uses to evaluate company and executive performance. We suggest the Commission could develop a metric that measures grid company performance in delivering

[2] This is roughly analogous to the international practice of placing EEOs on utilities. If the grid companies in China were restructured into separate transmission and distribution companies, as some observers suggest, it would probably make sense to place the obligation on the distribution companies.

energy efficiency and give that metric significant weight in the overall evaluation of each grid company's performance.

- **Implement regulations that change the ways in which the gridcos earn revenue and profit.** One approach used in many US states involves capping utility revenue. If designed well, a revenue cap breaks the link between utility revenue and utility sales volumes and reduces the disincentive for utilities to deliver energy efficiency to their end-use customers. Other regulatory mechanisms used in the United States (and elsewhere) to encourage utilities to invest in energy efficiency include providing financial incentives for utilities that achieve target levels of energy and demand savings. The recent pilot for the Shenzhen grid company, launched by the National Development and Reform Commission (NDRC) in November 2014, contains some building blocks for reform in these areas.[3] First, the pilot caps Shenzhen grid company revenue over a three-year period. Second, the Shenzhen grid company should, in principle, be able to claim compensation for expenditure on implementing energy efficiency programs, based on previous NDRC rules regarding DSM.
- **Review grid companies' use of energy services companies.** The grid companies have chosen to establish energy services companies (ESCOs) as subsidiaries to carry out end-use energy efficiency projects – and the government has decided to allow these ESCO projects to count toward meeting the grid company obligation. ESCOs can be a useful part of meeting EEOs, but investing in energy efficiency under the EEO should be an integrated part of the grid company business model. We offer two suggestions. First, the gridcos should target a portfolio of energy efficiency projects, with specified characteristics (that is, desired energy efficiency resources, guided by broader power sector planning). Second, the gridcos should fund the costs of carrying out energy efficiency projects within this portfolio, either directly or by "hiring" ESCOs to carry out the projects.

### Generator Operations and Pricing

Generator operations refers to the process, managed by system operators, of turning on and off ("committing") and dispatching generating units to meet demand. In most countries, dispatch and often unit commitment are optimized based on a "merit order approach." This approach seeks to minimize short-run marginal costs, subject to transmission and reliability constraints. In the best cases, this merit order approach reflects not just fuel and operating costs, but also includes the emissions costs associated with each generating unit. In other countries, there have been notable shifts toward centralized dispatch across wider balancing areas, driven by significant cost savings in operations, access to additional generation, and reducing the variability and uncertainty of load and variable generation (such as wind and solar power).

China is very different from other countries in its approach: generator operations in China are based, for the most part, on an annual planning process that sets annual operating hours for each thermal generating unit. This approach hampers efficiency, distorts resource investment decisions, and increases the difficulty of integrating variable generation, while increasing costs and emissions.

The problems with generator operations are rooted in the approach to generator pricing. Policymakers should recognize that dispatch and generation price reforms are fundamentally interconnected, and that they should be pursued in parallel.

***Recommendations:***

- **Move toward a merit order approach for unit commitment and dispatch that incorporates emissions costs.** Moving to a merit order approach to dispatch is an important step that would

[3] China National Development and Reform Commission (2014).

improve power sector efficiency in China. For ensuring that the power sector is able to meet environmental goals, the most efficient approach would be to ensure that the full social cost of emissions associated with each unit is reflected in dispatch. We suggest incorporating emissions constraints in dispatch or putting a price on emissions.

- **Transition from provincial balancing areas to utilizing regional dispatch.** In China, greater regional dispatch would decrease production costs, improve reliability, and reduce total emissions through decreasing the variability of both load and variable generation, and by accessing to a larger portfolio of generation resources for meeting electricity demand and for providing ancillary services. There are several models for how regional dispatch across multiple balancing areas can be achieved, ranging from the EU "market coupling" model to consolidating balancing areas and centralizing system operations, as is done in parts of the United States.
- **Reform generation pricing.** There are a number of different potential approaches to pricing reforms, but regardless of which approach is taken they should be designed to break the link between planned operating hours and generators' recovery of fixed costs. A straightforward approach would be to split the current benchmark tariff for thermal generators into a two-part price, with separate prices and payments for: (*1*) capacity (fixed costs), tied to generator availability, and (*2*) energy (variable costs), tied to generator output.

**Renewable Resources and Integration**

China has had great success in mobilizing investment to rapidly expand renewable energy resources. However, challenges remain in meeting renewables capacity targets on time and at least cost, and particularly in integrating wind and solar energy into the power system.

The main challenge is to put together a package of reforms in order to increase flexibility and thus support integration of the variable generation resources. We suggest consideration of the following options for inclusion in that package, in addition to the planning and generator operations recommendations mentioned previously.

***Recommendations:***

- **Create compensation arrangements to induce more flexibility from existing generation.** Currently there is little or no incentive for generators to provide flexibility; we recommend generation pricing reform for addressing this issue.
- **Prioritize flexibility when adding any new conventional generation.** The value of and need for flexibility should be carefully assessed and taken into account when comparing resources in power sector planning and investment.
- **Devise more formal compensation schemes for ancillary services.** Higher amounts of variable generation will require additional ancillary services, such as load following, spinning reserves, non-spinning reserves, or a combination of multiple types of ancillary services. Generators will need compensation to provide these services; the current compensation arrangements do not fully reflect their costs, including opportunity costs.
- **Revise grid codes.** Grid codes should be updated to take advantage of new capabilities in variable generation and to account for the needs of the grid as variable generation increases.
- **Improve transmission planning and coordinate with generation planning and interconnection.** China should ensure that transmission and location considerations are included when planning for and evaluating new renewable energy projects and flexible generation. Because significant amounts of wind capacity are not interconnected to the grid in China, clear and transparent interconnection procedures should also be established to evaluate the impacts of new generation on the transmission grid, as well as any transmission upgrades needed to accommodate new generation projects.

- **Expand linkages and increase regional power transfers between provincial balancing areas.** Barriers to increased interprovincial power transfers in China relate to the way provinces get revenue when electricity is generated within the province versus imported from a nearby province. The solutions vary, but all rest on increased trade resulting in lower total costs.
- **Adopt faster generation scheduling and dispatch practices.** Variable generation becomes more certain and easier to predict closer to real time. Allowing dispatch and scheduling closer to real time will help support integration of variable generation, and help reduce power system costs.
- **Improve and make better use of variable generation forecasting.** Better wind and variable generation forecasting is an essential tool for integrating renewable generation. In China, the accuracy of wind forecasting is lagging and wind forecasts are not widely used in generator unit commitment decisions in China.
- **Consider compensation when curtailing variable generation.** We suggest that wind generators and grid companies should share the costs for curtailment. This will provide incentive to grid companies to consider possibilities to reduce curtailment while also providing incentive to wind generators to locate in areas where transmission is adequate and curtailment is less likely.
- **Revise feed-in tariffs.** Increasing the feed-in tariff (FIT) price differential between high-quality wind and solar resource areas, and lower-quality wind and solar resource areas would help minimize the concentration of wind and solar plants and encourage the spreading of wind and solar plants across a larger geographic area.
- **Eliminate barriers to the development of distributed solar projects.** Increasing the FIT for Distributed Generation (DG) solar may be necessary. In addition, a successful business model for DG photovoltaics (PV) is needed. This may include clearer definition of rooftop ownership rights, development of standard contracts, and a smoother interconnection process.
- **Monitor interactions between the proposed renewable energy quota and other renewable energy policies.** The Chinese government is considering adoption of a renewable energy quota that has some unusual characteristics, including coexistence with the FIT, which may present design and implementation challenges.
- **Consider role of demand response.** Demand response can be useful in providing flexibility and helping to cost-effectively integrate wind and solar. Given the large share of end-user loads represented by industrial customers in China, the potential for demand response may be significant.
- **Implement priority dispatch.** China's renewable energy law requires that renewable energy generation has priority over other generation sources, otherwise known as priority dispatch. In part, this requirement recognizes that regardless of how renewable generators are paid, their operating cost is so low that they should always be the first to be dispatched. Grid operators in China, though, have largely not implemented priority dispatch, citing concerns about grid security and reliability. Many of the suggestions outlined in this paper would make priority dispatching easier, such as enlarging balancing areas, faster scheduling, improving and making more use of variable generation forecasting, and updating grid codes.

**Retail Pricing**

China has several very useful existing retail pricing policies that help align economic and environmental objectives, including differential prices for industrial consumers and tiered prices for residential consumers. However, retail pricing policy in China suffers from lack of transparency of power sector costs and lack of a rationalized approach to updating retail prices.

***Recommendations:***

- **Prices should be more transparent and better reflect power system costs, including the social costs of emissions.** Broadly speaking, electricity consumers (as a whole, not necessarily individually) should pay prices that cover the actual cost of providing electricity service. In the case of China, it is difficult to say whether or not electricity prices are meeting this objective, because there is lack of transparency. We suggest (*1*) clear and consistent application of accounting rules for costs (including emissions costs), revenues, and profits; (*2*) consistent application of those rules in a well-designed administrative process for review and application of the rules to set allowed revenues; (*3*) wider publication of information regarding retail prices; and (*4*) strengthened penalties for failures to comply with requests for information or the determinations of government.
- **Policies to allow "direct access" contracting between end-users and generators should be designed with caution.** Several regions of China have pilot programs allowing large users to bypass the gridcos and negotiate prices directly with generators, with the goal of moving away from the current system of administratively set on-grid prices toward a kind of wholesale market with "many buyers and many sellers." If there is to be a national transition to a direct access scheme, it will have to be designed to support emissions reduction goals. We urge careful policymaking here: first, preserve the positive aspects of retail pricing in China mentioned earlier. Second, ensure that direct access does not undermine the link between planning and investment. This could happen if, for example, end-users and generators end up contracting for more coal-fired generation than would be consistent with emissions reduction goals. Third, beware of allowing inefficient industrial customers access to low prices. Fortunately, the direct access pilots appear to only allow the most efficient industrial customers to participate in direct access. We recommend strengthening this component of direct access policy.

**Carbon Pricing and Trading**

Several Chinese provincial and municipal governments launched carbon emissions trading schemes, which include the power sector, in 2013–2014 and the Chinese central government is now designing a national scheme that is also expected to cover the power sector. These schemes were developed very quickly compared to emissions trading schemes in other countries and – partly as a result – are not yet well integrated with power sector policy.

***Recommendations:***

- **Integrate emissions trading schemes with energy efficiency programs.** Pairing emissions trading schemes with utility-run programs (similar to the grid company energy efficiency obligation in China) that mobilize capital for direct, comprehensive investment in energy efficiency, has worked well. Revenues from emissions trading schemes can be directed toward energy efficiency or renewable energy resources. The emissions trading scheme in the northeastern United States, which focuses on the power sector, is a useful example. In this scheme, emissions allowances are auctioned and a majority of the revenue is used to support end-use energy efficiency programs.
- **Design emissions trading schemes in a coordinated fashion with coal control policy and air quality policy.** In the regions of China currently subject to carbon trading pilots, coal consumption control, energy efficiency, renewable energy, and air quality policies may be driving most (or perhaps all) of regional emissions reductions. That is, the bulk of carbon emissions reductions currently underway in these regions may not be attributable to the emissions trading pilots themselves, but instead to other regional policy efforts. This should perhaps not be surprising given the ambitious targets associated with coal consumption control

and air quality management. In fact, a large role for these "other" policies in the overall policy package may be desirable – but the balance between the various policies should be carefully analyzed in order to rationalize the design of the emissions trading scheme and determine whether the package is likely to over-deliver or under-deliver in terms of emissions reductions. To put the point more simply, it is important to design a policy package as a package, not isolated fragments.

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# 1. Introduction

The Chinese government has set national goals to reduce carbon emissions. In addition, the government is pursuing closely related goals for coal consumption and air quality. These goals are set out in the 12th Five-Year Plan (2011–2015) and the *Air Pollution Prevention and Control Action Plan (2013–2017)*. In addition to these national goals, many provinces and municipalities have set goals for coal consumption reduction and air quality improvement for 2017 and beyond.

The power sector accounts for more than half of annual coal consumption in China.[4] It is hard to imagine achieving these goals in a cost-effective manner without a large contribution from the power sector.[5] However, the Chinese authorities have yet to set out a comprehensive agenda for the power sector's role in meeting emissions and environmental goals. Power sector policy and regulatory issues were largely omitted in the *Air Pollution Action Plan* and the associated local plans. More importantly, a major once-in-a-decade "power sector reform" guidance document is expected to be issued by the government soon – but media reports (as of the time of this writing) suggest that the draft reform plan has not been framed in terms of the government's air quality, coal cap, and carbon goals.

We offer concrete options for framing power sector reforms to meet these goals, and to meet them in a cost-effective, low-risk manner. These options are based on our analysis of international experience and of China's conditions, and are moulded in light of two important considerations for policymakers. The first is that an integrative approach is best. Although policymakers and media reports often discuss carbon emissions reduction, "conventional" emissions reduction, and coal consumption control as distinct goals, they are in fact inseparable and are best addressed in a comprehensive, integrated fashion. Integrating policy design, implementation, and monitoring across these activities will greatly increase the chances of achieving the goals – and minimizing the costs of doing so. The second is that regulatory processes, decisions, and mechanisms deeply affect power sector investment, operations, and emissions in complex and sometimes subtle ways. Many aspects of regulation that are not explicitly intended to address climate or environmental concerns nevertheless have important, and often negative, effects on emissions. No set of policy reforms can hope to be effective, if careful consideration of their unintended consequences isn't given.

This paper is a companion to the report *Low-Carbon Power Sector Regulation: International Experience from Brazil, Europe, and the United States* (henceforth referred to as *International Experience*). That report examined international experience with power sector regulation and policy. In light of that experience and of China's stated emissions, energy, and environmental objectives, this paper details a set of integrated policy options for comprehensive reform of the Chinese power sector. The introduction to that paper included a note on terminology that is worth repeating here: the term "regulation" can mean different things in different contexts. In particular, there is no clear dividing line between power sector "regulation" and power sector "policy." We take a broad view of regulation to include most government authority that affects the power sector, no matter whether that authority is exercised by executive government agencies, legislatures, independent bodies authorized by government, or judicial bodies. This authority may take a number of forms, including planning, standards-setting, price-setting, cost approval, market design, incentive mechanism design, permitting, monitoring, and enforcement. In China as in other countries, difficulties in coordinating the efforts of different authorities is often a significant obstacle to emissions reduction.

[4] China's total annual coal consumption accounts for roughly half of the world's total annual coal consumption.

[5] World Bank Energy Regulatory Research Group (2013) makes a similar point that "The power industry is the key field in dealing with climate change and reducing carbon dioxide emission."

We do not address all issues related to power sector reform, but instead focus on the most important topics for achieving carbon reduction goals. We offer recommendations for meeting carbon goals while providing reliable and affordable electricity services to a growing economy.[6]

This paper is organized in a similar fashion to *International Experience*, covering several key topics for low-emissions power sector regulation:

- Power sector planning and resource acquisition;
- Energy efficiency as a resource;
- Generator operations and pricing;
- Renewable resources and integration;
- Retail ricing; and
- Carbon pricing and trading.

We also briefly discuss climate impacts on the power sector.

Air quality regulation is largely beyond the scope of this *Low-Carbon* report. However, it is important to emphasize that low-carbon power sector regulation should be integrated with air quality management. Air quality objectives are currently motivating much of the effort on emissions reduction policy in China and these air quality policies will have important implications for carbon emissions. The *Air Pollution Prevention and Control Action Plan (2013–2017)* launched ambitious targets for air quality improvement and coal consumption control. Currently many provinces and municipalities are engaged in efforts to meet these targets. The integration of power sector regulation, air quality policy, and low-carbon policy will allow for more rapid, less expensive, and smoother reductions of both “conventional” pollutants and carbon emissions.

## Reference

World Bank Energy Regulatory Research Group. (2013). *Electricity Regulatory Authority Policies and Measures to Respond to Climate Change.* Unpublished manuscript.

[6] The term “electricity services” refers to services, such as lighting or cooling, provided by the use of electricity, as distinct from physical sales of electrical energy. A given amount of electricity service can be delivered using varying amounts of energy, depending on the level of energy efficiency.

# 2. Power Sector Planning

## 2.1 Introduction

Power sector planning is essential for providing reliable, affordable electricity services while meeting goals for reducing emissions. A basic task of planning is to support transparent, cost-effective tradeoffs among different resources – not just conventional power plants, but also end-use energy efficiency and demand response ("demand-side resources"), distributed generation, energy storage, renewable energy generation, and transmission.

Around the world, planning takes different forms under very different industry structures. Even in places with competitive retail and wholesale markets, such as parts of the United States and the European Union (an approach that, in any case, is unlikely to be fully implemented in China in the near term), careful attention to planning is important for meeting carbon reduction and other policy goals for the power sector. In particular, policymakers, regulators, and system operators in places with competitive markets need planning to determine whether markets are able to acquire reasonable quantities and kinds of resources to meet these goals or whether market design needs to be adjusted. They also need planning to make sure that investments that are typically not acquired primarily by market mechanisms – for example, transmission resources and end-use energy efficiency – are coordinated with other power sector investment decisions.

Discussions on power sector reforms in China have sometimes eschewed the term "planning" because of its perceived connotation of central planning. However, just as in other countries, good planning practices are essential in China, especially given ambitious emissions reduction targets. Currently, planning processes for demand-side, generation, and transmission resources in China are all individually flawed and not well coordinated. Planning is also not well linked with resource investment. That is, investment decisions are often made without regard to power sector planning. These problems urgently need to be addressed, if the power sector is to play its role in meeting national and local government objectives for carbon emissions and air quality.

## 2.2 Goals

China's ambitious targets for emissions reductions, renewable energy, and energy efficiency will be difficult to meet in a cost-effective manner unless power sector planning improves and becomes focused on meeting these goals in a coordinated fashion. Policymakers in China also need to review and adjust mechanisms that guide resource investments, including the approval process for new investments. Approvals should be done in line with power sector goals as identified by the planning process.

## 2.3 Current Issues and Barriers to Reform

The concept of a coordinated approach to electricity planning has some precedent in China, including the 1995 Electricity Law, which includes a general provision that "planning for electric power development shall reflect the principles of rational utilization of energy, coordinated development of the power sources and power networks, increasing economic benefits, and being conducive to environmental protection."[7]

As described in *International Experience*, in other countries planning is often overseen by regulatory authorities, with individual plans developed by electricity service providers – that is, grid companies,

[7]"电力发展规划，应当体现合理利用能源、电源与电网配套发展、提高经济效益和有利于环境保护的原则。"
Available at: http://www.nea.gov.cn/2012-01/04/c_131262818.htm

distribution companies, or retail providers. Customer demand is forecast periodically and suppliers develop plans to identify needed resource investments – demand-side, transmission, and generation – in advance to meet that demand, subject to reliability and environmental requirements. In the best cases, this resource mix is based on careful cost-benefit analysis of the various resource options, including consideration of the social costs associated with various types of emissions. For example, planners might ask: over the near term, to what extent is it societally more cost-effective to reduce or curtail demand than build new generation or transmission? To address local congestion, should suppliers acquire more transmission capacity, invest in energy efficiency and demand response, or procure more generation? Managing these tradeoffs requires tools and processes that accurately evaluate the cost-effectiveness of different alternatives in ways that align with overall policy goals.

In China, this kind of planning approach does not yet exist and there is no process to make tradeoffs across various supply-side, demand-side, and transmission resources. In practice, various authorities oversee different processes that are relevant to power sector planning, including: (*1*) national and local five-year development planning (五年发展规划); (*2*) longer-term resource and transmission planning (中长期发展规划); (*3*) pollution planning (污染防治行动计划); (*4*) project approval (项目核准); and (*5*) "orderly electricity use" demand planning process that rations electricity supplies during periods of scarcity (有序用电). Unfortunately these plans are prepared on separate tracks, each often with little reference to the others.

In addition to imperfect and fragmented planning processes, a major problem in China is that investment in various resources (particularly generation and transmission resources) is not well linked to the various planning processes. Instead of being guided by a clear planning process oriented around policy goals (including emissions reduction goals), investment is driven by a non-transparent project approval process in which generation and transmission companies appear to be able to circumvent, distort, or undermine planned investment outcomes. In addition, generation pricing and dispatch should provide signals to support emissions reduction and other policy objectives. However, generation pricing and dispatch were not designed with this in mind, and they currently are the source of significant distortions: generation prices are only loosely cost-based and dispatch is not economic (see Section 4). These shortcomings contribute to a number of problems faced by China's power sector: an inefficient amount and mix of generation, transmission, and demand-side resources; excessive resource costs; excessive renewable energy curtailment costs; difficulty in meeting emissions goals; and wide swings between periods of scarcity and oversupply.

For example, the low level of investment by electricity sector companies in end-use energy efficiency illustrates limitations in the current planning approach. There is no planning process that compares the benefits and costs of investments in end-use energy efficiency (EPPs) against alternative investments in supply-side resources, nor any planning process that incorporates the benefits of efficiency programs in reducing future capacity and energy needs (see Section 3). In 2010, the NDRC issued a policy requiring the grid companies to achieve energy savings of at least 0.3 percent in sales volumes compared with the previous year's results, but there is much scope to strengthen and expand this obligation.

Another example of the implications of weak planning practices is the significant expansion of combined heat and power (CHP) generation in the northeast over the past decade. This was done to take advantage of CHP's higher combined thermal efficiency. Although sensible on these narrow terms, the expansion of CHP was not guided by a planning process that would have required a more comprehensive view of the nature of demand growth, the resource mix, and the longer-term resource needs. The late 2000s and early 2010s saw a significant expansion of wind power in the region, driven by a separate planning process. During the winter, dispatch centers (the system operator) operate CHP units to meet heating demand, and they are thus unable to be operated more flexibly in response to changes in electricity demand and wind output. As a result, on windy winter days when output from CHP units cannot be reduced, significant wind curtailment has occurred, leading to substantial losses in revenue. Better planning could have anticipated and avoided at least some of these costs by more closely coordinating investments in electricity and heating resources, and in generation and transmission to allow for export from areas with excess generation.[8]

## 2.4 Options and Recommendations

Better planning processes are critical to meeting air quality and $CO_2$ reduction goals for China's electricity sector at a reasonable cost. We break our recommendations down into several categories.

**1. Clarify planning roles, responsibilities, and functions, and ensure that these roles are coordinated.** A first step in encouraging better planning in China would be to clarify which parties are responsible for what kinds of planning, and which parties are responsible for oversight of planning processes and review of plans. There are a number of possible options for how planning responsibility could be allocated. For instance, for resource planning, national, regional, and provincial government agencies could take a more active role in demand forecasting and identifying resource needs, or they could develop a process in which commercial actors do so with government oversight. Planning processes could be initiated and coordinated by national government agencies, or they could be more regional and provincial in orientation. In any case, these planning processes and their link to resource investment decisions should be clearly and transparently defined. As a general principle, planning should help to guide investment decisions.

**2. Integrate environmental goals into planning processes.** Environmental goals should be well-integrated into electricity planning so that the electricity sector contributes an appropriate amount to overall emissions reductions. This requires addressing a number of questions, such as which agencies should set environmental targets for the sector, how should the targets be set, who should be responsible for complying, which agencies are responsible for oversight, which for evaluation? In addressing these questions, it will be important to consider how environmental targets are implemented, via standards, fees, or markets. Improved planning will also require improved and more rigorous analysis tools, to better identify the effectiveness and cost-effectiveness of different emissions reducing measures. For instance, in a given province, will pollution controls on coal-fired power plants will be sufficient to meet local environmental goals? If not, what other power sector emissions reduction options are available?

**3. Implement transparent and accurate valuation of different resource options, including the full social cost of emissions.** Planning processes should facilitate a least-cost mix of resources to meet reliability and emissions goals, based on an accurate, up-to-date evaluation of resource benefits and costs. For generation, it is important to establish mechanisms to value different kinds of technologies, based on their function in the power system and their contribution to air quality and $CO_2$ goals. For instance, gas-fired generation is currently undervalued in China's power systems, because neither planning agencies nor companies explicitly assess its role in longer- and short-term balancing or reducing emissions.[9] As a result of the lack of mechanisms to reveal the value of gas-fired generation and other "low capacity factor" resources, investment in coal-fired generation in China is too high relative to what is economically and environmentally efficient. For transmission, it is important to have greater regulatory oversight of grid company transmission plans, with these transmission plans evaluated on the basis of their impact on reliability, cost-effectiveness, and emissions. For demand-side resources, we recommend better efforts to evaluate the costs of demand response and energy

[8] Kahrl et al (2011).

[9] Hu et al (2013).

efficiency, particularly the costs of investments made by the grid company under the efficiency obligation (see Section 3). Across all resources, valuation should take into account the need for flexible resources to support the significant planned scale-up of wind, solar, and nuclear generation in China.

**4. Within planning processes, establish a level playing field for different resource options.** To achieve a least-cost resource mix, demand-side, supply-side, and transmission should be able to "compete" against each other, based on their different emissions, costs, and other characteristics. Planning can help to create a level playing field by allowing for a comparison between resource options. For example, when and where are demand response, energy storage, low operating hour power plants, and new transmission most effective and cost-effective as means to meet peak demand, meet emissions goals, and address the variability of wind and solar generation? Answering these kinds of questions will require more coordinated planning processes, so that, for instance, new demand-side resources, generation resources, and transmission resources can be compared in transmission plans and possible new transmission lines can be incorporated in generation planning. It will also require use of improved resource planning and analysis tools that integrate environmental considerations and more accurately value the benefits and costs of different resources. For instance, in the United States, energy efficiency planning typically draws on quantitative assessments of the costs avoided by acquiring demand-side resources rather than building new generation or transmission assets.[10]

This concept of a level playing field could help resolve various resource debates. For example, there has been debate over the cost-competitiveness of gas-fired generation in China, particularly in relation to high-efficiency coal plants as a resource for meeting emissions reduction goals. Fortunately there are well-tested, internationally accepted methods for analyzing such problems, but they are not widely used in China. Typical economic comparisons in China between natural gas and coal-fired generation in China typically do not account for the value of the roles that gas-fired generation can have in the power sector. For example, our analysis shows that natural gas is already cost-competitive for peaking generation in China, and that using natural gas for peaking generation could help to improve the energy efficiency of existing coal-fired power plants.[11]

**5. Ensure that planning guides resource investment.** After the planning process determines what resources constitute a desired resource mix, a framework is needed to acquire these resources in a cost-effective, timely, and reliable manner. In other words, the resource mix identified in power sector plans should guide investment decisions.

This requires careful consideration of regulatory and business models for investment. In other sections, we discuss in detail resource acquisition mechanisms to guide investment in the two most important low-emissions resources, end-use energy efficiency (strengthening and expanding the gridco obligation; Section 3), and renewables (refining the FIT and proposed quota policies; Section 5). Resource acquisition mechanisms in China should be reviewed and adjusted in order to deliver the resources identified in power sector plans.

In addition, power planning of the type described in this section will likely justify some continued investment in new coal- and gas-fired power plants. There are many options – including market and non-market mechanisms – to guide investment in these conventional power plants. Many analysts and policymakers in China are calling for rapid movement to more competitive generation as a way to achieve lower costs. One competitive option that may be suitable for conventional resources in China is the auctioning of long-term contracts, in a fashion similar to that seen in Brazil, India, and parts of the

[10] See, for example, the energy efficiency planning tools used in California, available at: https://ethree.com/public_projects/cpuc4.php

[11] See: The Regulatory Assistance Project (2013)

United States.[12] Under this approach, generators compete for long-term contracts to build and operate new generation, as identified in the planning process. The benefits of this market-based approach include pressure for innovation through competition; scope for establishment of new pricing structures that support more efficient dispatch; and better integration of renewables. The success of this approach requires transparent rules, with careful government management and oversight. China has had some difficulties with bidding for conventional generation resources during the 1990s and with renewables more recently. However, there is recent international experience suggesting that a well-designed and well-governed contract auctioning mechanism can be effective.[13]

## 2.5 Conclusion

Like all countries, China will need to improve electricity planning to meet the challenges associated with the transition to a low-carbon, low-pollution energy sector. To improve electricity planning in China, we recommend the following near-term steps:

- Clarify roles, responsibilities, and functions associated with electricity planning, including how environmental targets for the sector are set and incorporated into sector planning and how resource investment decision-making links to planning processes;
- Integrate environmental goals into resource investment decisions;
- Develop planning and analysis tools that aid in evaluating the costs of different resources, their benefits to the power system, and their effectiveness and cost-effectiveness in reducing emissions; and
- Develop coordination mechanisms that enable a transparent, level playing field between and among demand-side, generation, and transmission resources.

These steps will require innovation. Returning to planning approaches used in the past will not be sufficient to address the complex challenges that China's electricity sector is now facing.

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[12] Auctions could also possibly be used for other resources, including renewables. See: Azuela and Barroso (2014); and Wang et al (2014).

[13] For more detail see Maurer and Barroso (2011); The Regulatory Assistance Project (2013); and *International Experience*.

http://documents.worldbank.org/curated/en/2014/06/19670594/promoting-renewable-energy-through-auctions-case-china

# 3. Energy Efficiency as a Power Sector Resource

## 3.1 Introduction

Policymakers around the world have placed obligations on electricity utilities to deliver *end-use* energy efficiency as a major component of their overall policies and strategies to achieve energy savings and reduce greenhouse gas emissions.[14] These utility energy efficiency programs have delivered verified, reliable, and highly cost-effective resources, displacing the need for investment in supply-side generation, transmission, and distribution resources. They have also been well documented to inexpensively and reliably reduce the deleterious impacts of electricity production on air, water, land, and climate.

Efficiency of conventional power plants is also an important issue, but one that is already reasonably well integrated into power sector policy in China, for example through emissions standards and policies to close down less efficient generators.[15] Generally speaking, there is already significant incentive for power plant owners to improve efficiency. (The recommendations regarding generator operations in Section 4 would provide further incentives.) This section focuses on the treatment of *end-use* energy efficiency as a resource for the power sector; this is a common practice elsewhere in the world, but it has yet to be adopted in China.

Section 2 briefly described how end-use energy efficiency should be treated in the planning process as a resource on a level playing field with supply-side resources. That section also mentioned the setting of targets for grid company acquisition of end-use energy efficiency resources. This section goes into these issues in greater detail, with a focus on gridco-run programs for investing in energy efficiency. Here we also present these issues in the broader context of energy efficiency policy in China.

## 3.2 Goals

Energy efficiency is currently playing a major role in reducing China's emissions (from the power sector and other sources). Even so, there are likely large amounts of efficiency resources in the form of unexploited opportunities to improve the efficiency of electricity end-uses. The challenge at hand is to integrate energy efficiency into the power sector so that it operates on a "level playing field" with other resources. This will allow it to take on an even larger role in displacing relatively expensive and high-emissions resources. To support this, policymakers need to design a coordinated planning process that includes energy efficiency, as described in Section 2. In addition, there is also a need to ramp up investments in end-use energy efficiency in the power sector – or, to put this a different way, there is a need for a mechanism to "construct" EPPs. The obligation on Chinese gridcos to meet end-use energy efficiency targets is an example of such a mechanism.

## 3.3 Current Issues and Barriers to Reform

***Energy efficiency policy in China.*** Policies to improve the efficiency of electricity end-use must be understood in the broader context of energy efficiency policy in China. China has a well-developed set of policies that have made major contributions to reducing energy intensity – however, these are not yet well integrated with the power sector. Energy intensity targets (targeted declines in energy use per unit of GDP) have been the centerpiece of China's energy efficiency policy since 2004.[16] The *12th Five Year Plan* (2011 to 2015) includes targets to reduce by 2015 energy intensity by 16 percent and carbon

[14] Crossley et al. (2012).
[15] World Bank Energy Regulatory Research Group (2013).
[16] Crossley (2013a).

intensity by 17 percent from their levels in 2010. Energy intensity targets are set for national, provincial, and local governments in China, and are rigorously monitored and supervised. Energy intensity targets are also set for individual commercial and industrial enterprises under energy savings responsibility contracts between the enterprise and the appropriate level of government.

The comprehensive system of energy intensity targets for both governments and individual enterprises, together with an extensive compliance monitoring process, have now been in existence for more than ten years and appear to be functioning relatively well. However, it is very likely that there are large amounts of energy efficiency potential that remain untapped, and that exploiting this resource would often be much less expensive than building supply-side electricity capacity.

***Grid company energy efficiency obligation in China.*** Effective from January 2011, a new type of energy efficiency target was introduced into China. The central government for the first time placed an energy efficiency obligation (EEO) on the State Grid Corporation of China and China Southern Grid Company, the two large government-owned entities that operate the electricity transmission and distribution networks and sell electricity directly to end-use customers throughout most of China.[17] The obligation requires the grid companies to achieve energy savings of at least 0.3 percent in sales volumes and demand savings of at least 0.3 percent in maximum load, both compared with the previous year's results.[18]

Currently the grid companies face two types of disincentives to change their business models to achieve the EEO energy savings and load reduction targets. First, the grid companies face significant costs in acquiring energy and demand savings that are not assured full recovery under current regulatory rules. In the United States, electricity industry regulators have implemented various mechanisms that enable utilities to recover their costs in acquiring energy and demand savings, but no similar mechanisms have been implemented in China.

Second, grid company revenues are reduced by end-use energy efficiency because the efficiency efforts mean that the gridcos sell less electricity. At present, the regulatory regime in China does not offer any compensation to grid companies for reduction in revenue.[19] In common with electricity utilities in other jurisdictions, Chinese grid companies are concerned about the net revenue reduction that results from encouraging customers to use electricity more efficiently. This is exacerbated in China because the State-Owned Assets Supervision and Administration Commission evaluates grid company performance primarily on the revenues they earn and the profits they make. Revenue reduction is therefore a major disincentive to grid company implementation of energy efficiency; consequently energy efficiency has been slow to become a core part of the grid company mission.[20]

The grid companies have chosen to establish subsidiary energy services companies (ESCOs) to carry out energy efficiency projects – and the government has decided to allow these ESCO projects to count toward meeting the grid company obligation. ESCOs can be a useful part of meeting EEOs, if their services are directly paid for by grid companies and if their investments are guided by grid company plans. However, the grid companies in China use ESCOs as separate, subsidiary business units outside the grid company core business rather than incorporating energy efficiency into the grid company

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[17] This is roughly analogous to the international practice of placing EEOs on utilities. If the grid companies in China were restructured into separate transmission and distribution companies, as some observers suggest, it would probably make sense to place the obligation on the distribution companies.

[18] China National Development and Reform Commission (2010).

[19] As discussed below, many US states have mechanisms that compensate utilities for reduction, owing to energy efficiency, in net revenue (that is, after accounting for any cost savings that accompany reduced sales).

[20] Crossley (2014).

business model.[21] This raises questions about the commitment of the grid companies to achieving the EEO targets and suggests that the EEO mechanism may not continue successfully over the long term.

The levels of the two EEO targets are low compared with targets for utility delivery of energy efficiency in other places.[22] For example, a number of US states have EEOs at 2.5 percent of sales or above. In 2013, the total energy savings achieved by the Chinese grid companies (on a first-year savings basis) were 16.2 TWh, and the total load reduction was 3.44 GW.[23] These savings are significant, but relative to China's huge electricity consumption they are not particularly ambitious.

## 3.4 Options and Recommendations

China can significantly reduce costs and increase economic efficiency by requiring the grid companies to acquire all cost-effective energy efficiency before purchasing electricity from generators. There is likely significant room to expand the EEO targets, guided by the type of power sector planning described in Section 2. We offer several supporting recommendations in three areas.

First, we suggest changing the way the State-Owned Assets Supervision and Administration Commission evaluates the performance of grid companies. Currently grid company managements are concerned that the performance of their companies may be downgraded because of the reduction in profit resulting from their implementation of energy efficiency projects in compliance with the EEO. This problem can be addressed by changing the metrics for evaluating grid company performance, in particular by developing a metric that measures grid company performance in delivering energy efficiency.[24]

Second, we recommend changing the ways in which the gridcos earn revenue and profit. In the United States and some other countries, regulatory regimes have been established that reduce the financial penalties experienced by utilities in acquiring energy efficiency. One method used in many US states involves capping utility revenue, thereby reducing the "throughput effect," when utilities rely on supplying increasing volumes of electricity to maintain their revenue and therefore profits.[25] Revenue capping "decouples" utility revenue from sales volumes and makes it easier for utilities to deliver energy efficiency to their end-use customers. Other regulatory mechanisms used in the United States and in other jurisdictions to encourage utilities to acquire energy efficiency as a resource include providing financial incentives for utilities that achieve target levels of energy and demand savings.[26]

Similar types of regulatory incentives recently appeared in China, in the form of a pilot for the Shenzhen grid company, launched in November 2014.[27] The pilot should make it more attractive for the Shenzhen grid company to implement end-use energy efficiency:

- It subjects the grid company to a form of decoupling by capping revenue over a three-year period.[28]
- The grid company should, in principle, be able to claim expenditure on implementing DSM and energy efficiency programs as allowed costs, based on an article in the 2010 *Guidance on Electricity Demand-Side Management Regulations*. [29]

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21 Crossley (2013b).
22 Crossley et al. (2012).
23 China National Development and Reform Commission (2014b).
24 Crossley (2013b).
25 Migden-Ostrander, Watson, Lamont, and Sedano (2014) and Lazar, Weston, and Shirley (2011).
26 Crossley (2014).
27 China National Development and Reform Commission (2014a).
28 The pilot regulation says "Allowed Revenue = Allowed costs + Allowed Profit + Taxes."

It would be beneficial to clarify and strengthen the relationship between the new pilot and the 2010 DSM regulations, so that the Shenzhen gridco is able to claim legitimate DSM expenditures under the Shenzhen pilot. We also recommend strengthening the DSM planning, monitoring, verification, evaluation, and program approval processes in order to support this new approach.

The Shenzhen pilot provides an opportunity for wider adoption of a new grid company business model and acceptance of energy efficiency as a power sector resource. Refining and expanding the Shenzhen pilot across the country will transform all of China's grid companies.[30] In the meantime, there are several funding sources from which Chinese grid companies (outside of Shenzhen) can recover the costs of implementing energy efficiency projects, including:[31]

- The financial incentives provided by the central and provincial governments for projects that deliver verified energy savings;
- The cost savings that the grid companies make from reducing energy consumption and energy demand; such cost savings can result from, for example, a reduced need for grid augmentation and grid expansion; and
- The additional funding sources identified in the regulatory document that imposed the EEO on the grid companies.[32]

Third, we recommend that the government review grid companies' use of ESCOs. We caution against continuing to allow grid companies to rely on wholly owned ESCO subsidiaries in the current manner. It would be better for the grid companies to:[33]

- Directly fund the costs of carrying out more complex and comprehensive energy efficiency programs and projects, in addition to using grid company ESCOs to undertake simpler projects; and
- Engage third-party ESCOs as contractors to collaborate with grid company ESCOs in carrying out energy efficiency projects in the particular market segments that the third-party ESCOs specialize in, rather than requiring grid company ESCOs to compete with third-party ESCOs across all market segments.

Directly funding end-use energy efficiency projects and engaging third-party ESCOs will assist the grid companies to change their business models from supplying electricity to providing comprehensive energy services to their customers, thereby reducing costs and increasing economic efficiency.

Finally, we suggest strengthening evaluation, measurement, and verification of the grid company's efforts, drawing on well-developed methods used in the United States and elsewhere.

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[29] China National Development and Reform Commission (2010) says "legitimate expenses in DSM implementation by power grid companies may be counted as power supply cost."

[30] Crossley, Wang, and He (2014).

[31] Crossley (2013b).

[32] China National Development and Reform Commission (2010).

[33] For more discussion of these recommendations as well as the international experience with ESCO performance, see Crossley (2013b).

## 3.5 Conclusion

China has had much success with energy efficiency policies, but these are still not well integrated with power sector regulation. End-use energy efficiency is not adequately integrated into power sector policy as a power sector resource and, as a result, the power sector resource mix is significantly greater in size, more polluting, and more expensive than it should be. In other countries, governments have placed obligations on grid companies to plan for and invest in energy efficiency. These gridco energy efficiency programs have delivered verified, reliable, and highly cost-effective resources, displacing the need for investment in more costly supply-side generation, transmission, and distribution resources. They have also been well documented to inexpensively and reliably reduce air and water impacts of electricity production.

China has taken some important steps in this direction, by placing an obligation on grid companies to meet energy efficiency targets and piloting EPPs– bundles of end-use energy efficiency that help meet projected demand in the same way that conventional power plants do (although typically at lower cost). In addition, in late 2014 the NDRC launched a pilot in Shenzhen that has the potential to transform the grid company business model, removing disincentives for the grid company to invest in end-use energy efficiency. The recommendations here focus on going beyond these initial steps so that energy efficiency can play a more robust role in displacing conventional high-emissions resources in the power sector.

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# 4. Generator Operations and Pricing

## 4.1 Introduction

"Generator operations" refers to the process, managed by system operators, of turning on and off ("committing") and dispatching generating units to meet demand. In most countries, dispatch and often unit commitment are optimized by the system operator based on a "merit order" approach that seeks to minimize short-run marginal costs subject to transmission and reliability constraints. In North America and the European Union, merit order dispatch and unit commitment are being carried out across increasingly wider geographic areas.

In China, generator operations are, for the most part, based on an annual planning process that sets a number of annual operating hours for each generating unit. This approach is suboptimal and results in higher costs, worse environmental performance, and distorted investment decisions. It is rooted in methods for compensating generators; improving generator operations will require parallel reforms in generation pricing.

## 4.2 Goals

Generator operations should seek to facilitate the least-cost operation of the power system, while meeting reliability and environmental targets, and to send efficient cost or price signals for investment. In power systems that have a significant share of solar, wind, and nuclear power, minimizing costs while meeting reliability and environmental goals requires greater flexibility in load and generation.

## 4.3 Current Issues and Barriers to Reform

China's current institutions and practices for generator operations were designed for a context in which demand was fairly predictable and constant, and could be served largely by baseload coal generation. In most provinces, grid company dispatch centers commit and dispatch generators according to an administratively allocated number of annual operating hours. The allocated hours are determined by government planning agencies. To allow generators a fair opportunity for investment cost recovery, they are roughly equal, in any given year, for generation units of a given type of technology (e.g., coal-fired units). Thus, instead of ensuring that the power system is operated at least cost, system operators (grid company dispatch centers) in China must instead focus on ensuring that each generation unit gets its assigned hours for the year.

The context in China has changed – electricity demand is becoming less predictable and more variable and, with ambitious goals for low-carbon generation, so is supply. This changing context increasingly highlights the inefficiency of the current "equal shares" approach to unit commitment and dispatch in China. This approach allows, for instance, inefficient coal generators to operate a similar number of hours as efficient ones. It can also lead to the curtailment of generation with lower marginal costs, such as wind units (see Section 5), in favor of higher marginal cost ones, such as coal-fired units.

Beginning in the mid 2000s, central and provincial government agencies proposed a series of solutions to improve dispatch efficiency. Jiangsu Province established a platform for trading annual "generation rights" (发电权交易 | fadianquan jiaoyi) in 2006, and other provinces subsequently set up similar trading platforms. Trading in these platforms has, however, been limited,[34] and short-term rights trading is not a permanent solution. In 2007, the NDRC and SERC launched five provincial "energy efficient dispatch" (节能调度 | jieneng diaodu) pilots, which established an administrative dispatch order based

[34] For instance, in 2011 generation rights trading accounted for approximately 2 percent of total generation in the State Grid region. See: SGCC (2012).

on environmental and resource priorities. However, energy efficient dispatch has not been expanded nationwide, as intended. Most provinces in China still use a dispatch based on administratively allocated operating hours, set through an annual planning process.

The timescale of generator operations also poses challenges in China. Coal units, which still dominate the country's generation mix, often have to be turned on or off several hours, or even days, ahead of real-time dispatch. The accuracy of load and wind and solar output forecasts improves as the forecast moves from days-ahead to real-time. In the United States and the European Union, system operators use wind and solar forecasts on multiple time scales, from long-term to near–real-time, and adjust unit commitment as necessary. In China, resolving the discrepancy between the longer startup/shutdown times of coal units and the shorter-term flexibility needed by variable loads and generation requires a more systematic unit commitment process, to optimize tradeoffs among generation, storage, and load resources.

As discussed in *International Experience,* in other countries there have been notable shifts toward centralized dispatch across wider balancing areas, driven by cost savings in operations, access to additional generation, and the need to integrate variable generation (see Section 5). In China, most balancing is still done at a provincial level. Dispatch is based on a complex five-level hierarchy, where national and regional dispatch centers have dispatch priority over provincial and sub-provincial ones. Generators that export across provincial boundaries are scheduled by national and regional dispatch centers and thus have dispatch priority. Cross-provincial power flows, rather than being the result of short-run optimizations, are planned far in advance. Dispatch hierarchy was designed to address geographical mismatches of load and resources: most of China's coal and wind resources are in the north region, most of its hydropower is in the south, and most demand has historically been in the east.

Although this multilevel dispatch hierarchy has supported a significant increase in cross-province power flows over the last decade, it does not lead to more integrated provincial operations and exacerbates short-term flexibility challenges by increasing the amount of generation that is "must run." Centralized dispatch across wider balancing areas in China would reduce total electricity costs and emissions and would support renewable integration efforts by increasing flexibility, diversifying loads and resources, and reducing forecast error. The central government piloted regional power pools in the early 2000s with the goal of facilitating a more regional dispatch, but these were discontinued because of provincial cost allocation issues. Shifting toward wider balancing areas in China would require addressing these issues.[35]

The need to move away from "planned generation" (发电量计划 | fadianliang jihua), described previously, toward a more economic system of dispatch is becoming increasingly urgent as China takes steps to reduce air pollutants and $CO_2$ emissions. The lack of least-cost unit commitment and dispatch has led to inefficient operation of coal units, and has contributed to high levels of wind curtailment.[36] It also sends the wrong signals for investment, by allowing coal units to recover their investment costs even when investing in low–operating-hour units with lower capital costs or investing in resources with greater operational flexibility (e.g., demand response, gas-fired units, energy storage, additional transmission) would be more cost-effective from a societal perspective.[37]

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[35] Specifically, the creation of power pool pilots in the East and Northeast Grids in 2002 was intended to facilitate a more regional dispatch. In the Northeast, the pilot broke down over provincial disagreements on how rising coal fuel costs should be allocated. See: Kahrl (2014).

[36] Kahrl (2014).

[37] Hu et al (2013).

Changing the current system of dispatch will create winners and losers, which is a key reason implementing reforms in this area is difficult. For instance, local government companies own many smaller, inefficient generators that may no longer be cost competitive, and local governments are concerned about stranded assets and the impact of plant closures on local economies. Coal generators are concerned that reductions in their operating hours caused by increases in renewable generation will reduce their profits. Overcoming these barriers will require better aligning incentives among generators, grid companies, and consumers, across multiple provinces.

## 4.4 Options and Recommendations

It is important that policymakers recognize that dispatch and generation price reforms are fundamentally interconnected, and that they should be pursued in parallel. Although there are a number of potential options for how dispatch reforms are designed and implemented, all solutions should ultimately aim to facilitate economic unit commitment and dispatch, ideally on a regional or interregional basis that is consistent with reliability and environmental goals.

As described in *International Experience*, there are many different approaches to generation pricing (even within the United States), but they all support a similar approach to generator operations. In regions with bid-based markets, economic unit commitment and dispatch are based on bids from market participants. Without bid-based markets, economic unit commitment and dispatch are based on variable cost and operating information submitted by generators to system operators. In either case, the approach to operations follows the same principles: system operators use information from generators to regularly update a merit order and determine a least-cost unit commitment and dispatch for the system.

Merit order dispatch alone will not necessarily produce environmental outcomes that are consistent with policy goals. Ensuring that merit order dispatch is consistent with environmental goals requires explicit strategies (e.g., emissions constraints in dispatch, emissions pricing) to ensure that the emissions costs associated with each generation unit are reflected in dispatch. These strategies should be assessed in terms of their effectiveness. For example, with emissions fees, if emissions are higher than desired, fees will need to be raised.

For integrating provincial balancing areas into a regional dispatch, there are broadly two models. The first, used by the European Union, is "market coupling," whereby multiple balancing areas, each with a separate system operator, use a shared software model with common inputs for dispatch to develop a centralized dispatch. The second, more common in the United States, is through regional system operators that dispatch across multiple regions. Politically, the latter approach might be difficult in China in the short term because it requires the provinces to cede dispatch authority to regional grid companies, which at present are mostly under central government authority. The former approach is more feasible in the near term, although it also requires negotiated rules for benefit and cost sharing among provinces.

Central to the development of provincial, and particularly integrated regional, dispatch are methods for congestion management. Congestion occurs when parts of the transmission system become constrained, which requires re-dispatching generators to alleviate constraints. This re-dispatch will diverge from the original, optimal dispatch. It is unclear how congested transmission systems in China currently are, but given the lack of a more systematic basis for transmission expansion, congestion management is likely to be a key issue for dispatch reforms.

Changes in unit commitment and dispatch will not be possible without reforms in generation pricing. There are a number of different potential approaches to pricing reforms, but regardless of which approach is taken they should be designed to break the link between planned operating hours and generators' recovery of fixed costs. A straightforward approach would be to split the current benchmark tariff for thermal generators into a two-part price, with separate prices and payments for: (*1*) capacity (fixed costs), tied to generator availability, and (*2*) energy (variable costs), tied to generator output.[38] Given the potential for generation pricing reforms to strand assets, these reforms will likely require a process to identify at-risk assets and regulatory principles for dealing with stranded assets. Even if addressing stranded asset concerns requires substantial costs, the long-run benefits of more efficient dispatch – in reduced fuel costs, lower curtailment, and more efficient use of the transmission system – will significantly outweigh these costs.

## 4.5 Conclusion

Although dispatch reforms have not been a central focus of China's power sector reforms, we argue that they should be. We recommend that reforms focus on four key areas:

- Least-cost merit-order dispatch that incorporates environmental constraints;
- Integrated regional dispatch, across multiple provincial balancing areas;
- Shorter-term unit commitment; and
- Development of methods for managing within- and cross-province congestion.

Again, dispatch reforms will be difficult, if not impossible, to implement without reforms in generation pricing. Reforms in these two areas should be pursued in parallel.

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[38] A similar recommendation is made by World Bank Energy Regulatory Research Group (2013).

# 5. Renewable Energy Resources and Integration

## 5.1 Introduction

China's investment in renewable energy capacity over the past decade has been impressive, with total installed capacity of 380 gigawatts (GW) as of 2013 (including hydro). This represents a tripling since 2005. China has ambitious targets to continue this growth:

- From a starting point of 1 GW in 2005 to 91 GW in 2013, China now has the most installed onshore wind capacity of any country in the world.[39] China is very close to meeting its target of 100 GW of wind capacity by 2015, which would put the target of 200 GW by 2020 within reach.
- China is also emerging as one of the leading countries in installed solar PV capacity, with 19.6 GW in 2013. Of this, 16.3 GW is from utility-scale PV and the remainder is from distributed PV installations. There are goals of 35 GW PV capacity by 2015 and 50 GW by 2020. China will meet the 50 GW goal before 2020, and as a result, there is consideration of raising the 2020 target to 100 GW.[40]
- Installed biomass capacity reached 8.5 GW in 2013, with 4.1 GW from combustion of agricultural and forestry waste and 2.3 GW from waste-to-energy plants. Biomass targets of 13 GW by 2015 and 30 GW by 2020 are in place.
- The 2020 goal for concentrating solar power (CSP) capacity is 3 GW.[41] Two CSP projects are in operation, a 1-megawatt (MW) demonstration project and the first 10 MW of a 50-MW CSP plant,[42] with another 342.5 MW under construction.[43]
- China also has a goal of 5 GW of offshore wind by 2015. Although only 400 MW of offshore wind is currently in operation, 1.56 GW are under construction and another 3.5 GW will reportedly start construction in 2015.[44]
- China currently has the most installed hydro capacity of any country in the world, with 280 GW. Even more hydro is technically achievable, as the amount of installed hydro capacity accounts for about 40 percent of the technical potential. China has had 2020 hydro capacity targets as high as 420 GW, including 70 GW of pumped storage (which would require the development of more than 50 large-scale hydro dams).[45]

However, China faces major challenges in integrating renewables and making full use of the growing wind and solar capacity.

## 5.2 Goals

There are two main goals for renewable energy. The first is to meet renewables capacity targets on time and at least cost. The second is to integrate wind and solar energy into the power system.

## 5.3 Current Issues and Barriers to Reform

China's renewables policy regime, centered on FITs, appears to be generally adequate to support the first goal regarding renewable capacity. However, one area of difficulty for capacity development is

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[39] It should be noted that of the 91 GW of wind capacity, only 77.1 GW is connected to the grid owing to transmission constraints and lack of transmission capacity.

[40] Haugwitz (2014).

[41] Gielen (2014).

[42] National Renewable Energy Laboratory (2014).

[43] Gielen (2014).

[44] Global Wind Energy Council (2014).

[45] Gielen (2014).

distributed solar: it appears 2014 targets were not met. Official statistics were not available as of this writing, but solar analysts predicted between 10.5 GW and 12 GW of solar PV were installed in China in 2014, with 4 GW of that being distributed PV and the remainder being utility-scale.[46]

The primary reason for the solar DG target not being met is the lack of a feasible business model, namely low rate of return, high project risks, and difficulties in obtaining financing. DG solar projects are eligible for a 0.42 yuan/kilowatt-hour production-based incentive that can be added to a customer's retail rate (if the power is consumed onsite) or on top of the coal tariff in the case of sale to the grid. A higher financial return is often possible when combining the production incentive with the retail rate, but that requires the site host to buy the electricity. DG solar projects are also eligible for a long-term contract under the solar FIT, reducing financing difficulties, but the FIT is considered too low to offset the lack of economies of scale for smaller DG projects.[47] The China Renewable Energy Industries Association recommends that compensation for DG projects should be 25 percent higher than that of utility-scale PV plants.[48]

Not surprisingly then, the rate of return for DG solar projects is low. One analysis found it would take nearly 17 years for residential rooftop solar system to recover the investment costs, and that the rate of return for these projects is just over six percent. It is somewhat better for industrial and commercial customers, at seven to nine years, because of a higher rate of return (eight percent). The other fuel sectors – coal, natural gas, nuclear, and wind – had rate of returns exceeding ten percent in 2013.

DG solar projects are also seen as risky, as businesses in China generally do not stay in business for the duration of the lifetime of the solar project. Who owns the roof and how to share benefits between the rooftop owner, solar consumers, and third-party owners are contested issues in China. Faced with a low rate of return compared to other alternatives, and the perceived high project risk, banks are reluctant to provide financing.[49] The development of a viable business model is thereby necessary if China's DG solar targets are to be met.

As for the second goal, China has made progress in integrating variable energy generation, although major difficulties remain. Wind curtailment has reportedly decreased to 10.7 percent in 2013, as compared to 17.1 percent in 2012.[50] Solar curtailment is reportedly on the rise in northwestern China, including in Gansu, Qinghai, and Xinjiang provinces.[51] Plans are underway for wind forecast data to have more geographic fidelity (from a nine-kilometer grid) and more frequent time resolutions (every five minutes).[52] Improvements in the geographic resolution of wind forecasts could lead to increases in wind forecasting accuracy. A large amount of ultra–high-voltage transmission is in the planning stages that could provide more connections to regional grids and allow for more long-distance transmission of wind and solar generation.[53] China already is home to two of the largest ultra-high-voltage direct current transmission lines in the world.[54] And in 2014, the NDRC issued a regulation requiring grid companies to

[46] Haugwitz (2015).
[47] Liang (2014).
[48] CREIA (2013).
[49] Liang (2014).
[50] Wang (2014). Caution should be exercised in interpreting these data, as it is not clear how curtailment was calculated or the reliability of the data.
[51] Indaa (2014).
[52] Gielen (2014).
[53] More long-distance transmission could also allow for the long-distance transmission of coal resources, heightening the importance of policies such as coal caps or air and water pollution limits to allow China to continue meeting its energy and environmental goals.
[54] Gielen (2014).

fully incorporate renewable energy in annual generation plans and to prioritize renewable energy in dispatch, as long as reliability is not compromised.[55]

China's integration challenges center on the heavy concentration of wind and solar resources and lack of flexibility to support intermittent renewables. China's wind capacity is heavily concentrated, with about 90 percent located in north, northwest, and northeast China, sometimes referred to as the "Three Norths." Even though the Three Norths have the best wind resources in the country, the concentration of wind investments in this region is not ideal. The output of more geographically diverse wind projects allows for a smoothing effect, as the wind is blowing at different rates and different times in a larger region. That would make wind less variable and more easy to forecast. In contrast, wind generators that are located near each other will tend to have similar wind profiles. In addition, in the Three Norths, the generation of wind power conflicts with the CHP plants that provide steam and heat in the winter, leading to high levels of wind curtailment.[56] Utility-scale solar resources are also concentrated (in northern and western China) and solar is likely to be increasingly curtailed absent new transmission and changes in operating practice.[57] The FITs for wind and solar include regional price differentials, but at least for wind they have not been large enough to motivate geographic diversity. In other words, larger differences in the FITs offered across regions would help mitigate concentration problems.

Approximately 80 percent of total generation in China is provided by baseload coal plants, which can be inflexible. There is no mechanism to compensate flexibility, and generators thus have no incentive to provide it. Planning for new generating plants does not incorporate or prioritize greater flexible generation. As we saw in the previous section, dispatch is not by merit order but by a guaranteed minimum number of operating hours for each plant, as determined annually. As a result, grid operators have to be conscious of the number of operating hours for coal plants even if dispatching generating plants with low variable costs, such as hydro, wind, and solar, would reduce system costs.

Grid management is via a complex, five-level hierarchy of dispatch organizations, from national to regional to provincial to prefecture to county, in that order. The multilevel approach requires extensive coordination and no one has visibility over all generation and transmission facilities within an entire control area. There is insufficient transmission interconnecting the provinces, and existing inter-regional transmission is scheduled annually and by contract, and is not available to manage the intra-day or inter-day variability and uncertainty of variable generation. Lack of transmission capacity also has contributed to the problem of approximately 15 percent of wind capacity not being connected to the grid.[58] Wind forecasting is not considered sufficiently accurate and is not factored into unit commitment decisions, meaning dispatchers overcommit coal generation and wind is curtailed when more thermal units are online than are necessary to reliably meet demand.[59]

Generators are required to provide ancillary services but are not directly compensated unless certain circumstances are met, such as ramping to 50 percent to 70 percent or more of its rated capacity. Requirements and compensation arrangements differ by region.[60] Furthermore, ancillary services are

[55] NDRC (2014a).

[56] Kahrl and Wang (2014).

[57] Kahrl and Wang (2014).

[58] Gielen (2014).

[59] The Regulatory Assistance Project (2013).

[60] Different regions have different requirements but the compensation for the load following occurs if they ramp lower than 50 percent to 70 percent (华中，华北 50% 西北 70%) of its rated capacity. For example, in the Northwest, if a non-CHP coal plant with more than 300 MW is required to ramp down to 50 percent of its capacity, only "the lost generation" (20 percent capacity * duration time) is subject to compensation. See: Northwest Ancillary Service Rule. Also see: Kahrl and Wang (2014).

not always clearly defined and are not designed to reflect operating practices with higher levels of variable energy generation.

## 5.4 Options and Recommendations

Drawing on the discussion of integration challenges in *International Experience,* the following are options and recommendations for China to consider.

***1. Create compensation arrangements to induce more flexibility from existing generation.*** Flexibility is defined as generators being able to quickly start and stop electricity generation as well as to be able to ramp up and down quickly and to operate at low generation levels. Grid operators desire greater flexibility from generators, but there is little or no incentive for generators to provide flexibility, as more fuel is consumed, a heat rate penalty is incurred, and operation and maintenance costs can increase. This situation is not unique to China; it exists also in the United States and European Union. China's current generation pricing approach is entirely at odds with the need for increased flexibility of operations. Single price contracts with minimum guaranteed hours provide inadequate incentives for flexible operation and the provision of most ancillary services. Adopting a two-price structure to cover variable and capacity costs will allow grid operators to use existing generation more flexibly without financial harm to generators or their owners.

***2. Prioritize flexibility when adding any new conventional generation.*** Although it has slowed in recent years, China still has growing demand for electricity, in contrast to low or flat growth in the United States. China therefore has the opportunity to add more flexible generation, and thereby make its overall fleet more flexible. It is also imperative to cease further additions of inflexible generation, especially in areas with already high levels of variable generation. If auctions for long-term contracts for new generation are implemented (see Section 2), then flexibility should be a factor taken into account when evaluating bids. (For example, a higher-priced bid may win if the bidder commits to delivering a relatively flexible generation unit. The rules for adjusting bids according to flexibility and other desiderata would be published in advance of the bidding.)

***3. Devise compensation scheme for ancillary services.*** Providers of ancillary services are compensated in the United States, either by contract or through bidding into competitive ancillary service markets. High levels of variable generation will require additional amounts of ancillary services such as load following, spinning reserves, and non-spinning reserves. New types of reserves, or a re-definition of existing reserves, may be needed, such as covering multi-hour wind ramps. Generators will need compensation to provide these services – the current compensation arrangements do not fully reflect their costs, including opportunity costs.

***4. Improve transmission planning and coordinate with generation planning and interconnection****.* The need for additional transmission to accommodate higher levels of variable generation is an issue that China, the United States, the European Union and Brazil have in common. As noted earlier, China already has impressive plans for developing new transmission and has some of the most advanced transmission technologies in the world. China should ensure that transmission and location considerations are included when planning for and evaluating new renewable energy projects and flexible generation (see Section 2). China could also consider international examples of transmission planning, such as competitive renewable energy zones in Texas in the United States, to interconnect areas with high renewable energy resource potential to load centers. In addition, transmission and generation planning should be coordinated to avoid concentrations of variable generation with inflexible generation, and in fact consider planning for renewables with flexible generation. Another important factor to consider is possible mismatch in the timeframes for development of new generation and for development of new transmission. Finally, because significant amounts of wind capacity are not interconnected to the grid in China, clear and transparent interconnection procedures should be established to evaluate the impacts of new generation on the transmission grid, as well as any transmission upgrades needed to accommodate new generation projects.[61]

***5. Revise grid codes.*** Countries often institute grid codes for variable generation but do not update them to take advantage of new capabilities in variable generation or to account for the needs of the grid as variable generation increases. Not frequently updating grid codes can be expensive – Germany, for instance, amended its grid code to require 315,000 distributed solar installations to be retrofitted to withstand grid disturbances, at a cost of $300 million.[62] Technological advances mean that wind can be equipped to provide automatic generator control, system inertia, and frequency control, whereas solar PV plants with enhanced inverters can generate or consume reactive power and provide fault ride-through capability. Updating grid codes to take advantage of these capabilities allows grid operators to rely on variable generation to contribute to system reliability and contribute to system flexibility.

***6. Reduce the number of balancing areas, either virtually (by sharing reserves, for example) or through consolidation.*** As discussed in Section 4, decreasing the number of balancing areas, and making them larger, eases variable generation integration, as the variability of load and variable generation is reduced, leading to a decrease in required reserves. In addition, a larger pool of generation can be drawn upon for balancing, and variable generation forecasting accuracy is improved. Physical consolidation of balancing areas may be difficult in China without more extensive regulatory reforms. However, in the near term, incremental steps taken to better coordinate operations between balancing authorities could significantly improve and reduce the costs of renewable integration. At the simplest level, these might include agreements to share operating reserves between provincial balancing authorities. More extensive coordination might include the creation of voluntary regional energy imbalance markets, where multiple provinces use a centralized real-time dispatch to handle deviations between day-ahead schedules and real-time net load conditions.

***7. Expand linkages and increase regional power transfers between provincial balancing areas.*** An important element of Denmark's ability to receive more than 30 percent of its energy from wind is the extensive transmission interconnections Denmark has with other Nordic countries and with Germany. That allows Denmark to export excess wind energy or to import energy when needed and provides unmatched flexibility to grid operators. However, transmission capacity between provincial balancing areas in China has historically been limited and may not be sufficient to address regional renewable integration challenges. Many of the barriers to increased interprovincial trade and interprovincial transmission relate to the way provinces get revenue when electricity is generated within the province versus imported from a nearby province. Similar barriers have been overcome in other countries. The solutions vary, but they all rest on the fact that increased trade results in lower total costs. Cost savings are by definition large enough to assure that both trading partners are better off.[63]

***8. Adopt faster generation scheduling and dispatch practices.*** Dispatch and scheduling provisions are important because variable generation is variable in the amount of energy that may be delivered, and uncertain as to the  time when it will be delivered. Variable generation becomes more certain and easier to predict closer to real time – hence, allowing dispatch and scheduling closer to real time is beneficial to variable generation. More broadly, dispatch and scheduling that are performed closer to real time are also beneficial for consumers. Faster dispatch and scheduling can be more precise, reducing the amount of operating reserves that are needed.

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[61] Regulatory Assistance Project (2013).

[62] San Diego Gas & Electric (2013).

[63] The Regulatory Assistance Project (2013).

***9. Improve and make better use of variable generation forecasting*****.** Better wind and variable generation forecasting is almost universally cited worldwide as an essential tool in integrating more renewable generation. Indeed, as more experience is gained in the United States and the European Union, variable generation forecasting is used to commit and decommit other generation plants. In China though, owing to ongoing issues with forecasting techniques, data quality, and data sharing, the accuracy of wind forecasting is not progressing as fast as it should. In addition, wind forecasts are not widely used in generator unit commitment decisions in China. The result is that dispatchers overcommit coal generation and curtail wind when more thermal units are online than are needed to reliably meet demand. Greater geographic fidelity in mesoscale data will aid in increasing forecast accuracy, but other steps noted earlier not related to forecasting, such as larger balancing areas and faster scheduling and dispatch, will help as well.

***10. Consider compensation when curtailing variable generation.*** In some instances, grid operators will partly or fully compensate variable generators if their generation was curtailed.[64] Such arrangements provide an impetus to grid companies to consider all possibilities before curtailing variable generation. The approach that best fits conditions in China is to have the wind generators and grid companies share the costs for curtailment. Grid companies could curtail wind without cost for a certain frequency (e.g., number of hours or times per day). Beyond that level, the curtailment cost is borne by the grid companies, that is, wind (and eventually solar) will be paid the FIT even if they are curtailed. The rationale here is that having the generator bear some of the risk provides an incentive to locate in areas where transmission is adequate and curtailment is less likely. Exposing the grid company at least partially to curtailment costs makes sense because they are well positioned to take action to address integration issues and reduce curtailments.

***11. Revise FITs****.* Eligibility for the FIT requires NEA approval and, at least for wind, NEA has placed greater priority on approving projects outside of northern China. In addition, increasing the FIT price differential between high-quality and lower-quality resource areas would help minimize the concentration of wind and solar plants and encourage the spread of wind and solar plants across a larger geographic area.

As noted in *International Experience*, the FIT is a policy that requires careful design and oversight to be effective, and several countries in Europe have amended or (in the more extreme cases) retroactively rolled back previously set FIT rates. There are numerous variations in setting the FIT, such as differentiating by resource quality, or reducing the FIT rate over time to reflect improving economics of individual renewable energy technologies. Setting the correct FIT rate to reflect the technologic and development costs is obviously of great importance – setting it too low will result in little development, whereas setting it too high creates a windfall and possibly an overheated market. The CSP[65] and offshore wind[66] industries contend that the initial rates for their technologies are too low, for example. By comparison, China reduced the FIT for new onshore wind projects beginning in 2015, reflecting the cost declines in that technology.[67] In short, the FIT is not a policy that can be set and forgotten – it needs periodic and regular oversight and, at times, a redesign.

***12. Identify and eradicate barriers to the development of distributed solar projects.*** As noted earlier, China will not meet its distributed solar targets for 2014. This is despite policy changes in 2014 that allowed DG projects to take the utility-scale FIT, or the self-consumption FIT, and increase the maximum

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[64] Bird (2014).

[65] Gielen (2014).

[66] Zhao (2014).

[67] NDRC (2014b). The changes in FIT compensation do not apply to Class IV wind resources, which apply to areas with the lowest wind speeds of the four FIT categories for onshore wind.

capacity size for DG systems located on the distribution network to 20MW.[68] Increasing the FIT for DG solar or adopting an upfront capital investment subsidiary may be necessary to overcome these problems. Interestingly, the increase in allowable capacity to 20 MW is leading some developers of planned utility-scale installations to reclassify their systems as DG, as the allowable provincial capacity for utility-scale PV is lower and, in some cases already met, whereas the DG capacity goals have not been met. In addition, a successful business model for DG PV needs to emerge, accounting for the unique characteristics of China. For example, ownership rights of the rooftops needs to be clearly defined, standard contracts need to be developed, and a smoother, well-functioning, and more expedient interconnection process is necessary.

***13. Monitor interactions between the proposed renewable energy quota with other renewable energy policies.*** The Chinese government is considering adoption of a renewable energy quota that is unique in that the quota would be placed on grid operators and regional and provincial governments, as opposed to load-serving entities, as is the case with renewable portfolio standards in the United States. The quota is intended partly to heighten attention to targets for renewable energy (in addition to those for renewable capacity) in order to promote integration of renewables into the power grid. Reported quota targets are somewhat higher than the targets included in the 12th Five-Year Plan.[69] The details of the proposed quota are still under development and may change prior to adoption, if the quota policy is adopted at all. Reportedly, regional governments would be required to meet non-hydro renewable energy targets ranging from two percent to ten percent of electricity consumption by 2015. The targets vary by a region's renewable energy resource availability, with the northeastern, northwestern, and some northern provinces subject to a ten percent target and the southern and central regions subject to targets ranging from two percent to four percent. The quotas would be raised in 2020, varying from 5 percent to 13 percent, again varying by region. Failure to meet quotas could lead to a loss of assistance from the central government and reduced approvals for new infrastructure projects, whereas meeting or exceeding the quota targets would give those regional governments priority in building new projects and receiving government funds for grid construction and technology development.[70] Stakeholders are pushing for the inclusion of trading of renewable energy credits, which was lacking in earlier proposals. It is also unclear whether enforcement and monitoring requirements will be part of the quota, or whether the central government views the quota targets as goals and not hard requirements.[71]

This proposed quota policy is quite different from other quotas (or "renewable portfolio standards") in the world. It will attempt to force regional governments and state grid companies to successfully address variable generation integration or, depending on the quota requirements, face the loss of government assistance. And, to our knowledge, China would be the only country that has both a quota and a FIT. Like the FIT, the quota is a complex policy that requires periodic oversight and changes, just as with state RPS policies in the United States. Interactions with the FIT in China will also have to be carefully monitored. For example, if the quota targets are set so high as to require the contribution of more emerging technologies like CSP or offshore wind but the FIT for those technologies is set too long, then the quota targets are not likely to be met.

***14. Consider demand response to assist with integrating renewables.*** Integrating variable energy renewables is a major challenge. There is now substantial experience with demand response in the United States and Europe.[72] This experience shows that, in addition to supporting peak load

[68] NEA (2014).
[69] Bloomberg New Energy Finance (2014b).
[70] Ng (2014).
[71] Bloomberg New Energy Finance (2014b).
[72] See Nolan (2014), European Climate Foundation (2010), and Schwartz (2010) for more information.

requirements, demand response can also be used to deliver energy services, balancing services, and operating reserve services – and can be useful in helping to cost-effectively integrate wind and solar. China has much experience with demand response, particularly load shifting to meet peak demand. However, China has relied heavily on rationing customer load reductions through administrative means, which can be inefficient. Incentives mechanisms, if well designed, can identify the lowest-cost opportunities for demand response. China has experience with interruptible load pricing mechanisms. These should be expanded to provide other energy services and help balance renewables. Given the large share of end-user loads represented by industrial customers in China, it appears likely that the potential for demand response may be significant. We recommend developing a better understanding of the full potential of demand response through a formal technical assessment of the resource.

Electric vehicle pricing and charging strategies are closely related to the topic of demand response. The Ministry of Industry and Information Technology has objectives that should lead to five million electric vehicles by 2020. Effective strategies to manage the charging of electric vehicles will be needed reduce power sector costs and help manage a system with increasing reliance on variable renewable energy generation.

***15. Implement priority dispatch.*** China's renewable energy law requires that renewable energy generation has priority over other generation sources, an approach known as priority dispatch. In part, this requirement recognizes that regardless of how renewable generators are paid, their operating cost is so low that they should always be the first to be dispatched. This is similar to the European Commission's Renewable Energy Directive requirement that renewables have priority in interconnection and in dispatch in order to ensure compliance with the European Commission's 20-percent renewables requirement by 2020. Grid operators in China, however, have largely not implemented priority dispatch, citing concerns about grid security and reliability, as allowed under the renewable energy law. The NDRC's 2014 regulation requiring grid companies to fully incorporate renewable energy in annual generation plans and to prioritize renewable energy in dispatch also allows grid companies' scope to curtail renewable energy generation based on reliability concerns. Although necessary from an engineering perspective, this unfortunately allows grid operators an easy way to avoid implementing these regulations. Many of the suggestions outlined in this chapter would make priority dispatching easier, such as enlarging balancing areas, faster scheduling, improving and making more use of variable generation forecasting, and updating grid codes. Section 4 provides a broader view of generator operations issues, with recommendations geared toward optimizing commitment and dispatch.

## 5.5 Conclusion

China has added impressive amounts of renewable energy capacity in recent years and looks poised to add even more in the future. China's integration difficulties seem particularly daunting though, because of the rapid growth of wind, and increasingly, solar capacity. These difficulties are compounded by operating practices that were designed to accommodate relatively flat loads and generation profiles. Moreover, they have not evolved to reflect the generation patterns of variable generation. Fortunately there are several countries and regions worldwide that have addressed integration of variable generation, and although every situation has unique circumstances, China can draw on this experience.

Apart from integration, several other challenges need to be addressed if progress is to be continued. China's current renewable energy policies, notably the FIT, have proven quite successful for increasing renewable energy capacity. However, the vast majority of China's installed wind capacity is located in northern China, in areas with large amounts of inflexible CHP plants and not enough load to consume the wind generation. Although China's FIT for wind divides the country into four wind resource areas, the difference in FIT prices is not high enough to strongly encourage wind companies to develop wind plants outside of northern China. Sharper locational differences in FIT prices are required for wind and may also be needed for the solar FIT. Greater geographic diversity with both wind and solar is needed to make grid integration easier, and therefore, greater variations in compensation favoring lower wind resource areas are needed. Other issues concerning China's FIT are whether the FIT rates are sufficient for CSP and offshore wind projects to be viable, and to continually revisit existing FIT rates to ensure that they are not set too high or too low.

Because of the concentration of solar resources in northern and western China, it is understandable that the government is pursuing DG solar to avoid the concentration of solar generation comparable to wind generation. Numerous legal, institutional, and financial issues need to be addressed if the DG solar targets are to be met, such as the development of a standard contract; addressing the ownership of rooftops and any necessary compensation arrangements for owners; expediting project interconnection; and ensuring project financing is available. Although DG solar projects are eligible for the solar FIT, developers are more likely to gravitate toward utility-scale because of lower transaction costs and reduced project development complexity. Allowing solar PV projects up to 20 MW to qualify as DG solar will help, but the FIT for DG solar may need to be increased to overcome these roadblocks.

China is considering whether to adopt a quota that is unlike any quota in that it is placed on regional governments and grid companies and is intended to add greater impetus for addressing variable generation integration issues. If a renewable quota is adopted, the government should determine whether the targets are goals or requirements, and provide clear guidance and training to provincial officials on how to comply. There may be a mismatch between the near-term targets and many of the strategies for addressing integration, such as transmission or consolidating balancing areas. The interactions with the FIT will also need to be carefully monitored.

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# 6. Additional Issues

This section addresses several topics that are very important but can be covered somewhat more briefly for the purposes of this paper.

## 6.1 Retail Pricing

Several aspects of retail electricity pricing in China are supportive of reduced emissions. These include:

- ***Differential price policy for industrial consumers.*** The electricity price varies across different categories of industrial consumers, based on the energy efficiency of industrial processes. The policy is designed to phase out inefficient enterprises and encourage efficient ones.
- ***Tiered pricing for residential customers***. Beginning in 2012, residential prices in China have been set in tiers so that households with heavier monthly consumption face higher marginal electricity prices. This policy (known as "inclined block pricing" in the United States) encourages energy efficiency while protecting poorer customers.
- ***Relatively high prices for industrial customers***. Industrial consumers pay higher rates, on average, than residential customers. Broadly speaking, this supports the Chinese government's overall efforts to eliminate inefficient industrial capacity and rebalance the economy away from investment in heavy industry.

However, there are also several areas of retail pricing policy in China that are problematic. Here, we highlight several issues that should be considered in the process of developing the next round of power sector reform.

***Prices should be more transparent and better reflect power system costs, including the social costs of emissions.*** Broadly speaking, electricity consumers (as a whole, not necessarily individually) should pay prices that cover the actual cost of providing electricity service. In the case of China, it is difficult to say whether or not electricity prices are meeting this objective, because there is lack of transparency. Power sector firms' costs are often opaque – including to regulatory agencies. In addition, retail prices, as paid by industrial customers, are also somewhat opaque, raising the possibility that some end-users receive preferential treatment. We recommend:

- Clear and consistent application of accounting rules for costs (including emissions costs), revenues, and profits;
- Consistent application of those rules in a well-designed administrative process for review and application of the rules to set allowed revenues;
- Wider publication of information regarding retail prices; and
- Strengthened penalties for failures to comply with requests for information or the determinations of government.[73]

The recent Shenzhen grid pricing pilot is an important step forward in these areas (see Section 3).

In addition, infrequent updates to retail prices – or more precisely, lack of clear procedures for updating retail prices – mean that retail prices as a whole may not adequately reflect power system costs. This is an issue that should be addressed as part of an overall effort to reconsider the business models and incentives of power sector firms. The procedure for updating retail prices should be based on consideration of incentives and the careful design of performance-based regulations. Note that this does *not* necessarily mean that retail prices need to be *immediately* updated to reflect changing costs. For example, internationally, performance-based regulations are sometimes designed to limit the ability of utilities to automatically pass certain cost changes through to customers. This gives utilities incentives to

[73] The Regulatory Assistance Project (2013).

improve cost performance and hedge certain volatile costs. Again, the Shenzhen pilot, which introduces rules for updating a component of retail prices, will be an important test case in China.

Finally, retail prices should reflect the full social costs of the power sector, including emissions costs. Emissions pricing (see Section 7.2) is an important aspect of this. However, internalizing emissions costs does not necessarily mean all consumers will face dramatically higher electricity bills. First, China's tiered residential prices can protect poor, low-consumption households. Second, as discussed in other sections of this paper, there are likely many opportunities to exploit low-cost, low-emissions resources, particularly in the form of EPPs (that is, investments in end-use energy efficiency). Exploiting these low-cost resources (by fully integrating them into power sector reform) should go hand-in-hand with policies to internalize emissions costs. In short, the power sector reforms we discuss in this paper – energy efficiency but also generator operations and grid flexibility, for example – will all help meet emissions reduction goals cost-effectively while mitigating upward pressure on electricity bills. For this reason, emissions pricing should be considered together with other aspects of power sector reform.

***Policies to allow "direct access" contracting between end-users and generators should be designed to support emissions reduction goals.*** Several regions of China have pilot programs allowing large users to bypass the gridcos and negotiate prices directly with generators, with the goal of moving away from the current system of administratively set on-grid prices toward a kind of wholesale market with "many buyers and many sellers." This is reportedly a major plank of the new (yet-to-be-announced) round of power sector reform. If there is to be a national transition to a direct access scheme, it will have to be designed, with caution, to support emissions-reduction goals. Any proposed direct access scheme should be subjected to careful review that asks the following questions: is this market mechanism a good tool to achieve low emissions goals (and other power sector goals)? If not, how can it be designed in the service of those goals? We have the following suggestions.

- Preserve the positive aspects of retail pricing in China listed earlier, or implement more comprehensive replacements.
- Ensure that direct access does not undermine the link between planning and investment. This could happen if, for example, end-users and generators end up contracting for more coal-fired generation than justified by the type of integrated planning process described in Section 2. Power sector planning needs to inform design of any market mechanisms, such as direct access, that affect resource investment decisions.
- Beware of allowing inefficient industrial customers access to low prices. Fortunately, the direct access pilots appear to have some good design elements in that they only allow the most efficient industrial customers to participate in direct access. This allays some of the concern that inefficient heavy industry customers will gain access to low prices. We recommend strengthening this component of direct access policy.

## 6.2 Emissions Trading and Pricing

Several Chinese provincial and municipal governments launched carbon emissions trading schemes, with scope including the power sector, in 2013–2014, and the Chinese central government is now designing a national scheme that is also expected to cover the power sector. These schemes were developed very quickly compared to emissions trading schemes in other countries, and – partly as a result – are not yet well integrated with power sector policy or other aspects of emissions reduction policy.

Carbon emissions trading schemes should be designed with consideration for interactions with other emissions reduction policies, particularly energy efficiency policies and coal consumption control policies. *International Experience* discusses examples of emissions trading schemes in other countries that are designed to complement and interact with other policies, including programs to support energy efficiency resources and renewable resources. One useful approach is to develop emissions trading as part of a package of policies to reach an emissions goal, while the Emission Trading Scheme (ETS) cap acts as a binding constraint. In this way, the ETS cap ensures that the emissions reduction objective is met, even if the other policies in the portfolio over- or under-perform. This design approach can be most clearly seen in California's portfolio of policies, in which the emissions trading scheme itself is expected to do less than a quarter of the emissions reductions, with energy efficiency policies and renewables programs responsible for most of the emissions reduction effort.[74] (The emissions trading component acts as a backstop: if the other policies fail to deliver expected emissions reductions, the emissions trading scheme will fill the gap.)

In the regions of China currently subject to carbon trading pilots, coal consumption control, energy efficiency, renewable energy, and air quality policies may be driving most (or perhaps all) of regional emissions reductions. That is, the bulk of carbon emissions reductions currently underway in these regions may not be attributable to the emissions trading pilots themselves, but instead to other regional policy efforts. This should perhaps not be surprising, given the ambitious targets associated with coal consumption control and air quality management. In fact, a large role for these "other" policies in the overall policy package may be desirable – but the balance between the various policies should be carefully analyzed in order to rationalize the design of the emissions trading scheme and determine whether the package is likely to over-deliver or under-deliver in terms of emissions reductions. To put the point more simply, it is important to design a policy package as a package, not isolated fragments.

As discussed in Sections 2 and 3, policies to support investment in EPPs (end-use energy efficiency) can play a particularly important "complementary" role in emissions trading schemes, owing to market failures and market barriers that prevent the uptake of energy efficiency as a resource. High energy prices are typically required to motivate end-users to invest in energy efficiency, even though energy efficiency investments are often cost-effective. *International Experience* explained how emissions trading schemes in other countries – such as the power sector emissions trading scheme known as the Regional Greenhouse Gas Initiative in the northeastern United States – have designed energy efficiency programs to mobilize energy efficiency resources.

Auctioning emissions allowances has an important advantage over free allocation of allowances: it raises revenue that can be used for socially beneficial purposes. The Regional Greenhouse Gas Initiative has had success with auctioning nearly all allowances and "recycling" these auction revenues into end-use energy efficiency programs, largely administered by power sector utilities, similar to the energy efficiency obligation on China's grid companies (see Section 2).

Some of the other reforms discussed in this paper would help rationalize the role of emissions trading in the power sector. In particular, reforming generation operations and pricing (see Section 4) will allow emissions pricing to impact the variable costs of generation units and, in turn, to impact the merit order of power plants. In this way, lower-emissions plants will run more often than higher-emissions plants, lowering overall power sector emissions in an efficient manner. In the absence of this reform to generator operations, an important channel for emissions pricing to affect emissions will be blocked. Similarly, a rationalized system for updating retail prices will allow for appropriate price signals to flow through to end-users. As noted in Section 7.1, emissions pricing and emissions trading should be regarded as one part of the overall power sector reform effort – and will be much more effective, and also less disruptive, in that case.

[74] The Regulatory Assistance Project (2011).

## 6.3 Climate Impacts on Power Sector

The main focus of this paper has been the need to transform power sector regulation in order to reduce emissions and meet climate objectives – what might be called the impacts of the power sector on climate. This section briefly considers the direct impacts of climate change on power sector infrastructure and resources and discusses ways that regulatory authorities should consider these impacts when formulating power sector regulation.[75] Power sector infrastructure built now may be expected to still be in operation decades in the future. Accordingly, investment decisions made now have to take into account the risks associated with climate change. There are many effects to consider. Here are some that are particularly important for the power sector.

- Flooding and droughts will affect hydropower energy production and the availability of cooling water for thermal power plants. The scarcity of water resources is already a significant issue for the power sector in China and the severity of the problem will likely grow in coming decades.
- Extreme events and increases in storm intensity will increase the risk for damage to power sector infrastructure (electricity generation, transmission, and distribution infrastructure, as well as fuel distribution systems).
- Generation efficiency for coal- and gas-fired generators may be reduced by small but significant amounts, depending on the amount of local air temperature change.
- Wind generation may experience (positive or negative) changes in wind field characteristics and wind resources.

Unfortunately there is currently little effort in China to consider the risks and costs of these impacts in a consistent way when approving new generation units and other resources. This should not be surprising, given the overall difficulties in power sector planning (see Section 2). These effects should be integrated into power sector planning. In particular, when considering the relative costs of various resource choices, the costs of risks associated with climate change impacts should also be considered. Some resources and some locations for resources may be more sensitive to climate change than others. Overall, these risks will tend to bolster the relative cost-effectiveness of end-use energy efficiency as a resource. Power sector planning should also consider the amount of resources that should go to adapting *existing* (already built) power sector resources and infrastructure to expected impacts of climate change. Finally, climate change impacts also increase the importance of integrating power sector planning with other types of resource planning – particularly water resources.

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[75] This section is based on Ebinger and Vergara (2011).