

# China's Power Sector and Air Quality Reforms

Global Lessons on Getting Institutional Responsibilities Right

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## Acronyms

BACT . . . . .	Best available control technology	FGD . . . . .	Flue gas desulfurization
BAT . . . . .	Best available techniques	GDP . . . . .	Gross domestic product
CAA . . . . .	(U.S.) Clean Air Act	GHG . . . . .	Greenhouse Gas
CAEP . . . . .	Chinese Academy of Environmental Planning	GW . . . . .	Gigawatt
CASS . . . . .	Chinese Academy of Social Sciences	INDC . . . . .	Intended nationally determined contributions
CEMS . . . . .	Continuous emissions monitoring system	LAER . . . . .	Lowest achievable emissions rate
CO <sub>2</sub> . . . . .	Carbon dioxide	MACT . . . . .	Maximum achievable control technology
CRAES . . . . .	Chinese Research Academy of Environmental Science	MEP . . . . .	Ministry of Environmental Protection
DRC . . . . .	Development and Reform Commission (provincial-level)	MW(h) . . . . .	Megawatt(-hour)
EIA . . . . .	Environmental impact assessment	NEA . . . . .	National Energy Agency
EIC . . . . .	Economic Industrial Commission (provincial-level)	NDRC . . . . .	National Development and Reform Commission
EPA . . . . .	(U.S.) Environmental Protection Agency	NOX . . . . .	Nitrogen oxides
EPB / EPD . . . . .	Environmental Protection Bureaus / Departments	NRC . . . . .	(U.S.) Nuclear Regulatory Commission
EPS . . . . .	Emissions performance standard	RAP . . . . .	Regulatory Assistance Project
ERI . . . . .	Energy Research Institute	RGGI . . . . .	Regional Greenhouse Gas Initiative
ESPD . . . . .	Energy saving power dispatch	RNB . . . . .	Renminbi
ETS . . . . .	Emissions trading system	RTO . . . . .	Regional transmission organization
FERC . . . . .	(U.S.) Federal Energy Regulatory Commission	SCR . . . . .	Denitrification
		SO <sub>2</sub> . . . . .	Sulfur dioxide
		TWh . . . . .	Terawatt-hour
		WHO . . . . .	World Health Organization

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# 1. Introduction

China's 13th Five-Year Plan includes goals to establish electricity markets and deepen progress toward improving air quality. But achieving the plan's energy and environmental targets could result in unintended consequences, including increased pollution, shifting pollution from one region to another, and falling short in the utilization of China's renewable energy resources and new high-efficiency thermal plants.

Regulators in the European Union and the United States also faced competing policy and regulatory choices as they sought to establish or liberalize electricity markets while at the same time improving air quality and reducing greenhouse gas (GHG) emissions. In those regions, successful policy implementation hinged on the answers to these questions:

- How should regulators address new thermal power plants?
- How should regulators address existing thermal power plants?
- As electricity markets are developed, what environmental standards should apply?

While the European Union and United States continue decades of progress to reform electricity markets and improve air quality, an analysis of energy and environmental principles from those regions offers insights that are relevant for China to consider today. First, air pollution must be thought of in absolute terms: tons must be removed. Intensity-based targets alone are insufficient to meet China's goals. Second, new power plants are subject to a rigorous review and approval process. In air basins that exceed public health standards, more tons must be taken out of the basin than may be added by a new plant. Finally, existing plants are required to meet emissions standards by a certain date, or must cease operations.

Collaboration and cooperation among air and energy regulators is essential, as illustrated by examples from the European Union and the United States. In the process of reaching agreement on many key policies, regulators working together in each of these places also sought to avoid placing constraints on one another, as illustrated by these examples:

- Implementation and enforcement of consistent emissions standards across regions;
- Adjustment of air quality processes to reflect electricity market practices;
- Agreement on model rules and processes to treat distributed energy resources and to qualify energy efficiency and renewable generation as energy and capacity resources in regional electricity markets; and
- Establishment of market-based programs to control nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), and carbon dioxide (CO<sub>2</sub>) emissions on both the regional and national levels, all done with extensive coordination between air and energy regulators and electricity grid operators.

As China moves to simultaneously establish and expand markets for electricity, and deepens progress to improve air quality, its regulators can take advantage of lessons and best practices from Europe and the United States. Evolving to a competitive retail power sector will require the National Development and Reform Commission (NDRC) to coordinate its planning authority with other agencies, such as the Ministry of Environmental Protection (MEP) and provincial and local Environmental Protection Bureaus or Departments (EPB/EPD). Independent third-party consultants and auditors will be needed to liaise with enterprises, participate in stakeholder processes, and help develop and improve information systems.

Local and provincial air quality regulators will continue to face choices to approve new thermal power plants in air basins with unhealthy air quality. Articles 22 and 86 of China's Air Law offer a framework for regional cooperation and consistent environmental standards, and a process for suspending approval of new projects that would add pollution to these air basins.

Constructive engagement between energy and environmental planners can ensure equal qualification of all energy and capacity resources, which helps to fully utilize renewable energy resources, encourage more efficient operation of fossil-fuel resources, and improve knowledge about customer behavior.

To facilitate the transition to competitive electricity markets *and* continue to improve air quality, the system of air quality management needs to change. New power plants cannot be approved without accompanying reductions of air pollution in the same air basin. Emissions standards for existing power plants must be consistent across regions. These standards must be consistently enforced so that liberalization of electricity markets does not result in shifting pollution from one region to another, or encourage the greater use of generation with high emissions because of differences in regulatory standards. Planning must also account for and support end-use energy efficiency and renewable energy generation as measures to improve air quality. Full use of energy efficiency and renewable energy reduces multiple pollutants, as well as reducing or avoiding negative effects on water and land resources. Several articles in the 2016 Air Law provide a basis for air quality agencies to insert themselves into energy planning processes, and to ensure that electricity markets require that participants meet consistent environmental standards.<sup>1</sup>

End-of-pipe emissions controls alone will achieve at best only one-half of the emissions reductions needed for China to cut PM<sub>2.5</sub> concentrations to 30 ug/m<sup>3</sup> by 2030.

As emphasized by Ma Jun<sup>2</sup> and others, end-of-pipe emissions controls alone will achieve at best only one-half of the emissions reductions needed for China to cut PM<sub>2.5</sub> concentrations to 30 ug/m<sup>3</sup> by 2030. Structural, market-based adjustments are needed to ensure that energy and environmental plans are well integrated and economically efficient, so that this goal can be fully met.

The example of the Regional Greenhouse Gas Initiative (RGGI) in the northeast United States is particularly instructive for China today. The original ideas for the RGGI

program, developed by air regulators, would have resulted in unwanted market outcomes had energy regulators and other experts not also been involved in the design process. Input from energy regulators:

- led to the auctioning of 100 percent of GHG allowances, investing the revenue in state end-use energy efficiency and renewable energy programs, and measures to protect low-income consumers;
- incorporated a three-year compliance period (instead of one year) to account for variations in generation caused by weather, asset availability, and fuel-price fluctuations;
- exempted small, emergency-only units from the program; and
- encouraged states to set aside a portion of GHG allowances for new, more efficient generation.

These design features assured that the RGGI program would simultaneously minimize CO<sub>2</sub> emissions and program costs—and would do so in a way that spurred innovation and improved the power sector's economic efficiency. This

was unlikely to happen if the environmental regulators, who had little understanding of the economics and operations of the electric sector, had designed the program without the help of energy regulators and industry stakeholders.

This paper provides additional case studies from Europe and the United States to illustrate how energy and environmental regulators tackled similar challenges as those faced by Chinese policymakers and regulators today. It draws lessons from these experiences that may be useful in China today. The paper also discusses risks to achieving China's air quality and power sector reform goals, such as uneven implementation, silos of responsibility that impede success, the possibility that power sector reform will evolve in ways that degrade air quality, and reliance on air quality control measures that impose higher costs on businesses and consumers. Final sections recommend power sector reform policies that will improve air quality.

1 Several articles are relevant to this discussion. Article 22 authorizes agencies to suspend environmental impact assessment (EIA) approval in air basins that exceed pollution targets. Article 32 requires multiple agencies to work together to re-structure energy consumption. Article 42 requires that electricity grid operators dispatch the cleanest generation first. Article 86 requires joint pollution prevention and control on a regional basis. English translation of the Air Law retrieved from: [http://](http://en.cleanairchina.org/product/7332.html)

[en.cleanairchina.org/product/7332.html](http://en.cleanairchina.org/product/7332.html)

2 Ma Jun. (2017). *The Economics of Air Pollution in China: Achieving Better and Cleaner Growth*. New York: Columbia University Press. Ma Jun's literature review has extensive citations to work dating back more than a decade to emphasize his points that energy restructuring is essential to achieving air quality goals.



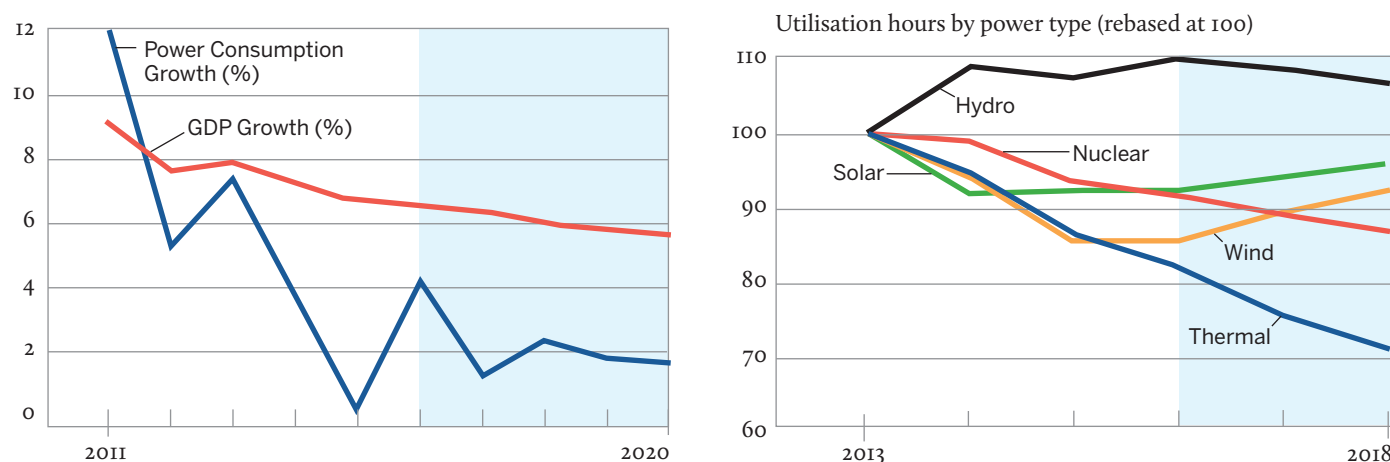
## 2. Current Policies and Regulations: Solid Progress on Environment and Energy

Unprecedented resources have been deployed since 2010 to reduce China's air pollution. Air and environmental laws have been strengthened and made more comprehensive. Tighter standards for coal-fired power plants were adopted and then further strengthened, intending to make emissions from these plants meet the same standards as natural gas-fired plants.<sup>3</sup> Provincial governments and more than 300 city- and county-level environmental protection departments have been directed to develop and implement air quality management plans.<sup>4</sup> Although progress has not been even across all regions, the measures included in these plans have certainly contributed

to the decrease in PM<sub>2.5</sub> concentrations since 2013. Annual averages of key pollutants declined in all 74 key Chinese cities.<sup>5</sup> Beijing's PM<sub>2.5</sub> concentrations have decreased from 89.3 ug/m<sup>3</sup> in 2013 to 73 ug/m<sup>3</sup> in 2016.<sup>6</sup> Shenzhen is the first city to reach the World Health Organization's (WHO) interim target I of 35 ug/m<sup>3</sup>, and has announced plans to reach the WHO interim target II of 25 ug/m<sup>3</sup> by 2020.<sup>7</sup> Shenzhen is also the first of China's 113 key cities to reach China's Grade I PM<sub>2.5</sub> standards.<sup>8</sup>

Top-level, consistent commitments emphasize actions to restructure the energy sector to reduce air pollution and GHG emissions.<sup>9</sup> Contributions to China's gross domestic

**Figure 1. China's Economy and the Power Sector**



Source: *South China Morning Post*, using data from National Bureau of Statistics, National Energy Administration, China Electricity Council, and Daiwa Capital Markets

- 3 Zhao, L., James, C., & Seligsohn, D. (2012). *China Adopts World Class Pollutant Emission Standards for Power Plants*. Washington, DC: World Resources Institute. Retrieved from [http://www.chinafaqs.org/files/chinainfo/China%20FAQs%20Emission%20Standards%20v1.4\\_0.pdf](http://www.chinafaqs.org/files/chinainfo/China%20FAQs%20Emission%20Standards%20v1.4_0.pdf) (2012 standards), and Kahrl, F., Wei, J., Graycar, K. & Xie, T. (2016). *A Clear Opportunity: U.S.-China Collaboration on Clean Air*. Beijing: Asia Society. Retrieved from <http://asiasociety.org/sites/default/files/L/LKG-CleanAirReport-Full-Web.pdf>. (Table 3, page 32)
- 4 There are 113 key cities and either 338 or 341 key city and county level agencies (including the 113 key cities). One 2007 report from the World Bank cites 341, whereas the 338 number is more consistently cited by some Chinese researchers. To avoid confusion, "over 300" is used in this document.
- 5 Lu, F., Wei, W., Weihao, Z. & Huihui, C. (2016). *China Air 2016: Air Pollution Prevention and Control Progress in Chinese Cities*. Beijing: Clean Air Asia. Retrieved from <http://cleanairasia.org/china-air-2016/>
- 6 Zhang, C. (2017, January 25). Can China Meet Its 2017 Air Quality Goals? *China Dialogue*, citing data from the Beijing Environmental Protection Bureau. Retrieved from <https://www.chinadialogue.net/article/show/single/en/9574-Can-China-meet-its-2-17-air-quality-goals-?>
- 7 Clean Air Alliance of China. (2016, April 20). *Shenzhen Aims for WHO-II PM2.5 Standard*. Retrieved from <http://en.cleanairchina.org/product/7658.html>
- 8 Xie, T., et al. (2015). *China Air Quality Assessment Report*. Beijing: Clean Air Alliance of China. Retrieved from [en.cleanairchina.org/file/loadFile/96.html](http://en.cleanairchina.org/file/loadFile/96.html)
- 9 China to 'declare war' on pollution, premier says. (2014, March 4). *Reuters*. Retrieved from <http://www.reuters.com/article/us-china-parliament-pollution/china-to-declare-war-on-pollution-premier-says-idUSBREA2405W20140305>. Co-benefits to energy restructuring also improve water quality and reduce waste and impacts to land.

product (GDP) today come from the higher-value manufacturing and service sectors, and less so from primary industrial sectors, such as iron/steel and cement. China's 15-year commitment to decrease energy intensity per unit of GDP has helped to flatten electricity growth in primary industry, and slow overall electricity growth to about one percent per year in 2015 and 2016.

Economic policies alone cannot achieve China's environmental goals; they have been complemented by solid environmental and energy policies and regulations issued over the past several years. Key moves in this area reflect a deepening commitment to comprehensive air quality management:

- 2010: State Council Guidance required regional plans to be developed to manage air quality;
- 2012: NO<sub>x</sub>, SO<sub>2</sub>, and mercury emissions standards for new and existing power plants;
- 2013: State Council "Ten Measures" Regulations, binding across departments, which set specific reduction targets for PM<sub>2.5</sub>, NO<sub>x</sub>, and SO<sub>2</sub>, and a specific ambient target of 60 ug/m<sup>3</sup> PM<sub>2.5</sub> annual average to be achieved by 2017 for Beijing;
- 2015: Effective date of revised and strengthened environmental law that increased the penalty authority of MEP; and
- 2016: Effective date of revised and strengthened air law that expanded MEP's authority to manage air quality.

Although these air quality policies and regulations are just becoming effective today, evaluations suggest that their benefits are beginning to be realized. In addition to the falling concentrations of PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> emissions from

industry and the power sector have continued to decrease.

Solid policies and regulations have also been adopted by NDRC and the National Energy Agency (NEA) over the past several years:

- 2006: Generation rights trading was first piloted in Jiangsu, then expanded to other provinces. This policy allowed more efficient thermal plants to purchase the right to be dispatched from less efficient plants;<sup>10</sup>
- 2007: A priority dispatch policy was issued, wherein the most efficient and lowest emitting plants were to be dispatched before less efficient and higher-emitting plants;
- 2007: NDRC policy required that China's grid companies purchase all renewable energy output; and
- 2015: NDRC Documents 9 and 518 were issued, establishing a vision in which the lowest-emitting power plants would operate the most and initiating a procurement system for renewable energy generation.

Also in 2015, the State Council and Central Committee of the Communist Party launched a new power sector reform effort, including the "basic principle" of "energy saving and emissions reduction."<sup>11</sup>

These sustained and consistent policy and regulatory efforts have made China a world leader in wind and solar capacity, and in building the most thermally efficient power plants. At the end of 2016, China had 148.6 gigawatts (GW) of wind (an increase of 18.7 GW since 2015) and 77.4 GW of solar (an increase of 34.6 GW since 2015) capacity.<sup>12</sup> New plants in China can achieve thermal efficiencies as high as 45 percent, and China has completed upgrades at existing coal plants to increase their thermal efficiencies to an average of 37.2 percent (compared with a global average of 33 percent).<sup>13</sup>

10 The policy worked well in facilitating the shutdown of some 100 GW of small, older, and particularly inefficient generating facilities, but it has not been effective in supporting a shift to more economically efficient dispatch.

11 National Development and Reform Commission. (2015). *On the Improvement of Power Regulation to Promote Clean Energy*. Retrieved from [http://www.gov.cn/xinwen/2015-03/23/content\\_2837637.htm](http://www.gov.cn/xinwen/2015-03/23/content_2837637.htm). (Note: Google Chrome will automatically translate documents if this browser is used.)

12 China Electricity Council. (2017). *Summary of National Electric Power Industry Statistics Express Data for 2016*. Retrieved from <http://www.cec.org.cn/guihuayutongji/tongjixinxi/niandushuju/2017-01-20/164007.html>

13 Burnard, K., Jiang, J., et al. (2014). *Emissions Reduction Through Upgrades of Coal-Fired Power Plants: Learning From Chinese Experience*. Paris: International Energy Agency. Retrieved from <https://www.iea.org/publications/freepublications/publication/PartnerCountrySeriesEmissionsReductionthroughUpgradeofCoalFiredPowerPlants.pdf>

### 3. Risks to Achieving Energy and Environmental Objectives: Uneven Implementation, Lack of Agency Coordination

**R**ecent law and policies encourage and require<sup>14</sup> coordination of energy planning and concurrent integration of energy and environmental policy, backed up by commitments and support from high-ranking officials. Implementation has been uneven, however: energy and environmental personnel do meet, but they nevertheless operate in their own policy and operational “silos,” and do not integrate principles from other disciplines that would help to achieve their various goals without imposing additional constraints on others. For example, the new environmental permits issued to power plants do not require implementation of energy management systems or techniques to improve energy consumption, although these policies are embedded in Articles 32 and 42 of the revised Air Law. Enforcement is inconsistent, with well-publicized attention given to certain factories in a given area for a short period of time, while other areas do not receive such attention.<sup>15</sup> Severe pollution episodes now result in closure of factories and airports, with restrictions on driving cars—but after strong winds blow to decrease pollution levels, these short-term restrictions are removed. Likewise, billions of renminbi (RNB) have been spent to produce blue skies for events such as the 2008 Beijing Olympics or meetings of

the Asia-Pacific Economic Cooperation forum, only to see pollution levels spike again once the events end and industrial productivity is resumed. The ability to cut pollution during events when China is on the global stage illustrates that achieving clean air is possible, but the level of pollution reductions achieved to yield these short-term successes must be sustained consistently for years and years.

China has had a priority dispatch for renewable energy and clean generation for several years, but recent solar and wind curtailment rates as high as 43 percent have occurred during some months of 2016, whereas the hydroelectric curtailment rate for all of 2016 was 5.6 percent. Solar and wind curtailments have been highest in northern and northwestern provinces such as Gansu and Inner Mongolia.<sup>16</sup> Credible sources for hydroelectric curtailment rates have been more difficult to locate, but one source reports that Yunnan curtailed 40 terawatt-hours (TWh) during 2016<sup>17</sup> (out of a total of 70 TWh curtailed that year across all provinces).<sup>18</sup> The quantity of hydroelectric power curtailed in Yunnan in 2016 is almost equal to that amount curtailed during the previous five-year period (41 TWh were curtailed during the 12th Five Year Plan, 2011–2015).<sup>19</sup> China has tripled the capacity of new coal-fired thermal plants since 2008, and the average plant

14 For example, Air Law articles requiring clean energy and green dispatch. NDRC Document 9 requirements that power sector reforms integrate environmental outcomes.

15 Recent evidence suggests that there may be more focused attention on enforcement. MEP recently strongly criticized officials in Jing-Jin-Ji for failure to take serious action to reduce air pollution. See, for example: Pinghui, Z. (2017, July). China's environment watchdog reads riot act to megacity over litany of pollution failures. *South China Morning Post*. Retrieved from <http://www.scmp.com/news/china/economy/article/2104793/chinas-environment-watchdog-reads-riot-act-megacity-over-litany>. On the other hand, results from some third-party inspections of certain industrial facilities reflect that companies do not want the auditors to find too much pollution, because it would have to be reported and perhaps penalized (personal communication, Tonny Xie, Director Clean Air Alliance for China, August 1, 2017).

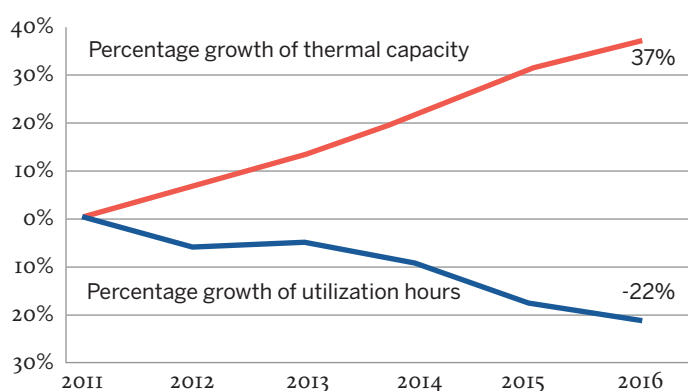
16 Wind curtailment rates from National Energy Administration. (2017). *2016 Wind Power Grid Operation*. Retrieved from [http://www.nea.gov.cn/2017-01/26/c\\_136014615.htm](http://www.nea.gov.cn/2017-01/26/c_136014615.htm); solar curtailment rates (for the northwest only) from National Energy Administration. (2017). *New Situation of Operation of New Energy in Northwest China in 2016*. Retrieved from [http://www.nea.gov.cn/2017-01/19/c\\_135996630.htm](http://www.nea.gov.cn/2017-01/19/c_135996630.htm)

17 Changyao, W. (2017). *2016 Southwest curtailed hydropower record high*. CN Energy. Retrieved from [http://www.cnenergy.org/dl/sd/201701/t20170113\\_411387.html](http://www.cnenergy.org/dl/sd/201701/t20170113_411387.html)

18 China curtailed 70 TWh of hydro power in 2016 (a curtailment rate of 5.6 percent). Retrieved from <http://news.bjx.com.cn/html/20170314/813747.shtml>

19 China Society for Hydropower Engineering. (2017). *How to Break the Dilemma of Hydropower Discharge in Southwest China*. Retrieved from <http://www.hydropower.org.cn/showNewsDetail.asp?nsId=20562>



**Figure 2. Growth in Coal-fired Capacity vs. Utilization Hours**

Source: Center for American Progress with data from 2011-2016 China Electricity Council annual reports.

operating hours have declined by 20 percent over that same period.

China's new Air Law requires agencies to include clean energy measures in their air quality plans, but the plans continue to emphasize end-of-pipe controls rather than more comprehensive measures. With limited resources and pressure to achieve targets linked to personal performance, agencies tend to follow the same template once an approach has been created and used. The following examples highlight the inconsistent or conflicting ways in which air quality and energy policies and regulations have been implemented.

### 3.1 Air Quality

Despite the 2010 guidance requiring regional coordination of air quality planning, each of the Jing-Jin-Ji provinces submitted its own air quality management plan to MEP without discussing it with the others.<sup>20</sup> This defect was partially remedied by the 2013 State Council "ten measures," which put teeth into the guidance and compelled cooperation, and by the visible and resource-intensive Jing-Jin-Ji air quality management plan, which applies to Shanxi, Shandong, and Inner Mongolia in addition to the original three members: Beijing, Tianjin, and Hebei provinces. However, the Jing-Jin-Ji efforts have not yet accounted for possible air quality benefits that could be acquired from clean energy resources and improved electricity dispatch, both of which are identified in the revised Air Law (in Articles 32 and 42, respectively).

The regulations described here both encourage and require integration of energy policies into air quality

management plans. However, the default choice for air regulators continues to be end-of-pipe measures to abate air and water pollution. Emissions control equipment for power plants uses mature and effective technologies, and discharges can be continuously monitored to ensure compliance. But these end-of-pipe technologies impose parasitic loads of one to three percent on thermal plants that increase the plant's GHG emissions. Ash from boilers and pollution control equipment also requires proper collection and treatment.

Blunt efforts to improve air quality in the short term have been the default approach applied during major sporting events (Beijing 2008 Olympics, Shanghai 2010 World Expo, Nanjing 2014 Youth Olympics) and global economic meetings (APEC 2012). Each of these events imposed major disruptions to businesses and the public, costing billions of renminbi, only to see air pollution return after the conclusion of the event. The quantity of pollution reduction needed to achieve blue skies is known through dispersion models.<sup>21</sup> Adoption, implementation, and consistent enforcement of regulations would avoid the need for these expensive short-term interventions. If cities and counties are to achieve long-term progress, their clean air plans must account for increased renewable energy generation, zero-emitting hydroelectric and nuclear power, integration of storage and transport electrification, and an accounting of the full savings potential of end-use energy efficiency programs.

### 3.2 Power Sector

From 2006 to 2015, China closed more than 100 GW of inefficient power plants smaller than 200 megawatts (MW), and increased its thermal power plant capacity from 391 GW to 916 GW.<sup>22</sup> This growth rate was initially synchronized with electricity consumption, which grew by ten percent or

20 Personal communication with Chinese Academy of Environmental Planning.

21 During the Beijing Olympics, 200 tons per day of PM10 were removed from the local air shed. Personal communication, Wang Zifa (2011), then with Chinese Academy of Social Sciences (CASS), now a consultant to RTI International.

22 Hervé-Mangucci, M., et al. (2015, December). *Slowing the Growth of Coal Power in China: The Role of Finance in State-Owned Enterprises*. Climate Policy Initiative. Retrieved from <https://climatepolicyinitiative.org/wp-content/uploads/2015/12/Slowing-the-Growth-of-Coal-Power-in-China-%E2%80%93-the-Role-of-Finance-in-State-Owned-Enterprises.pdf>

more annually. Recent electricity growth rates have slowed for the primary and secondary economic sectors, whereas residential electricity growth rates have remained robust. During 2016, the electricity growth rate for the primary industrial sector was 5.3 percent, for secondary industry 2.9 percent, for heavy industry 2.6 percent, for tertiary industry 11.2 percent, and for the residential sector 10.8 percent.<sup>23</sup> The secondary and tertiary sectors produce GDP using less fuel than the primary sector, and coal consumption overall declined in 2014 and 2015, even as GDP grew by seven percent. China has decoupled economic growth from energy consumption, but has continued to invest in thermal power plant infrastructure, which is increasingly not needed.

Instead of economic dispatch, China's thermal power plants operate under a generation quota system that assigns annual operating hours to each plant. Structural shifts in China's economy mean that much of the thermal capacity that has recently been added is not required. Decoupling energy consumption from economic growth has resulted in decreasing the average number of hours that each thermal power plant operates from 5,991 hours in 2004 to 4,706 hours in 2014. Capacity utilization declined to about 4,000 hours in 2016, when much new capacity was added and the electricity growth rate declined across all sectors. The decreased utilization rates affect the economics of many thermal power plants, and plants in several provinces have been unable to recover investment costs.<sup>24</sup>

Another factor contributing to the recent acceleration in the decline of power plant operating hours is that approval for their licensing was devolved from central to local authority in 2015. This created opportunities for local officials

to augment their GDP, because the value of construction counts toward local economic development even if the power plant does not operate or operates for only limited hours. As electricity demand growth has dropped, these local approvals have led to a perverse "tragedy of the commons" situation in which more and more thermal plants are approved but compete for fewer and fewer hours. An estimated 200 GW of new plants were approved for construction in 2015 and 2016.<sup>25</sup> However, NEA canceled approval for about 30 GW of such plants in late 2016.<sup>26</sup> Approval for as much as 120 GW of planned and under-construction plants may be canceled during 2017.<sup>27</sup>

From 2006 to 2016, China's Top 10,000 Program, an initiative in the 12th Five Year Plan that requires energy savings from the country's leading industrial enterprises, reduced coal consumption by 300 million tons. There is significant potential for additional energy savings, as a recent analysis of several dozen of the Top 10,000 projects shows.<sup>28</sup> Although some air quality plans consider energy conservation measures, policymakers have not analyzed the potential air quality improvements that these measures could effect. If China were ranked among the U.S. states and territories, its modest obligation on grid companies to achieve energy savings of 0.3 percent of annual sales would place it just 37th out of 54; 17 U.S. states achieve rates equal to one percent or greater of electricity sales.<sup>29</sup> Energy efficiency programs have contributed to approximately one-third of the air quality improvement in jurisdictions including California and the United Kingdom. They could also contribute to significant air quality improvement in China if there were better coordination between air quality and energy planners.

23 China Energy Portal. (2016). *Detailed Electricity Statistics*. Retrieved from <http://chinaenergyportal.org/en/2016-detailed-electricity-statistics/>. China Energy Portal is a crowd-sourced translation of government and institutional documents related to China energy topics.

24 North China Electric Power University. (2016). *Study on Economics of Coal-Fired Power Generation Projects in China*. Retrieved from <http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/climate-energy/2016/Study%20on%20Economics%20of%20Coal-fired%20Power%20Generation%20Projects%20in%20China%20Report.pdf>

25 China building 200 GW of coal-fired power despite capacity glut: Greenpeace. (2016, July 12). *Reuters*. Retrieved from <http://www.reuters.com/article/us-china-power-coal-idUSKCN0ZT09B>

26 National Energy Administration. (2016, October 10). *Bureau of Energy: Notice on Further Regulating the Planning and Construction of Coal and Electricity* (in Mandarin). Retrieved from: <http://news.bjx.com.cn/html/20161016/780696.shtml>

27 It is unclear if the 120 GW is in addition to the 30 GW already cancelled or not. This document assumes a conservative reading of both announcements. Reference for the 120 GW is Boren, Z. (2017). *China suspends 104 planned coal power plants*. Greenpeace. Retrieved from: <http://energydesk.greenpeace.org/2017/01/16/china-coal-power-overcapacity-crackdown/>

28 James, C., Taylor, B., & Junchao, G. (2016). *Integrating Industrial Energy Efficiency Measures Into Air Quality Plans*. Beijing: Regulatory Assistance Project. Retrieved from <https://www.raponline.org/wp-content/uploads/2016/05/rap-james-taylor-industrialefficiencyasairqualitystrategy-2015-nov.pdf>

29 Berg, W., et al. (2016). *The 2016 State Energy Efficiency Scorecard*. Washington, DC: American Council for an Energy-Efficient Economy. Retrieved from <http://aceee.org/sites/default/files/publications/researchreports/u1606.pdf>

### 3.3 Discussion

As written, China's comprehensive air quality and energy policies and regulations provide a solid footing to achieve clean air and a reliable, affordable energy supply—if implementation is coordinated and consistent, and goals are enforced across agencies and jurisdictions. For each of the policy and regulatory successes mentioned, there are also failures that have impeded efforts to improve air quality and reform the power sector. In air quality regulation, enterprises have not been required to install best available controls or apply best available techniques when they are built or expanded. In the power sector, the capacity of wind and solar generation is not fully utilized as China has continued

to build new thermal power plants. The capacity factors of all thermal plants have decreased by nearly 33 percent since 2004, owing to slowing electricity growth and economic shifts away from primary industries (like iron/steel and cement) to the service sector and higher-value manufacturing, which use less fuel or electricity to contribute to GDP.

Even if power sector reform were not a priority today, the current overcapacity in thermal power generation argues for clear roles and responsibilities for energy and environmental officials. All elements of power sector policy and regulation—planning, market structure, pricing, investment, and operations—must be designed to meet those goals at least-cost and subject to reliability constraints.



## 4. Global and Chinese Best Practices: Power Sector Reform and Air Quality

Unhealthy pollution levels and the need to reform power sector policies have been addressed in other regions. Europe and the United States each have experience that may be applicable in China. Both of these regions also had institutions that lacked coordination with others, which at one time imposed additional costs or environmental impacts. The examples provided here illustrate how these institutions reached a state of cooperation, as well as offering cautionary advice.

### 4.1. Engaging Air Quality and Energy Regulators to Maintain Electricity Reliability and to Meet Air Quality Standards

**Region:** Northeastern United States

**Agencies involved:** State air quality and energy regulators, regional grid operator, U.S. Environmental Protection Agency (EPA) regional office and headquarters

**Description:** In the spring of 1995, the U.S. federal Nuclear Regulatory Commission (NRC) placed all nuclear reactors located in the state of Connecticut on its Watch List, requiring the plants to shut down to address safety concerns. At the time, these reactors provided more than 50 percent of Connecticut's electricity, and the state exported their remaining output to adjacent states. As a result of the shutdowns, the state was faced with a deficit of 3,000 MW of electricity just a few weeks before the start of summer, when demand would significantly increase owing to residential and commercial air conditioning load.

The NRC listing came at a sensitive time, because periods of unhealthy air quality in the northeastern states occur during the summer. Connecticut was designated by the EPA as having seriously unhealthy levels of ozone in the air, and adjoining states also experienced unhealthy concentrations of ozone. Nuclear energy generation does not emit pollutants, such as NO<sub>x</sub> or SO<sub>2</sub>, which cause or contribute to ozone or fine particle pollution.

Initially the region's energy regulators and the grid

operator proposed that a fleet of diesel generators be deployed around Connecticut to replace the lost 3,000 MW. One part of this proposal included installing diesel generators on ships that would be connected to the grid at various locations along Connecticut's shoreline.

Both Connecticut's air quality regulators and those in adjoining states opposed the proposal. Diesel generators emit high levels of NO<sub>x</sub> per megawatt-hour (MWh). Adding NO<sub>x</sub> to an air basin that already exceeded federal air quality standards would have caused ozone concentrations to spike in Connecticut, and the additional pollution would have been transported downwind to other states, causing them to also experience unhealthy air quality.

At the request of the air regulators, regional meetings were convened to develop a solution to the electricity crisis. They had only a few weeks before summer's arrival and temperatures of 30 to 35 C, with high humidity, that would lead to residents and businesses turning on their air conditioners. Weekly meetings and nearly daily conference calls were held among state air regulators, state energy regulators, the region's electricity grid operator, and utility companies. The regional EPA office and EPA headquarters monitored the meetings to keep apprised of any solutions that might require revisions to regulations and to assess the potential for any additional pollution that might influence public health.

These multi-party discussions led to a solution with two key components:

- increased use of natural gas-fired plants in states adjoining Connecticut, and
- utility obligations to offset any extra emissions that might occur from use of temporary fossil-fueled generators.<sup>30</sup>

<sup>30</sup> Connecticut measures air quality that exceeds EPA public health standards for ozone. NO<sub>x</sub> from combustion sources like power plants are precursors to the formation of ozone. Connecticut requires any enterprise that increases NO<sub>x</sub> emissions to offset such emissions by purchasing allowances through emissions markets, by installing additional emissions controls at the enterprise location itself, or by the subject enterprise paying for the installation of emissions controls at another location in the same air basin. Offsetting emissions must be greater than any possible emissions increase that would occur, so as to result in a net air quality benefit for the proposed activity.

During the summers of 1995 and 1996, the region's grid operated reliably and there was only one instance for which the use of temporary generators required utilities to obtain offsets for extra emissions.

**Lessons Learned:** As important as this example is in showing how air quality and energy regulators working together can quickly address an electricity emergency in ways that do not increase emissions, the longer-term lesson is that this experience built trust and lasting relationships among the region's regulators. These groups continue to work actively together and they have served as a model to other regions and at the national level for regulatory collaboration and cooperation. The issues they have addressed include:

- restructuring of electricity regulation and development of regional markets;
- developing model regulations for distributed energy resources that provide for performance-based emissions standards;
- working with the regional electricity grid operator to revise standards to ensure that dispatched generation resources meet environmental requirements;
- creating the first GHG regulatory program in the United States; and
- working with the regional electricity grid operator first to qualify energy efficiency and distributed renewable generation as resources, and then to agree on measurement and verification protocols that are consistently applied to all resources that generate electricity or provide capacity.

## 4.2. Licensing New and Regulating Existing Power Plants in Air Basins With Unhealthy Air Quality

**Regions:** United States and Europe

**Agencies Involved:** National-level environmental agencies, sub-national or state-level environmental and energy agencies

**Description:** The United States and the European Union have two different approaches to permit new fossil-fuel-fired power plants and to regulate the emissions from existing plants. The focus of U.S. regulation is at each emissions point, whereas the EU scope covers an entire plant and considers water and waste emissions and a plant's energy

consumption.

New plants (or expansions of existing plants) in the United States are required to offset any emissions increase by a ratio of at least one to one (meaning that if a plant proposes to increase emissions by 100 tons, offsets must decrease emissions elsewhere by that same 100 tons). The emissions are subject to Best Available Control Technology (BACT) and Lowest Achievable Emissions Rate (LAER). BACT applies to pollutants for which the air basin meets public health standards and requires "best" emissions controls while also considering energy, economic, and environmental factors. LAER applies to pollutants for which the air basin exceeds public health standards and requires "best" emissions controls, period, without consideration of other factors. New or modified plants must meet BACT and LAER, and secure the necessary offsets, before being authorized to initiate construction.

The European Union requires plants to apply Best Available Techniques (BAT). For air quality, BAT is similar to the U.S. BACT, but a range of emissions standards is provided for Member States to apply to their own situations. Emissions ceilings (like the concept of total emissions control in China) are established for each Member State, and offsets are not typically required (although local jurisdictions may require them). Plants that cannot or do not meet BAT may continue to operate for a limited number of hours over a two- or three-year period, then must either comply with the emissions limits or shut down.

**Lessons Learned:** The U.S. system is highly prescriptive and technology-focused. The EU system also emphasizes technology, but considers a plant's entire operations, and Member States have some flexibility in applying specific environmental limits to local conditions. Critics of the U.S. system state that the focus on specific emissions points and new plants has kept many older plants operating beyond their expected lives (although dozens of GW of older plants have closed in recent years because of competition from natural gas, wind, and solar, as well as increased energy efficiency). Critics of the EU system point to Member States in Central and Eastern Europe delaying application of new emissions standards for many years, and emissions from these plants have contributed to poor air quality in these regions. The EU enterprise-wide permit deserves consideration by China, as it would allow agencies to focus on water and land emissions

(which are also serious problems in China) in addition to air. The U.S. principle that “best” emissions control should apply everywhere, regardless of economic status, also deserves consideration, because public health effects are not distinguished by economic class.

### 4.3. Power Sector Reform

**Region:** Europe

**Agencies Involved:** Energy agencies from each member State, owners and operators of fossil-fuel-fired power plants

**Description:** The European Union has a significant excess of coal-fired power plants. Reserve margins in some Member States are 80 percent.<sup>31</sup> Renewable energy and energy efficiency investments have been sustained for many years to diversify the resources used to provide electricity and to help meet EU goals to reduce GHG and criteria pollutant emissions. As a result, the hours that generators operate each year have decreased. Owners and operators of incumbent generators are advocating for capacity markets to be established, so they can receive guaranteed payments to improve their balance sheets. The EU 2030 legislation package includes continued commitments to renewable energy, energy efficiency, building performance, reforms of the emissions trading system (ETS), and establishing an energy-only market.

**Lessons Learned:** The EU work is in progress and bears watching. Incumbent generation is losing money and wants a stream of capacity payments to avoid closing down entirely. However, the penetration of renewable energy, its continued development, and its competitive costs suggest that creation of a capacity market for Europe would raise costs for consumers and businesses and detract from helping to achieve the European Union’s environmental goals.<sup>32</sup>

### 4.4. Curtailment of Renewable Energy and Expansion of Balancing Areas

**Region:** Scandinavian Countries, Europe

**Agencies Involved:** European Commission (Energy Directorate), transmission system operators

**Description:** Energy balancing areas in Europe have been traditionally fixed by the boundaries of each Member State, often for national security reasons. Each Member State had its own national electricity company. Free trade considerations have encouraged the European Commission

**Figure 3: Nord Pool Markets**



Source: Nord Pool, A joint European Journey

to expand balancing areas to beyond fixed national boundaries. The Nord Pool in Scandinavia allows the transmission system operators to count on resources in neighboring countries for reliability purposes. For example, Denmark can count on the hydroelectric resources in Norway to help provide electricity during periods of low wind generation. Likewise, Norway (and now northern Germany) can count on wind resources in Denmark to help meet reliability requirements in those countries, and also to help lower overall energy costs. The Nord Pool countries complete periodic resource assessments and include resources in neighboring countries to be available to them for reliability, demand, and emergency response. The Nord Pool has expanded beyond Scandinavia and is now a Nominated Electricity Market Operator in 15 EU Member States.<sup>33</sup> The European Commission has created a goal of ten percent of electricity sales to be

31 Personal communication, Richard Cowart, Director of European Programmes, The Regulatory Assistance Project, 8 December 2016.

32 Ibid.

33 Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Great Britain, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, and Sweden.



supported by capacity that is interconnected between more than one Member State. The EU Commission has created a competition for funding for “projects of common interest,” that is, those projects of benefit to several Member States, which include transmission expansion.

**Lessons Learned:** Larger balancing areas allow energy and transmission planners to use resources efficiently and economically. If the Nord Pool members continued to use country-only boundaries to conduct resource planning and managed demand, periods of peak load, sudden loss of a critical unit, or weather conditions (extreme heat or cold, high winds) would require use of more expensive units (small thermal plants or diesel generators), or potential loss of the entire system if no other units were available to meet demand.

These countries’ environmental objectives are also met more readily through larger balancing areas. Wind resources are fully utilized, and in the cases of peak demand, Nord Pool members can call on cleaner generating resources (e.g., hydro power from Norway), rather than be forced to turn on smaller units that have little to no emissions controls and that may be situated in dense urban areas. The larger Nord Pool balancing area allowed Denmark to keep the lights on during an unexpected hurricane on October 28, 2013.<sup>34</sup>

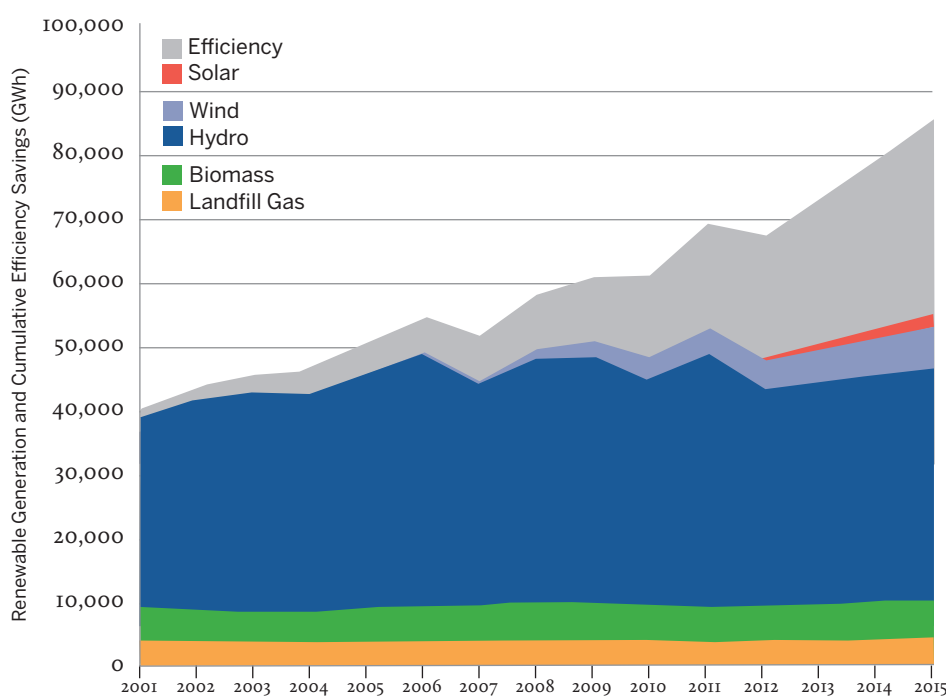
## 4.5. Regional Greenhouse Gas Initiative (RGGI)

**Region:** Nine northeastern states, United States

**Agencies Involved:** State-level environmental and energy regulators. Public meetings were held approximately four times each year and were facilitated by an independent person selected and paid by the states. Public meeting attendees included federal agencies (the Federal Energy Regulatory Commission [FERC], the EPA, and the Department of Energy), environmental groups (Natural Resources Defense Council, Environmental Defense Fund), utilities (load-serving entities and generation owners), and consultants.

**Description:** RGGI is a collaborative effort between state

**Figure 4. RGGI's Impact: More Efficiency and Renewables**



Source: Acadia Center, Regional Greenhouse Gas Initiative Status Report Part I: Measuring Success

environmental and energy regulators in nine northeastern U.S. states. Its initial environmental emphasis grew from the success of the acid rain program, an emissions trading program for SO<sub>2</sub> and NO<sub>x</sub>. Affected sources, power plants larger than 25 MW, were the same for both acid rain and RGGI. End-of-pipe controls for CO<sub>2</sub> are embryonic and expensive, and switching to a different type of coal or to natural gas would not be sufficient by itself to achieve full program compliance; these compliance options impose costs that must be borne by or passed through to consumers. Including the RGGI region’s energy regulators in the conversation revealed that energy efficiency could be a least-cost compliance option. Furthermore, informed by reports from German and U.K. audits of power sectors in those countries, the RGGI energy and environmental regulators realized that regardless of whether RGGI priced carbon or not, the affected sources did place a value on carbon, and would intend that this price be seen in the hourly bids that generators placed into the RGGI region electricity markets. By capturing that value in their prices, but not having to incur the allowance cost, the

34 Tornbjerg, J. (2016, July). Powerfully Balanced. *Foresight Magazine*. Retrieved from <https://foresightdk.com/powerfully-balanced/>

affected generators would, in fact, increase their profitability under the program, which indeed was what had happened in Europe. Anticipating that RGGI would repeat the EU experience in the absence of additional policy action, RGGI environmental and energy regulators agreed to auction 100 percent of the CO<sub>2</sub> allowances, to use the vast majority of the auction proceeds to invest in new energy efficiency and renewable programs, and to protect low-income consumers. RGGI's decision to auction allowances avoided the EU experience in which audits highlighted windfall profits of \$1 billion to generators in the United Kingdom and provided a low-cost compliance path to meet the CO<sub>2</sub> reduction goals.<sup>35</sup>

**Lessons Learned:** Absent collaboration and sustained dialogue between energy and environmental regulators, the decision to auction all CO<sub>2</sub> allowances and to recycle auction revenue would not have occurred. Such a flaw would have resulted in revenue flowing to generators and load-serving entities with few, if any, consumer benefits. Auctioning allowances and directing most of the auction revenue into state energy efficiency, renewable energy, or low-income programs diversified overall funding for these programs, put downward pressure on allowance prices, enabled multiple energy benefits to be achieved, and amplified the CO<sub>2</sub> reductions from RGGI given that energy efficiency and renewable energy investments also reduce such emissions. Nearly \$2.7 billion in auction revenue has been raised by RGGI auctions to date.<sup>36</sup>

## 4.6. Federal Policy to Restructure the Utility Industry; Federal Regulations to Improve Regional Air Quality

**Region:** United States

**Agencies Involved:** FERC, EPA, regional transmission operators, state public service commissions, state environmental regulators

**Description:** Starting in the late 1970s, the United States began to deregulate large sectors of the economy, taking the view that competition would encourage creation of markets, promote increased consumer choice, and be more cost-effective. The deregulation began with the airline industry and continued into the 1990s. In 1996, FERC issued Order 888, which encouraged wholesale competition for electricity sales. Sixteen states in the populated northeast, Middle

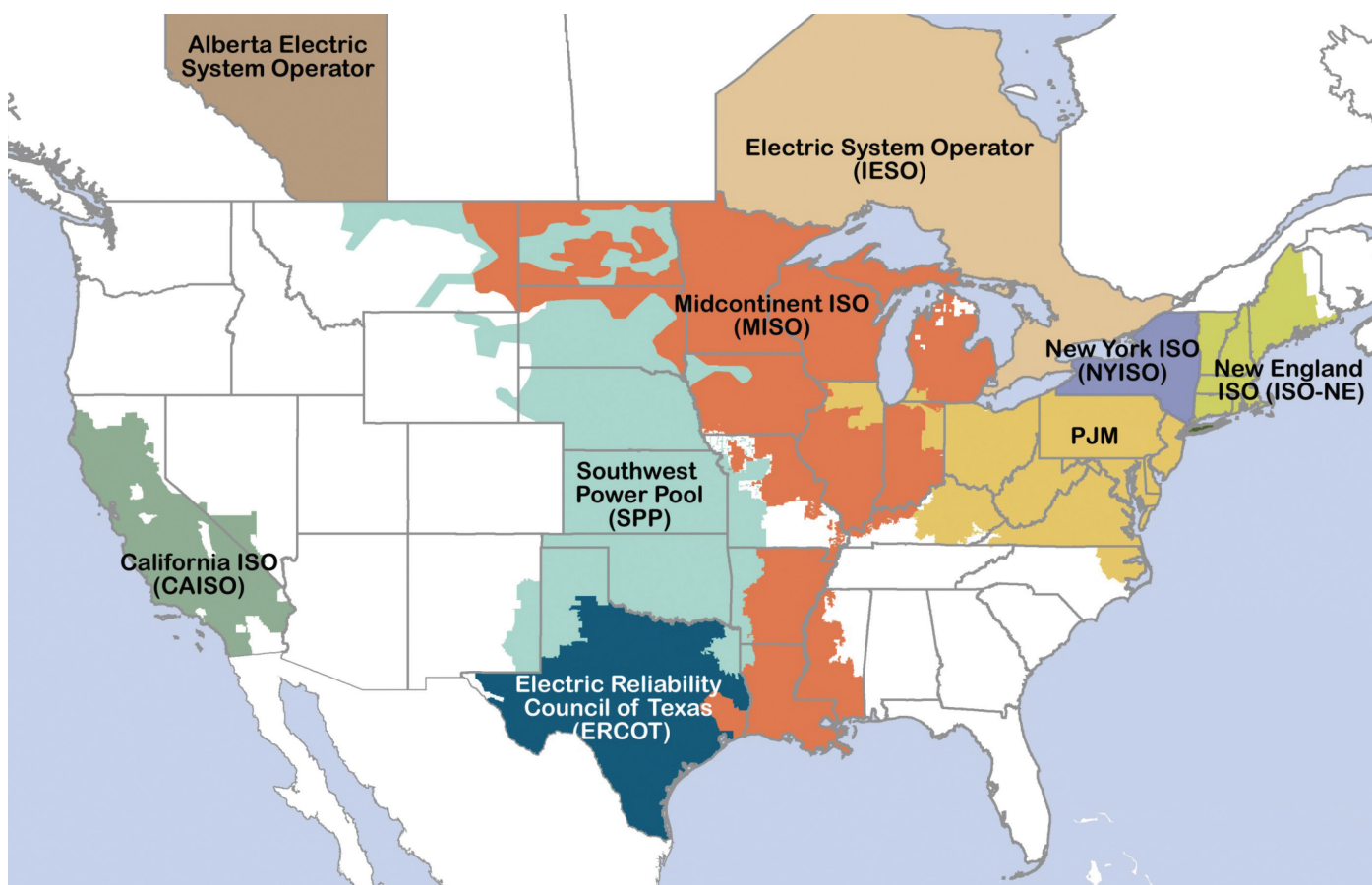
Atlantic, and Great Lakes regions, and Texas, California, and Oregon implemented Order 888 to restructure their utility industries from a vertically integrated model to a disaggregated one in which different entities were responsible for generation, transmission, and distribution. Several regional transmission grid organizations were also formed during this period to provide consistent platforms to transmit electricity across several states. The unbundling of the main components of the electricity system was based on the premise that opening up the system to wholesale competition would increase customer choices and reduce their costs. In the United States, FERC is responsible for the regulation of interstate and wholesale commerce related to the electricity system.

The FERC actions were concurrent, and not initially coordinated, with actions by the EPA to implement the significantly revised and strengthened Clean Air Act (CAA) Amendments of 1990. Air pollution does not respect geographic boundaries. Improved science and modeling techniques enabled eastern states to document that their efforts to meet air quality standards were impeded by transported pollution emitted from upwind coal-fired thermal power plants. With this evidence, several of the downwind states took advantage of one of the key provisions of the 1990 CAA and successfully petitioned the EPA to develop a regionally applicable market-based program to reduce NO<sub>x</sub> and SO<sub>2</sub> emissions from power plants. This program started first as a state-led effort in 1998 and was expanded in 2003, with the EPA then taking the lead.

State environmental regulators expressed concerns that utility restructuring might increase emissions as electricity markets were created. Their thinking was that thermal plants without emissions controls would bid their lower marginal costs, be dispatched more often, and further affect the downwind states' ability to reduce pollution.

35 UK House of Commons, Environmental Audit Committee. (2004). *Environmental Audit – Fourth Report*. (articles 33-35). Retrieved from <https://publications.parliament.uk/pa/cm200405/cmselect/cmenvaud/105/10506.htm>. Note that some groups estimated even higher windfall profits. German auditors also found evidence of windfall profits.

36 Ramseur, J. (2017). *The Regional Greenhouse Gas Initiative: Lessons Learned and Issues for Congress*. Washington, DC: Congressional Research Service. Retrieved from <https://fas.org/sgp/crs/misc/R41836.pdf>.

**Figure 5: Regional Transmission Organizations in North America**

Source: Federal Energy Regulatory Commission. (2017). *Regional Transmission Organizations (RTO)/Independent System Operators (ISO)*. Retrieved from <https://www.ferc.gov/industries/electric/indus-act/rto.asp>

FERC Order 888, with its focus on competitive open access at wholesale, led to the creation of several regional transmission organizations (RTOs, also known as grid operators), notably ISO-NE (covering the six New England states), and PJM (initially covering Pennsylvania, New Jersey and Maryland, but now covering states from New Jersey to Illinois), and MISO (covering 15 states in the Plains and the Canadian province of Manitoba). RTOs are independent, non-governmental bodies responsible for managing the grid, ensuring dispatch of least-cost resources first, and maintaining compliance with reliability standards. Environmental regulators engaged with RTOs as they were formed, at first to inject the concomitant importance to meet air quality regulations. This interaction continued as RTOs established rules for demand response and considered how behind-the-meter resources such as combined heat and power, distributed solar, and energy efficiency programs could be managed.

**Lessons Learned:** The FERC and EPA actions occurred in parallel and were not initially coordinated. Utility restructuring garnered the attention of air regulators as this group realized that the creation of regional transmission operators could lead to fuller utilization of generation in states that had less stringent air pollution requirements. Downwind states experienced serious levels of ozone and fine particle pollution that would have been exacerbated had thermal generation in upwind states increased their hours of operation in order to serve customers in other states. Likewise, state energy regulators and utility owners and operators were concerned that the EPA's more stringent regional air pollution requirements would require significant and concurrent maintenance at dozens of power plants and would lead to potential reliability concerns if units were not available to meet customer demands. Bringing air regulators into the FERC discussions resulted in efforts by the regional transmission operators to improve and upgrade transmission

to meet reliability requirements and to more fully utilize the cleaner combined-cycle natural gas plants that had been constructed in the late 1990s. Bringing energy regulators and utility companies into the EPA regional air quality work resulted in improved air quality modeling and studies by the EPA on emissions control equipment manufacturers to ensure that these companies had adequate labor and materials, and that work to install emissions controls could be completed without affecting the reliability of electricity transmission and distribution.

The experience described was replicated again for development of model rules for distributed resources, as well as for RGGI (discussed earlier).

## 4.7. Southern Grid's Energy Saving Power Dispatch Green Dispatch Pilot

**Region:** China

**Agencies:** Provincial Development and Reform Commission (DRC)/Economic Industrial Commission (EIC), provincial EPBs, Southern Grid dispatch centers at all levels

**Description:** In 2007, the State Council released the energy saving power dispatch (ESPD) rule to improve the operational efficiency of the power sector and reduce pollution.<sup>37</sup> This rule gives dispatch priority to renewables, nuclear, and natural gas power plants before coal-fired generation units. The dispatch sequence of coal plants is determined by coal consumption efficiency (heat rate). In case of similar heat rates, the dispatch priority is next determined by the generator's pollutant (SO<sub>2</sub>) emissions.

Unlike the current quota-based dispatch, which allocates a set (roughly equal) number of annual operating hours to all thermal generators, irrespective of their relative operational efficiencies, the ESPD rule puts environmental and efficiency criteria first by favoring generation units with higher thermal efficiency and lower emissions in dispatch. It is a mandatory rule to maximize renewables utilization and limit the use of fossil fuel generators while maintaining the safe operation of power system and secure supply.

Five provinces—Guizhou, Guangdong, Jiangsu, Henan, and Sichuan—were the first to pilot implementation of the rule, but the results were mixed. In 2010, Southern Grid announced that it would expand the experiment to all five provinces in its jurisdiction (Yunnan, Guizhou, Guangdong,

Guangxi, and Hainan).

In the Southern Grid region, the provincial DRCs organize and develop annual, quarterly, and monthly generation plans. The plans are first made within provinces, then optimized to include interprovincial bulk power transactions; provincial dispatch centers at all levels refine the plans and make day-ahead plans by adjusting the modes of each plant in consideration of system constraints and security. The dispatch order of thermal generators is judged according to real-time measured coal consumption rate and pollutant emissions monitoring data provided by provincial EPBs. EPBs are also responsible for verifying the emissions levels and ensuring the installation and operation of continuous emissions monitoring systems (CEMS). The information related to ESPD is also required to be published under the supervision of NEA and NDRC. In the 12th Five Year Plan, ESPD in Southern Grid has significantly contributed to emissions reduction and energy conservation. It reduced standard coal by 39 million tons and achieved CO<sub>2</sub> emissions reduction of 1 million tons and SO<sub>2</sub> emissions reduction of 752 thousand tons.<sup>38</sup>

The 2015 power sector reform has brought some new elements to system operation in China. Yunnan and Guizhou were first selected to establish market mechanisms in the form of direct trading and centralized power markets. Guangdong and Guangxi later joined the pilots. The big picture of power sector reform raised questions about how ESPD or green dispatch in Southern Grid's area will evolve. Recently, Guangdong province released its mid- and long-term trading rule, which explicitly requires ESPD to be used to determine the dispatch order for coal generators that have not entered the market (baseload generation).<sup>39</sup>

37 State Council. (2007, August). *Energy Saving Power Dispatch Rule (Trial)* (in Mandarin). Retrieved from [http://www.nea.gov.cn/2007-08/28/c\\_131053158.htm](http://www.nea.gov.cn/2007-08/28/c_131053158.htm)

38 China Southern Power Grid. (2015). *CSR Report* (in Mandarin). Retrieved from <http://www.csg.cn/shzr/zrbg/201605/P020160525418047616815.pdf>

39 South China Regulatory Bureau of NEA. (2017, January). *Guangdong Power Market Trading Rule* (in Mandarin). Retrieved from [http://nfj.nea.gov.cn/action/front/contentAction\\_initViewContent?content.contentId=402881e55992395f0159b57e91820035](http://nfj.nea.gov.cn/action/front/contentAction_initViewContent?content.contentId=402881e55992395f0159b57e91820035)



**Lessons learned:** The ESPD rule is very effective at improving the efficiency of the power sector and generating air quality benefits. It is also a good example to demonstrate that the joint efforts of environmental agencies and power agencies in making dispatch plans result in a cleaner generation portfolio in Southern Grid jurisdiction. The challenge of balancing various interests indicates a need to reform the generators' compensation method. In the context of transition to power market, the ESPD could still be meaningful for non-market generators until the economic dispatch is fully adopted in China.

## 4.8. Environmental Pricing for Coal-Fired Generators

**Region:** China

**Agencies:** NDRC, MEP, local EPBs and DRC/EIC, grid companies

**Description:** To improve air quality and reduce coal-fired power plants' emissions; since 2004, the central government has given a price premium to coal-fired power plants with flue gas desulfurization (FGD), and since 2011, a price premium to plants with denitrification (SCR) facilities. This policy has encouraged coal-fired generators to install and operate FGD and SCR equipment. In 2014, NDRC and MEP jointly released a "regulatory rule of environmental pricing to coal-fired generators and operation of environmental protection facilities," which continues providing payments to power plants equipped with desulfurization, denitrification, and dust removal facilities.<sup>40</sup> The new rule modified the price premium based on the operation and performance of environmental protection facilities.

- The emissions levels must comply with the latest national emissions standards for coal-fired power plants.

- Coal generators should install and operate CEMS and transmit the real-time data to EPBs.
- Generators who fail to meet these two requirements are subject to fines and should return the compensations in proportion to noncompliance time.

NDRC is responsible for setting benchmarked coal generating prices as well as environmental premiums. In 2013, the premiums for desulfurization, denitrification, and dust removal were adjusted to 0.015 RMB/kWh, 0.01 RMB/kWh, and 0.002 RMB/kWh, respectively.<sup>41</sup> Local governments also developed provincial implementation rules that specify the roles and responsibilities of each entity. To enforce the environmental pricing, EPBs audit the CEMS data on a day-to-day basis; provincial pricing departments of DRC/EIC and local EPBs also conduct regular field inspections to make sure that emissions levels are within the limits and the CEMS data are reliable. According to MEP, during the 12th Five Year Plan, the capacity rates of coal-fired power plants with desulfurization and denitrification facilities have been increased from 82.6 percent and 12.7 percent in 2010 to 96 percent and 87 percent in 2015.<sup>42</sup>

**Lessons learned:** The environmental premium payments provide financial incentives for generators to install and run their environmental protection facilities properly. The pricing departments of NDRC and MEP coordinate on the design, implementation, and enforcement of this policy. CEMS enables better supervision that reduced time and resources for inspection. So far, the continuous efforts have contributed to significant reduction of NOX, SO<sub>2</sub>, and dust emissions.

40 NDRC, MEP. (2014, March). *Regulatory Rule of Environmental Pricing to Coal Fired Generators and Operation of Environmental Protection Facilities* (in Mandarin). Retrieved from [http://jgs.ndrc.gov.cn/zcfg/201404/t20140403\\_605765.html](http://jgs.ndrc.gov.cn/zcfg/201404/t20140403_605765.html)

41 NDRC. (2013, August). *Notice on Adjusting Renewable FiT and Environmental Pricing* (in Mandarin). Retrieved from [http://www.nea.gov.cn/2014-09/29/c\\_133682226.htm](http://www.nea.gov.cn/2014-09/29/c_133682226.htm)

42 MEP. (2016, January 11). *National environmental protection work conference held in Beijing* (in Mandarin). Retrieved from <http://news.bjx.com.cn/html/20160113/700672.shtml>



## 5. Recommendations for China: Reforming Power Sector, Improving Air Quality, and Reducing Carbon Emissions

**P**ower sector reform and continued commitments to improving air quality are emphasized in the energy and environmental components of China's 13th Five Year Plan. China's Intended Nationally Determined Contributions (INDC) also commit to reducing the intensity of CO<sub>2</sub> emissions 60 to 65 percent by 2030, which equates to peak GHG emissions no later than that year. Moving toward a market-based system for the power sector while at the same time continuing to improve environmental conditions will require inter- and intra-agency cooperation. Lessons learned from Europe and the United States on best practices and cautionary notes are also instructive for China. This section considers the major components for power sector reform and improved air quality.

### 5.1. Adopt and Implement Permit/License System to Address Existing and New Power Plants

**Description:** Consistent treatment of new and existing thermal power plants would help to improve air quality and help to ensure that the cleanest, most efficient power plants operate. Continuing to permit new plants in air basins that exceed public health standards constrains the ability of local and regional agencies to improve air quality. A hybrid program, which uses a U.S.-style New Source Review for new or modified sources and an EU-style program to require existing sources to meet BATs by a certain date or close

down, would help to improve air quality and more effectively use the thermal power plant fleet.

**Agencies Responsible:** The MEP, to establish the system to address new and existing thermal plants; local and regional EPBs/EPDs, to implement and enforce the emissions requirements; and MEP, to provide oversight, training, and guidance.

**Challenges and Barriers:** This effort would have to be well coordinated with local officials. Today, local officials may continue to approve new thermal plants for economic development purposes, even if there is adequate capacity in that region. Existing thermal plants in the same region operate less, which presents operational challenges to boilers and emissions control equipment.

**Recommended Actions:** In conjunction with development of MEP's permit program, adopt and implement a permit system in which BATs are applied to new and existing thermal plants. In this instance, BAT means both technologies, such as end-of-pipe controls, and processes that focus on the entire electricity system, such as end-use energy efficiency, renewable energy generation, and combined heat and power. The effectiveness of this recommendation will be enhanced if it is jointly implemented with the next recommendation below: addressing and eliminating the generation quota system. China can follow examples from Europe,<sup>43</sup> the EPA MACT standards for boilers,<sup>44</sup> and California's requirements for large combustion sources, petrochemical facilities, and cement plants.<sup>45</sup> Permits issued to industrial facilities

43 European Commission. (2010). *Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control)*. Retrieved from <http://ec.europa.eu/environment/industry/stationary/ied/legislation.htm>, and European Commission. (2012). *Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency*. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX:32012L0027>

44 United States Environmental Protection Agency. (2011). *Industrial, Commercial and Institutional Area Source Boilers: National Emission Standards for Hazardous Air Pollutants (NESHAP)*. Retrieved from <https://www.epa.gov/stationary-sources-air-pollution/industrial-commercial-and-institutional-area-source-boilers>

45 California Air Resources Board. (2010). *Regulation for Energy Efficiency and Co-Benefits Assessment of Large Industrial Facilities*. Retrieved from <https://www.arb.ca.gov/regact/2010/energyeff10/energyfro.pdf>

and power plants should require large industrial sources and power plants to implement energy management systems to improve and reduce energy consumption both on- and off-site.

**Metrics to Measure Progress:** Emissions should decrease in the cities and regions where this recommendation is implemented. These decreases should be reflected in annual and periodic emissions inventories, changes in ambient air quality monitors at those locations closest to a plant that closes or installs “BAT” controls or processes, thus contributing to changes in the daily and annual air quality indices.

## 5.2. Eliminate the Generation Quota System and Move to a Cost- or Market-Based System of Electricity Production

**Description:** The generation quota system described earlier in Section 2 is scheduled to be phased out by 2020. In its place is intended to be a market-based system that allows customers to select their electricity provider. This change will occur first with large industrial electricity users, who will be allowed to sign bilateral contracts (akin to power purchase agreements).

**Agencies Responsible:** NEA, NDRC

**Challenges and Barriers:** Phasing out the quota system has the potential to more fully utilize existing generation. A lack of specificity on bilateral contract terms and conditions could lead to increased use of older, inefficient thermal plants, while newer, efficient thermal plants and renewable generation is curtailed. Energy balancing areas that are narrowly restricted to that of provincial boundaries distort markets through closing off access by participants to lower cost, more efficient, or cleaner units and leads to construction of more power plants than are necessary. As is the case today, these conditions will lead to higher emissions, greater costs, and restriction of customer choice, and may not be an improvement over the current generation quota system.

**Recommended Actions:**

- Changing from generation quotas to bilateral contracts should produce a net air quality benefit. Engage and sustain interdepartmental cooperation and coordination to make sure that the target of net air quality benefit is achieved.

- Replacing the generation quota system with bilateral contracts can reduce air pollution and manage customer costs through: including environmental attributes as a condition to be eligible for a bilateral contract. Evolve China’s “上大压小” (Shang Da Ya Xiao) to national environmental performance standards<sup>46</sup> for (NO<sub>x</sub>, SO<sub>2</sub>, and CO<sub>2</sub>) to accelerate the phase-out of inefficient thermal plants and help to reduce curtailment of renewable generation. The MEP, the Chinese Academy of Environmental Planning (CAEP), and the Chinese Research Academy of Environmental Science (CRAES) can evaluate the range of an emissions performance standard (EPS), then establish a national-level EPS with a 10-year trajectory. Grid companies can augment current practice, where CEMS data are transmitted to them, and develop a tracking system for environmental attributes (following the RGGI example, where system operators in the RGGI states track attributes; this data is also useful to assess renewable generation).
- MEP and local EPBs can provide emissions data from each power plant. NEA/NDRC (whoever is responsible for overseeing and managing the transition from generation quotas to bilateral contracts) should conduct energy systems modeling that assesses how a transition to a market-based electricity system can be part of the overall program to meet air quality and GHG reduction goals.
- Conduct energy planning that includes generation resources from surrounding provinces. Per the Nord Pool example, planners should evaluate the mix of resources available across several provinces to assess how to best meet reliability requirements, minimize costs, and promote environmental improvement. The planning horizon considered should include that of Five Year Plans, but also extend to 10 to 15 years to assess long-term resource needs, and to sustain progress to reduce air pollution.

46 James, C. (2017). *Emissions Performance Standard Could Improve Environmental Outcomes and Complement China's Energy Transition*. Regulatory Assistance Project. Retrieved from <http://www.raponline.org/blog/emissions-performance-standard-improve-environmental-outcomes-complement-chinas-electricity-market-transition/>

**Metrics to Measure Progress:** Curtailment rates of wind and solar (one-, five-, and ten-year averages), capacity factors of thermal plants constructed since 2010 (emphasis on ultra-supercritical), other.

## 5.3. Improve Air Quality to Meet Specific Ambient and Mass-Based Requirements

**Agencies Responsible:** MEP, CAEP, CRAES, local EPBs.

**Challenges and Barriers:** The revised and strengthened Air and Environmental Laws provide MEP with additional authorities to regulate pollution. MEP has also been tasked with developing a new permit system and a catalog of air pollutants for which to establish ambient and emissions standards. Several universities have been matched with local air quality agencies to model the efficacy of pollution control measures to meet the State Council's specific pollutant reduction targets, that is, 20 percent below 2012 levels in Shanghai by 2017, or ambient concentration levels, for example, annual average PM<sub>2.5</sub> for Beijing of 60 ug/m<sup>3</sup> by 2017. To date, local air quality plans and modeling have emphasized technologies to reduce emissions, e.g., SCR and FGD on power plants, and have not assessed the potential air quality and GHG benefits from clean energy generation or energy efficiency.

**Recommended Actions:**

- Air quality management must be synchronized with efforts to reform the power sector. The Urumqi air quality pilot<sup>47</sup> analyzed a suite of control measures that would reduce NO<sub>x</sub> emissions, using a cost curve that ranked each measure in terms of the RMB per ton of removal and the actual mass of pollution that would be reduced. RAP evaluated the investment costs, verified energy saving results, and SO<sub>2</sub> and NO<sub>x</sub> emissions abatement from 84 projects completed during 2008–2014 in some of the top 10,000 energy consuming enterprises in China (see FN 28). The results of this assessment can be extrapolated to identify cost-effective efficiency measures that also

reduce emissions.

- Conduct a “top-down tons” analysis for each air shed. Each air shed has a particular carrying capacity, above which ambient air quality monitors will measure unhealthy levels of pollution. The top-down ton quantity for each air shed is the minimum amount of pollution that must be removed in order to reach China's air quality standards.<sup>48</sup> The potential contributions to improved air quality from full utilization of all non-emitting power sources (wind, solar, hydroelectric, and nuclear) can be determined using the tons reduced by these programs as inputs to ambient air quality models to assess their effects on local pollution concentrations. Air quality models are already used routinely by environmental agencies and the universities assigned to help them develop air quality management plans. Adding these clean energy variables as inputs to the models would be a minor task.
- Local DRCs should be consulted to determine the capacity of renewable resources and the amount planned for construction to improve the precision of the air quality models. The local DRCs and DSM centers should be consulted to assess the potential energy savings possible from continuation and expansion of the Top 10,000 Industries program.

**Metrics to Measure Progress:** Inclusion of specific renewable energy measures (in MW or tons of pollution avoided) and energy efficiency programs (MWh, tons avoided, percent of annual electricity consumption saved) in local and regional air quality plans. Increasing the contributions of renewable energy and energy efficiency over time (increased MW of renewable energy, increased percent electricity consumption saved from energy efficiency) as air quality control measures. Development of provincial-level emissions factors for generation (akin to marginal emissions analyses completed by regional transmission operators in the United States) to improve precision of air quality plans and models.

47 Mao, X., et al. (2013). Co-Control of Local Air Pollutants in the Chinese Iron and Steel Industry. *Environmental Science and Technology*. 47 (21), pp 12002–12010. Retrieved from: <http://pubs.acs.org/doi/abs/10.1021/es4021316?journalCode=esthag>

48 The Regulatory Assistance Project's E-Merge process provides a complete step-by-step description of top-down tons and how to conduct such analyses. See: Colburn, K. & James, C. (2017). *E-Merge: Re-Tooling Regulation for Clean Air and Clean Energy* (webinar). Regulatory Assistance Project. Retrieved from <http://www.raponline.org/event/retooling-regulation-for-clean-air-and-clean-energy-webinar/>

## 5.4. Energy Resource Planning

**Agencies Responsible:** NDRC, NEA, and the Energy Research Institute (ERI); MEP and local EPBs should be involved in future energy planning

**Challenges and Barriers:** Solid policies and regulations like priority dispatch and energy efficient power plants have not been evenly implemented; commitment to do so has waxed and waned, or has occurred in specific provinces but without national oversight and steering. A priority dispatch policy has existed for nearly a decade, but compliance is uneven or non-existent (i.e., high curtailment rates of wind and solar, which should be dispatched first according to the policy). The terms “green dispatch” and “clean energy measures” (which appear in the revised Air Law) need to be defined, and then guidance needs to be developed to show responsible agencies how to implement and enforce them.

The existing obligation on grid companies to achieve energy savings equal to 0.3 percent of annual consumption is modest. Seventeen U.S. states today achieve energy savings rates of 1 percent or higher.

**Recommended Actions:** Today, the different elements of power sector policy are disparate. This can be resolved through coordinated energy planning, like that which has been conducted for decades in the European Union and the United States. NDRC is the obvious choice to be designated as the lead responsible agency to reform energy planning. It has a large staff and significant presence in all provinces. The ERI office within NDRC should be tasked with working with MEP, local EPBs, and grid operators toward a systematic approach to energy planning. The basic steps are:

- Develop resource adequacy plans with a time horizon of 10 to 15 years. Such plans could be at national, regional, and local levels of granularity. Evaluation of the influence of energy balancing areas greater than that of individual provinces is an essential component of such planning, as is evaluation of transmission upgrades and expansion to ensure greater access to

China's clean energy resources by population centers in the south and east.

- Conduct energy system and air quality modeling that includes current and anticipated air quality regulations and standards in order to optimize the mix of energy resources needed to meet future energy needs and to harmonize with air quality requirements.
- Complete energy savings potential studies to inform efforts to increase the annual energy savings obligations to 1 percent over 5 years, and to 1.5 to 2 percent over 10 years. This “ramp rate” is conservative. EPA's Clean Power Plan used a ramp rate of 0.3 to 0.4 percent per year, to increase energy savings obligations over time to 1.5 percent of annual electricity sales. U.S. state energy efficiency programs have also demonstrated the experience that a 0.3-percent ramp rate per year is readily achievable. EPA's AVERT program or the Blumont “JuiceBox” power plant emissions and electricity model could both be adapted to reflect Chinese characteristics. Initially, both programs could be populated with default national or regional emissions and electricity data, then revised as more granular data becomes available over time. Calculate the NO<sub>x</sub>, SO<sub>2</sub>, and CO<sub>2</sub> emissions that will be reduced through the expanded energy savings programs and use these data in air quality models (per “top-down tons” above) to help MEP and local EPBs' air quality management planning.

**Metrics to Measure Progress:** NDRC, NEA, and ERI develop a template for energy resource planning. The template is applied as a pilot in a region (Jing-Jin-Ji, for example), then expanded to other regions. Resource plans that evaluate larger energy balancing areas (beyond that of a specific provincial boundary). Increased energy savings requirements for grid companies, ramping up over a period of 5 to 10 years to achieve full economic savings potential.

49 United States Environmental Protection Agency. Avoided Emissions and generation Tool (AVERT). Retrieved from [https://19january2017snapshot.epa.gov/statelocalclimate/avoided-emissions-and-generation-tool-avert\\_.html](https://19january2017snapshot.epa.gov/statelocalclimate/avoided-emissions-and-generation-tool-avert_.html)

50 “Juice Box” is an energy systems model developed by Dr. Paul Meier at Blumont Engineering. A demonstration simulation of the model was made to Tianjin. Retrieved from <https://blumont.org/innovation/blumont-director-engineering-clean-energy/>. Full documentation for Juice Box is retrieved from <https://docs.google.com/document/d/1EXq6n959cC2ZF1K75KTpdUZFYLUXM5xMaW4uLaR8S10/edit>

## 6. Conclusions

**T**he scope and pace of economic development in China are in parallel with rapid advancement in scientific knowledge and technical capabilities. While GDP in Europe and the United States grew at 7 to 10 percent after World War II, these economies grew during a period in which scientific knowledge about the negative effects of economic growth was more limited,<sup>51</sup> and the tools available to access methods and policies to mitigate these effects were absent or rudimentary.

China's strong GDP growth has caused significant, persistent, and hazardous levels of pollution throughout much of the country. At the same time, we now know about the cumulative health effects of these pollutants, and have a range of models and policies, along with massive computing power, that can readily assess the efficacy of policies to reduce pollution and the costs of doing so.

As China moves to reform its power sector to transition to a market-based system for electricity transmission and sales, lessons from Europe and the United States demonstrate that this transition can occur while also producing the co-benefits of improved air quality and reduced GHG emissions. An essential step is that planners from economic and environmental disciplines establish and then sustain regular communications, and that they coordinate on their respective planning processes to take advantage of co-benefits and to avoid unintended consequences. These additional steps will further help to ensure that air quality plans work to help improve China's energy structure, and vice versa:

- Engage technical staff in agencies, research institutions, and universities to conduct analyses of energy and environmental policies, their affects on air quality and energy structure, and their costs and benefits.
- Identify leading provincial or municipal-level agencies, such as Guangdong in the energy area, or Beijing or Shanghai for air quality, to evaluate how success on a local level can be replicated and expanded to more and larger geographic areas.
- Publish clear guidance defining how to include clean energy measures in air quality plans, how to assess the environmental benefits of energy efficiency and renewable energy programs, and so forth. This will help staff at energy and environmental agencies consistently implement laws and directives.
- Develop a process to review the efficacy of environmental and energy plans, and to make “mid-course” corrections when needed. This step can be accomplished through the periodic meetings and coordination of various plans, identified earlier as an essential first step.
- Recognize that transitioning to a market-based power system and achieving blue skies will require more than five years. Build in systems to accommodate long-term planning and the ability to adjust plans and direction over time, when needed, in order to successfully achieve the desired objectives.

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<sup>51</sup> In Los Angeles in the 1940s, air pollution was initially thought to be mostly originating from oil refineries. Dr. Arie Jan Haagen-Smit built a “smog chamber” to prove that automobile tailpipe emissions were the dominant cause.







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