Energy Policy 37 (2009) 1809–1824

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Greener plants, grayer skies? A report from the front lines of China's energy sector ☆

Edward S. Steinfeld [a,*], Richard K. Lester [b], Edward A. Cunningham [c]

[a] Department of Political Science, MIT E53-455, 30 Wadsworth Street, Cambridge, MA 02139, USA
[b] MIT Industrial Performance Center, E38-104, 292 Main Street, Cambridge, MA 02139, USA
[c] MIT Industrial Performance Center, E-38, 292 Main Street, Cambridge, MA 02139, USA

ARTICLE INFO

Article history:
Received 1 October 2008
Accepted 8 December 2008
Available online 27 February 2009

Keywords:
Electric power
Environment
China

ABSTRACT

This article presents findings from the MIT China Energy Group's first-of-its-kind, independent nationwide survey of Chinese coal-fired power plants. It is well understood that developments in China's energy sector now have global environmental implications. It is also well understood that this sector has in recent years experienced rapidly rising fuel costs. The MIT survey, by delving into technology choice, pricing, fuel sourcing, and environmental cleanup at the firm level, provides insights into how the Chinese power sector as a whole responds, and what the environmental implications are. The findings suggest rapid uptake of advanced combustion technologies across the system, largely in response to rising fuel costs. Environmental cleanup systems, particularly for sulfur dioxide, have also spread rapidly, in large part due to regulatory enforcement. Yet, operationally, plants pollute substantially. Price hikes encourage them to source low-grade fuel and idle cleanup systems. On the whole, the Chinese system infrastructurally has a proven capacity for rapid technological upgrading in the face of new market and regulatory pressures. Operationally, however, in part due to exposure to market forces, and in part due to limited state capacity for monitoring operations, even the most advanced power plants remain major polluters.

1. Introduction

To a significant degree, our planet's energy and environmental future is today being written in China. Consequential energy decisions are now being made throughout this rapidly transforming nation. In no domain are these decisions more crucial and the linkages to the global environment more direct than in electric power. China's electric power sector is large, still growing rapidly, and fueled primarily by coal. In 2007, installed generating capacity stood at 713 thousand megawatts, or 713 gigawatts (GW), second only to the United States' roughly 1075 GW.[1] The sector has roughly doubled in size since 2000, and in 2006 alone, 102 GW of new generating capacity was added, an increment substantially larger than the United Kingdom's entire electric power system. Roughly 80% of Chinese electricity is generated through coal combustion, as compared to 50% in the United States, the world's second largest coal user.

This matters partly because the byproducts of coal combustion have major environmental consequences. Atmospheric emissions of sulfur oxides (SO_x) and nitrogen oxides (NO_x) have long been recognized as the primary drivers of acid precipitation. Other harmful emissions include fine particulates, volatile organic compounds, and toxic trace metals like mercury and arsenic. And now, carbon dioxide, because of its link to global warming, has become the most prominent item on the pollutant list. Coal is the most abundant energy resource globally and the most carbon-intensive. Its combustion worldwide is the largest single driver of anthropogenic climate change. In 2005, coal accounted for 42% of global CO_2 emissions. In that year, coal combustion accounted for

☆ Edward Steinfeld and Richard Lester co-direct the MIT Industrial Performance Center's China Energy Group. Steinfeld is an associate professor of political science at MIT, and Lester is director of the Industrial Performance Center and professor of nuclear science and engineering at MIT. Edward Cunningham is a doctoral candidate in the MIT political science department.

The authors wish to thank Shell, the MIT Energy Initiative, and the MIT Sloan School of Management China Program for their generous financial support. Throughout this project, we have benefited greatly from discussions with other members of the MIT Industrial Performance Center's China Energy Group: Greg Distelhorst, Valerie Karplus, Jonas Nahm, Kyoung Shin, Lily Tong, and Hiram Samel. We are also grateful to Janos Beer for his detailed comments on an earlier version of this paper.

* Corresponding author.
E-mail address: edstein@mit.edu (E.S. Steinfeld).

[1] China figure from China Electricity Council, 2008; US figure from Energy Information Agency (EIA), U.S. Department of Energy. Existing Capacity by Energy Source (http://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.html).

0301-4215/$ - see front matter
doi:10.1016/j.enpol.2008.12.018

82% of China's CO_2 emissions, and 36% of America's CO_2 emissions.[2]

Despite much current attention to alternative energy technologies such as wind and solar power, fuel cells, biomass, and nuclear power, the likelihood is that coal will remain the world's largest source of electricity for decades to come. Thus the most important questions for the earth's environmental future, at least over the coming decades, concern how coal will be utilized. Will it be used cleanly or destructively? Will it be used efficiently or inefficiently? And will its pollutant byproducts be dealt with effectively or effectively ignored? These questions matter wherever coal is being used, but they matter most where coal is being used most extensively, China. And within China, coal is being used most extensively in the power sector.

It must be noted that this paper does not directly address any efforts on China's part to deal specifically with CO_2 emissions. China—like other countries including the United States—has yet to embark on a serious effort here. What the paper does do, however, is to examine two sets of issues that will be of great importance should serious efforts at climate change mitigation ultimately move forward. The first pertains to the efficiency with which fossil fuel-based energy production is being carried out. The second concerns the overall responsiveness of the system to change and innovation. By examining how the Chinese system is responding today to a variety of new economic and environmental pressures—namely, rising fuel costs and growing concerns over air pollution—this paper aims to illuminate the system's ability to deal in the future with the even greater regulatory, economic, technological, and operational innovations that will be necessary to deal with carbon.

Many accounts of the China's power sector today take a pessimistic stance regarding the system's ability to innovate and change.[3] They tend to argue first that while China's energy infrastructure is expanding rapidly, it is being built with retrograde, antiquated, and inefficient technologies. Furthermore, these technologies are being deployed in small plants, which neither capture minimum scale economies nor are subject to effective regulatory supervision. They argue second that the main fuel for that infrastructure, domestically sourced coal, is heavily subsidized and of low quality. Because coal prices are controlled by the state, utility operators face few incentives to switch to cleaner alternative fuels or use technologies that burn coal more efficiently. Finally, they argue on a third front that China has neither the political will nor the governmental capacity to shift from the environmentally destructive, resource intensive path it is currently on.[4]

The aim of this paper is to subject these assumptions to empirical analysis using survey data collected by our team of researchers in the MIT Industrial Performance Center's China Energy Group during 2007 and early 2008. Our nationwide study of coal-fired power plants in China was conducted in partnership with a domestic Chinese research firm, Beijing-based Horizon. The survey—administered at the level of the plant and covering multiple areas of power plant infrastructure, investment, operations, and environmental cleanup—encompassed 85 power plants, many of which had multiple generating units. Two-hundred ninety-nine separate generating units were surveyed in total. Senior specialists within each plant—plant managers, chief engineers, senior environmental officers, and chief financial officers—were called upon, via telephone or face-to-face interview, to answer portions of the survey corresponding to their respective areas of professional responsibility. To the best of our knowledge, this survey—in terms of its nationwide scope, its focus on plant-level phenomena, and its independent, non-governmental status—represents a first-of-its-kind effort in China.

As will be discussed in the main body of the paper, the survey results uncovered a reality far more complicated than anything suggested by the conventional wisdom. An important conclusion on the environmental front is that while Chinese coal-fired power plants are performing poorly today, they are investing in the sorts of physical infrastructure necessary for better performance in the future. There is also evidence that governmental regulatory efforts are showing hints of real efficacy, at least with respect to the enforcement of technological standards. The real question is whether societal pressure and political determination—governance, in effect—will tilt the balance, transforming the potential for better environmental performance into actual reality.

2. Description of the survey and sampling technique

MIT's 2007 China Power Survey covered 85 power plants across 14 Chinese provinces. The geographic distribution of the respondents is illustrated in Chart 1 and Table 1.

These plants encompass 299 separate generating units, the vast majority of which are coal-fired. The exceptions are 9 small units that burn oil, one that burns coke oven gas, and 13 that burn coal gangue, a solid waste product from the processing of coal. These ended up in the survey because they happen to be ancillary units of some of the coal-burning utilities that responded. Similarly, the survey also captured 7 units that are either planned or currently under construction, and 35 units that have already been shut down. Among the closed units are two oil-burning facilities.

The plants surveyed comprise a total combined generating capacity of 32.68 GW, though 2.2 GW of that total pertains to units no longer in operation, and 2.7 GW pertains to plants not yet completed. Power plants within China are categorized as "large sized" if total capacity equals exceeds 300 MW, "medium-sized" if capacity is below 300 MW but above 50 MW, and "small-sized" if capacity is below 50 MW. Of the 85 power plants in the survey, 24, or 28.2% of the total, are large scale, 18 (21.2% of the total) are medium scale, and 43 (50.6% of the total) are small scale. Not surprisingly given the relatively recent expansion of China's energy sector, for over three-quarters of the plants surveyed, their first unit came on line after 1980.

The MIT survey captured a significant fraction of the "known universe" of coal-fired power plants in China, at least in terms of what Chinese governmental figures officially recognize. Industrial boilers or other "within the fence" forms of power generation by major industrial energy users are included neither in the MIT survey nor in official state statistics on the electric power sector.[5]

[2] Energy Information Agency, World Carbon Dioxide Emissions from the Consumption of Coal, 1980–2006 (http://www.eia.doe.gov/pub/international/iealf/tableh4co2.xls); Energy Information Agency, World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980–2005 (http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls).

[3] Berra, N., Lamech, R., Zhao, J., 2001. Fostering Competition in China's Power Markets. World Bank Discussion Paper No. 416. Zhang Chi. 2003. Reform of Chinese Electric Power Market: Economics and Institutions. Stanford PESD Paper. Xu, S., Chen, W., 2006. The reform of electricity power sector in the PRC. *Energy Policy* 23, 2455–2465.

[4] World Bank, The Cost of Pollution in China: Economic Estimates of Physical Damages, Conference Edition Report, February 2007.

[5] Results of earlier MIT studies on the efficiency, emissions and health effects of small industrial boilers in China are discussed in: Fang, J., Zeng, T., Shen, L.I., Yang, Oye, K.A., Sarofim, A.F., Beér, J.M., Coal utilization in industrial boilers in China—a prospect for mitigating CO_2 emissions. Applied Energy, 63(1), 35–52, 1999, and Fang, J., Li, G., Aunan, K., Vennemo, H., Seip, H.M., Oye, K.A., Beér, J.M., 2002. A proposed industrial efficiency program in Shangxi:potential CO_2-mitigation, health benefits and associated costs. Applied Energy 71, 275–285.