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APRIL 2020

Electrification and Power Sector Reform: Coordinating Dual Challenges

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Overview

Electrification and power sector reform are closely related challenges for countries and regions around the globe. This policy brief emphasizes two points that are true for Europe, North America and China as well as other countries, although the details differ. First, the contribution of electrification to air quality improvements and greenhouse gas emissions reductions will depend on power sector reforms that change the evolution of the electricity generation mix. Rational design and implementation of electricity markets, improved power sector planning and well-enforced environmental regulations are needed to motivate the move away from fossil-fueled generation while minimizing costs. Second, controlling the cost of electrification and supporting the integration of renewable energy into the power system will depend on power sector reforms that unlock the flexibility of electrified end uses. China has emerged as a world leader in certain aspects of electrification — notably uptake of electrified transportation — and there is potential for China to become a world leader in terms of the power sector reforms needed to revamp the way that end users interact with the power grid.

Electrification and Decarbonization in Long-Term Scenarios

Studies of potential pathways for achieving both air quality goals and deep reductions in greenhouse gas emissions in China by midcentury all include major roles for building, industry and transportation electrification, as well as a major role for a transformed power sector.

[1] The review team for the paper included Frederick Weston and Ruth Hare. Helen He managed the translation and production of the Chinese language version of this paper, and Wang Xuan contributed to ensuring the accuracy of the translation.

Table 1 shows the results of several ambitious decarbonization scenarios, as well as 2014 data for comparison. The percentages in the table indicate the share of electricity in final energy consumption.[2] Although the scenarios vary significantly, they all envision a similar transition in which 1) the power sector decarbonizes, moving away from coal-fired generation, and 2) end uses are electrified.

Table 1. Share of electricity in energy consumption and electricity emission factors, by study

Study	Year	Total	Buildings	Industry	Transportation	Electricity emission factor (tons of CO_2 per MWh)
International Energy Agency (2016)	2014	20%	22%	27%	2%	0.77
International Energy Agency (2016) 450 Scenario	2040	31%	40%	39%	17%	0.08
Khanna et al. (2017) Maximum Electrification Scenario	2050	45%	Commercial: 83% Residential: 68%	40%	25%	N/A
Teng et al. (2015) Deep Decarbonization Scenario	2050	34%	47%	39%	7%-10%	0.07
China National Renewable Energy Centre (2018) Stated Policies Scenario	2050	48%	~53%	~53%	30%	N/A
China National Renewable Energy Centre (2018) Below 2 Degrees Scenario	2050	53%	N/A	N/A	N/A	N/A

Sources: International Energy Agency. (2016). *World Energy Outlook 2016*; Khanna, N., Fridley, D., Zhou, N., Karali, N., Zhang, J., and Feng, W. (2017). *China's Trajectories Beyond Efficiency: CO_2 Implications of Maximizing Electrification and Renewable Resources Through 2050*; Teng, F., Liu, Q., Chen, Y., Tian, C., Zheng, X., Gu, A., Yang, X., and Wang, X. (2015). *Pathways to Deep Decarbonization in China*; and China National Renewable Energy Centre. (2018). *China Renewable Energy Outlook 2018*

Getting this ambitious dual transition right will require coordination across a wide range of policies, including regulatory standards and mandates (such as emissions standards on equipment), tax incentives, research and development programs, emissions pricing (for example, the new national carbon trading regime) and power sector reform. Power sector reform is particularly important if electrification is to play its role in the ambitious scenarios in Table 1 — and in meeting air quality goals and decarbonization. A crucial aspect of power sector reform to support the scenarios in Table 1 is the need for policies, regulations and market reforms to 1) cost-effectively reduce the share of coal in the resource mix and 2) unlock flexibility of electric end uses.[3]

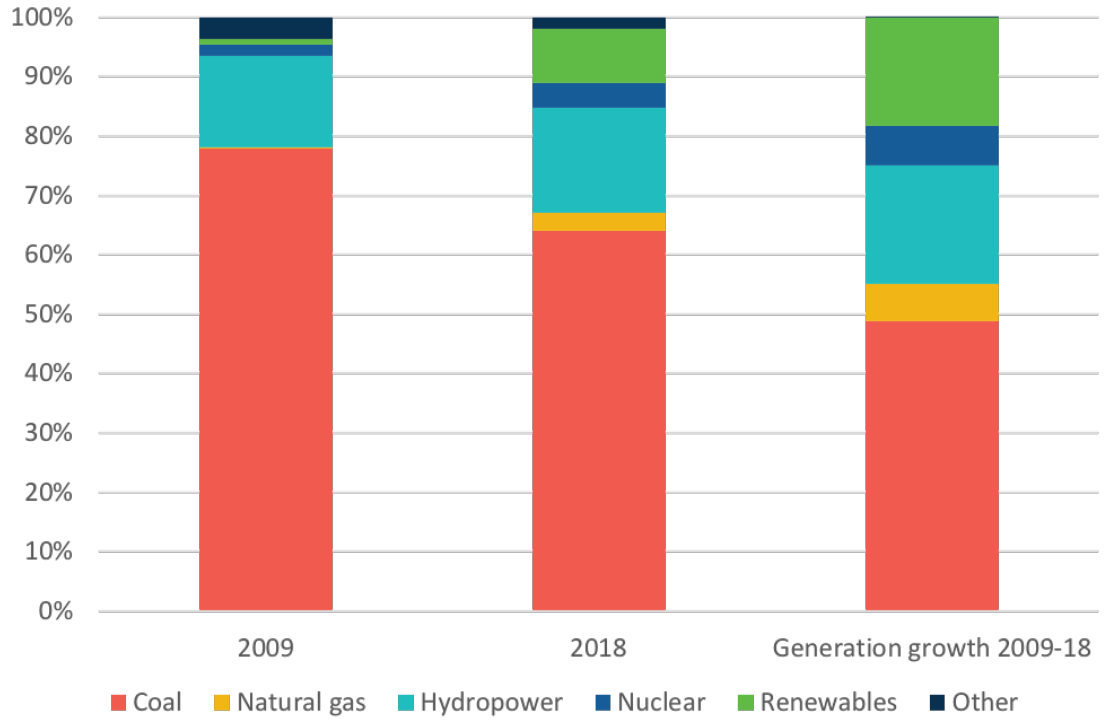
[2] These studies are not strictly comparable due to different definitions and assumptions. For instance, the International Energy Agency definition of final energy consumption includes primary biomass consumption, whereas it is unclear if the Teng et al. (2015) and Khanna et al. (2017) studies do.

[3] In work for audiences in the United States and Europe, RAP has described conditions that electrification must satisfy if it is to be considered beneficial — that is, in the public interest (Farnsworth et al., 2018). That work is closely related to our discussion of power sector reform here.

Policies for Rationalization of the Power Sector Resource Mix

The case for electrification as a tool to support air quality management and attainment of greenhouse gas reduction scenarios hinges on the further reduction of coal in the electricity generation mix. The share of coal in China's generation mix has already fallen significantly, from 78 percent of generation in 2009 to 64 percent in 2018, as illustrated in Figure 1 (China Electricity Council, 2013-2019). More than half the growth in generation between 2009 and 2018 was non-coal. However, there is reportedly significant new coal capacity under construction and ongoing debate about capacity targets for the next five-year plan (Shearer et al., 2020).

Figure 1. China's national electricity generation mix



Source: China Electricity Council. (2013-2019). *Table of Key Electricity Statistics*

How can China's policymakers ensure that the generation mix evolves in a way that is cost-effective, reliable and in line with air quality goals and the scenarios in Table 1? The answers lie in getting the policy design and implementation details "right" in the following areas of power sector reform.[4]

Power Sector Planning

Existing investment planning and decision-making processes are still oriented around coal generation and are not set up to facilitate least-cost investment across all possible resource options. Experts in China have the planning tools and expertise to plan for an electricity system

[4] For more detail, see Yue et al. (2019) and Dupuy et al. (2018).

that is increasingly less reliant on coal generation, but it does not appear their tools are being used in a comprehensive manner in investment planning and decision-making.[5] In addition, planning processes in China have not yet been aligned with the emerging wholesale spot markets. This is in contrast to the parts of the United States that have well-developed electricity markets. In these areas, power sector planning processes remain crucial for evaluating market outcomes, identifying needed market rule changes, and integrating market-driven decisions with aspects of the power sector that are less (or not fully) "marketized," such as transmission investment and energy efficiency investment. In exploring how investment planning and wholesale markets can be better integrated, resource planning processes in the United States could be a useful reference for China. One example is California's statewide integrated resource planning process, which is implemented in, and makes efficient use of, a well-developed wholesale market that is roughly analogous to the spot markets now being implemented in various provinces (California Public Utilities Commission, n.d.).

Electricity Markets

Electricity markets can be very helpful for rationalizing operational, investment and retirement decisions. China's nascent spot markets and other market mechanisms in various provinces have already begun to change the incentives driving these decisions, and coal generators have seen downward pressure on operating hours while wind and solar curtailment rates have declined. The challenge will be to focus on ensuring that these markets fully support the principle of economic dispatch, which has been stated in the provincial market policies, and on ensuring that the markets transmit rational price signals for generator investment and retirement decisions. The existing spot market pilots are promising but appear to have problematic design elements that may undermine efficient outcomes for operations and investment. These elements include restrictive price floors and ceilings, insufficient market monitoring, and potentially inefficient "medium- and long-term" contracting mechanisms, which feature contracts between generators on one side and end users or retailers on the other, typically lasting one month or one year (Dupuy, 2019).

Ensuring workable market rules is a complex undertaking. Market rules in analogous markets in the United States and Europe are still under debate even decades after the markets were first implemented. Should the spot market implementation efforts stumble or run into gridlock in China — or be implemented only in the current spot market pilot provinces — it would be worth having a practical alternative approach at the ready that would support the crucial objectives of better dispatch and better signals for investment and retirement. This might involve targeted administrative efforts to continue to improve dispatch, supported by reformed generator compensation (Dupuy, 2019). International experience can continue to be an important reference in the development of China's electricity markets. The experience from the United States and Europe should continue to be useful. There is also practical experience to be gleaned from countries like South Korea, India and Brazil that have implemented market models to suit their own institutional conditions.

[5] Elucidating and implementing the guidelines that the National Energy Administration issued in 2016 would set a more equal investment playing field and significantly reduce the risks of new coal investment. See National Energy Administration (2016) and Dupuy and Wang (2016).

Environmental Regulations and Emissions Pricing

China has among the most stringent emissions standards in the world for coal-fired power plants. Better monitoring and enforcement of these standards would reduce inaccurate reporting by coal generators and help meet air quality standards, which are based on measured concentrations rather than reported emissions (Karplus et al., 2018). Meanwhile, moving ahead with the national carbon trading scheme for the power sector in a way that puts a meaningful price on carbon emissions will further help rationalize incentives for generation investment and retirement.

These challenges are closely interrelated and ideally should be approached as part of an integrated power sector reform effort.

Implementing Policies, Pricing and Market Mechanisms to Unlock Flexibility

Many types of electrified end uses — including electric vehicle charging, water heating and even building cooling — are inherently flexible in their demand; that is, able to be shifted in their times of use to take advantage of lower, off-peak prices or alleviate high-demand strains on the system. For example, water can be heated and electric vehicles can be charged at times of the day when the grid is less stressed. This flexibility has significant implications for the costs of electrification and for overall costs in the power sector. If new electric vehicles, boilers, heat pumps and furnaces consume electricity during times when the electricity system is already stressed, electrification will trigger the need for costly new investments in distribution, generation and transmission infrastructure. However, if consumption occurs during times when there is spare capacity, electrification can improve utilization of the electricity system and help lower costs. To encourage low-cost electrification, regulators in the United States and Europe have recently begun efforts to create and improve incentives for flexibility in electrified transportation and building end uses (Farnsworth et al., 2018, and Hildermeier et al., 2019).

In China, unlocking the flexibility of electrification — and unlocking cost savings — will depend on electricity price designs, new market mechanisms and other policies that allow electricity consumption to react to conditions on the grid and that shape the timing of electricity consumption. Here again, the wholesale electricity spot markets under development in various provinces can play an important role, if well designed, by identifying and signaling times and places on the grid where costs are high or low. And, again, if spot market implementation efforts bog down, it should be feasible to design cost-based administrative mechanisms that are "good enough" (at least for the short term) in sending these signals and accompanying incentives (Dupuy et al., 2017, Section 1).

The need for flexibility of electricity consumption also highlights the importance of retail electricity price design. Policies to encourage electrification should be pursued in tandem with new price designs that seek to incentivize efficient use of the electricity system. These include time-of-use tariffs (which have a long history in certain industrial and commercial sectors in China but could usefully be expanded, including to residential consumers) and demand response programs that offer economic incentives to end users for flexible consumption.[6]

[6] For more discussion of demand response programs including international context and recommendations for China, see Dupuy et al., 2017, Section 3.

On an energy basis, electricity costs are on average much higher than the cost of oil products, natural gas or coal. However, the cost of producing electricity varies significantly over the course of a day. For new electric loads that have flexibility in when they consume power — electric vehicles, some industrial loads, some building heating equipment — time-of-use tariffs that align power consumption with the costs of supplying electricity can lower the cost of electricity to consumers and encourage electrification. Changes in retail tariff design are intertwined with the current power sector reform process.

Conclusion

Electrification and power sector reform are interdependent challenges, in China and around the world. Both will be central components of strategies to achieve deep reductions in greenhouse gas emissions by midcentury (Williams et al., 2014, Williams et al., 2015, and Eurelectric, 2018). In China, the urgency of addressing air quality challenges, limited natural gas supplies, and the strategic importance of electric technologies for national industrial policy suggest it may be advantageous to electrify even faster than the United States and Europe. Getting the benefits of electrification in terms of air quality improvements, carbon emissions reductions and cost savings will be dependent on ongoing power sector reform efforts, with a focus on rationalizing resource and operational decisions in the power sector and unlocking the flexibility of electrified end uses. Policy coordination and shared learning among China, the United States and Europe can help to drive the large-scale commercialization and adoption of these technologies.

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