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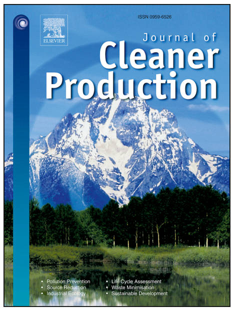

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Regulatory Incentives for a Low-carbon Electricity Sector in China

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Abstract

This paper reviews the incentives for pursuing a low-carbon electricity sector that are embedded in China's regulatory and policy framework. To do so, we first describe the industry structure and the regulatory framework. Second, we explicitly review the policies that were developed to promote energy efficiency and renewable energy. These policies range from the introduction of legal requirements to undertake particular actions to pricing mechanism and financial incentives. Based on this, we tease out the challenges faced by a sector governed by a myriad of complex arrangements, different institutions and agents who face different and often conflicting incentives for pursuing environmental and energy efficiency objectives. Finally, we provide suggestions to scientifically set up low-carbon policies and to achieve the expected goals with minimum social cost.

Keywords: Regulatory Incentives, Energy Efficiency, Renewable Energy, Electricity Sector, China

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1 Introduction

The high dependence on coal is a well-known feature of the Chinese electricity sector. Over 70% of China's electricity is generated from coal. To reduce such dependence, and to achieve its carbon emissions reduction goals, the Chinese government has pursued a number of policies to promote energy efficiency and renewable energy.

The breadth and diversity of these policies is impressive. They range from national initiatives (e.g., legislation establishing standards, a pricing mechanism, financial incentives and emission trading schemes) to pilot programs targeting particular geographical areas (e.g., energy saving power dispatch and demand side management). The aim of this paper is to provide a comprehensive review of these policies with a focus on identifying the incentives that they generate for the pursuit of energy efficiency or renewable energy opportunities.

While there has been substantial interest in the policies designed to promote renewable energy and energy efficiency in China, research has typically focused on specific policies. Cherni and Kentish (2007), for example, examine the renewable energy policies in the context of the electricity sector reforms in China. Drawing upon information collected from interviews with key stakeholders, Cherni and Kentish (2007) identify the barriers to renewable energy development including the high cost of renewable energy, limited connection to grids, and institutional obstacles (e.g., a weak regulatory framework). In contrast, Li et al. (2011) focus on energy conservation. These authors identify a number of challenges that need to be overcome to bring China to the same level of developed countries in terms of policy outcomes. These include the lack of local government support for energy conservation, inappropriate electricity pricing mechanisms, a lack of focus on the assessment of policy outcomes, and an underdeveloped legal system.

In contrast, Zhang (2015) develops a conceptual framework to examine how well the Chinese electricity regulatory framework relates to environmental goals. Our paper is complementary in nature to Zhang (2015). In particular, our contribution is to provide a systematic review, through the lenses of the economic theory of regulation and incentives, of the existing regulatory and policy settings that govern renewable energy and energy efficiency in the Chinese electricity sector. Rather than an assessment of the performance of the various policies, our focus is on teasing out the incentives that are embedded in the complex Chinese electricity market design and regulatory framework.

Given that we consider separate dimensions of the regulatory and policy settings that govern the pursuit of a lower carbon footprint in the Chinese electricity sector, we refer to relevant literature in the particular context we are analysing. In other words, instead of simply reviewing the literature, we provide an analysis of the incentives that are embedded in the current regulatory and policy settings which have a positive impact on carbon emissions mitigation. Doing so allows us to put forward a number of suggestions aimed at avoiding conflicting incentives and at striking a more effective balance between markets and direct regulatory interventions.

This paper is organized as follows. Section 2 presents an overview of China's electricity sector. Section 3 to Section 6 review the regulatory incentives for low-carbon development in China's electricity sector, including the overall legislative framework, Five-year Plans (FYP) on energy and command-and-control energy policies, pricing mechanism and pilot incentive measures. Section 7 provides our key conclusions.

2 The Electricity Sector in China

China's electricity sector has developed rapidly over the last two decades, surpassing the U.S. in electricity generation from 2011 to become the largest in the world. Total electricity generation in China achieved 6,417.9 Terawatt-hours (TWh) in 2017, an increase of over 100 per cent from 2007 levels, and 1.6 times the amount generated in the U.S. in the same year.[1] As of 2017, China's total installed capacity reached 1,777.03 GW, an increase of 7.6 per cent over the previous year, being the world largest.[2] This section provides a brief overview of the electricity sector in China with a focus on fuel mix, demand, industry structure, the regulatory framework and institutions, and energy efficiency levels.

2.1 Installed Capacity and Generation

Both electricity generation and installed capacity in China are characterized by a high dependence on thermal energy. Particularly, coal's share in the generation mix is even higher than its share in installed capacity. In spite of the intermittency attribute of renewable energy that makes the installed capacity of renewables never be fully utilized, the traditional dispatch order—with which coal plants serve both as base load and for peak loads adjustment—can partly explain this feature.

To reduce this high dependence on coal for electricity generation, and the associated consequences in terms of emissions, China has adopted a trial dispatch approach (the Energy Saving Power Dispatch or ESPD), which will be discussed in more details in Section 6.1. A rapid expansion of renewable energy has also occurred, making China become the largest renewable electricity generator in the world.

The combination of high dependence on coal and the rapid expansion in renewables has important implications for the development of China's energy strategy. To put it briefly, the high dependence on coal implies that energy efficiency initiatives may yield a high return by reducing total overall consumption. The high rate of expansion of renewables requires revisiting dispatching rules (and associated prices), and the development of regulatory arrangements in distribution and transmission to ensure a timely connection to grid and to promote efficient investment.

Another issue related to the installed capacity of Chinese electricity sector is the overcapacity and potential investment bubbles. With the advent of "new normal", the overall speed of electricity consumption growth has slowed down much, whereas the investment to coal power was not abated at a reasonable rate. As pointed out by Yuan et al. (2016), if all the coal power projects submitted for Environmental Impact Assessment (EIA) approval were put into operation in 2020, capacity excess would reach 200 GW. Consequently, a number of undesirable outcomes will be induced,

[1] US Energy Information Administration (`http://www.eia.gov/`).
[2] National Energy Administration (`http://www.nea.gov.cn/`).

such as enormous investment waste, poor economic performance of generators and delay of low-carbon energy transition.

2.2 Demand

Regarding China's electricity demand, the secondary industry accounts for more than 70 per cent of the total consumption, whereas residential consumption remains around 13 per cent. This contrasts, for example, with a 35 per cent share of residential consumption in the U.S. over the last decade.[3]

The growth rate of electricity consumption in China averaged around 12 per cent in the last decade, a rate much higher than in other countries (IEA, 2014). As economic growth slows down, and as the services sector outweighs the manufacturing sector, the overall growth in electricity consumption will decelerate but the share of the residential and services sectors in the total demand will increase. Moreover, the increased adoption of electrical appliances, along with increases in income, implies that household consumption will not only represent a larger share of total consumption but also will continue to grow rapidly over the next decades.

The extent of the potential for growth in electricity consumption by households becomes obvious once we compare per capita consumption with other countries. For example, currently, China's per capita consumption of electricity falls between developed countries and other large developing countries such as India and Egypt. However, the residential electricity consumption per capita is lower than developing countries such as Brazil and Egypt (Hu, 2013), and the disparity with developed countries is even larger being around one-tenth of that in the U.S., one-sixth of that in Australia, one-fifth of that in Japan and France, and one-third of that in Korea, in 2012.[4] If the residential per capita consumption in China catches up to that of Korea in 2012, this would add 1,103.95 TWh of demand to the system, necessitating an increase of over 10 per cent in installed capacity.

The increase, both in absolute and relative terms, in the residential consumption has implications for energy policy as these consumers are likely to be more responsive to changes in prices than manufacturers.[5] This suggests that the benefits associated with demand side management initiatives, where consumers are incentivized to either conserve energy or to smooth their consumption to reduce peak demand, are likely to increase, as the share of residential users of total consumption increases.

[3]Calculated on the basis of statistics from the OECD library.

[4]This comparison is based on the data from OECD, World Bank and China Bureau of Statistics, with residential electricity consumption of OECD countries from `http://stats.oecd.org/BrandedView.aspx?oecd_bv_id=elect-data-en&doi=data-00462-en`, and the data of population from `http://data.worldbank.org/indicator/SP.POP.TOTL`.

[5]For instance, based on the computable general equilibrium model, He et al. (2011) calculates the price elasticity of residential electricity consumers in China as -0.3, contrasted with that of industry and commerce which is around -0.018.

2.3 Industry Structure

Historically the electricity sector in China was characterized by the existence of a single vertically integrated utility operated by the central government. In 2002, the monopoly utility was broken into 11 independent state-owned companies, including five generation companies (i.e., the 'Big Five'), two grid companies and four auxiliary service companies.[6]

One feature of China's electricity sector is the dominance of state-owned companies. For instance, the 'Big Five' generation companies controlled by the central government own about half of the nation's installed capacity. Other generators administered by the central government and large generators administered by local governments represent around 20 per cent of the total capacity. The largest state-owned grid corporation, the State Grid Corporation of China, owns transmission grids in 26 provinces, while the Southern Power Grid only operates in five provinces in the South.[7] These two grid companies control more than 90 per cent of the national transmission capacity (IEA, 2006). The prevalence of government ownership in the sector is associated with low operating efficiency and productivity (Geng et al., 2009).

Under the current system, grid companies control both transmission and distribution (T&D).[8] They also sell electricity directly to final consumers and dispatch electricity according to wholesale contracts and dispatch protocols signed annually between grid companies and generators. The contracts allocate the number of operating hours to generators.[9] A dispatch protocol stipulates how the dispatch is arranged to reconcile the contracted amount, taking into account the demand and supply of electricity, the availability of generators, and other conditions at the time of dispatch.[10]

2.4 Regulatory Institutions

The Chinese electricity sector is governed by a complex web of institutions, at different government layers, and at times, with overlapping responsibilities. At the central government level, key institutions include the State Council, the National Development and Reform Commission

[6]The 'Big Five' refers to Huaneng Group, Datang Group, Huadian Corporation, Guodian Corparation, and Power Investment Corporation. The two grid companies are the State Grid Corporation of China (SGCC) and China Southern Power Grid. The four auxiliary service companies include China Power Engineering Consulting Group, China Hydropower Engineering Consulting Group, China Water Resources and Hydro-power Construction Group, and China Gezhouba Group. The auxiliary service companies are responsible for the design, construction and maintenance of the electricity system.

[7]In total there are six multi-provincial regional grids across China. Five of them (i.e., Northeast, North China, Northwest, Central China and East China) are operated by the State Grid Corporation of China and one is owned by the Southern Power Grid. In addition, there are two provincial networks in Inner Mongolia and Tibet owned by local governments, not being part of any regional company. The western part of the grid in Inner Mongolia is managed by an independent company.

[8]Provincial/municipal grid companies operate the transmission and distribution within the boundary of each province. Regional grid companies control the development and operation of regional grids and regional electricity markets, as well as regional electricity dispatch. The State Grid Corporation of China is responsible for the interconnection and trading between regional grids, including the China Southern Power Grid.

[9]See the details of the Interim Measures for Promoting the Transparency, Fairness and Justness of Electricity Dispatch at `http://www.sgcc.com.cn/fgbz/dlfg/37302.shtml`.

[10]See `http://www.mianfeiwendang.com/doc/4ed2a10a4a0c6efc6195cdc6/5` for a sample dispatch protocol.

(NDRC), and the National Energy Administration (NEA). Other relevant institutions are the Ministry of Environmental Protection (MEP) and the State Owned Assets Supervision and Administration Commission (SASAC).

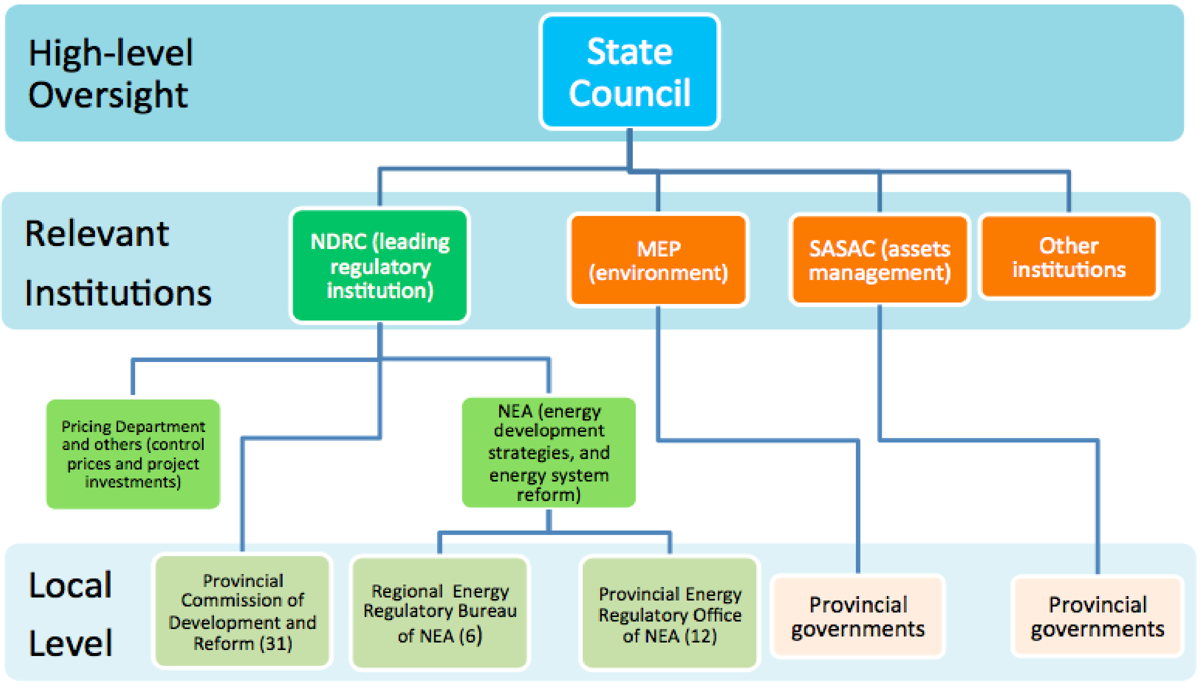

Figure 1: Regulatory Institutions of the Electricity Sector

The State Council, the top administrative authority for the Chinese economy, assigns responsibilities and tasks to central and provincial regulatory authorities. Although the State Council is not directly involved in the regulation of the electricity sector, it has the ultimate control over the decision-making on its development and operation.

NDRC is the leading regulatory institution that controls prices and investment in the electricity sector. NDRC reviews the costs of electricity corporations and controls prices through its Pricing Department. It also has the power to make decisions on the construction of large generation plants. The construction of small plants is controlled by the provincial-level counterpart of NDRC (i.e., the provincial Development and Reform Commission).[11]

NEA, a department under the jurisdiction of NDRC, drafts and implements energy development strategies, plans and policies, and advises on energy system reform, and regulates the sector. NEA was established in 2008 and was restructured in 2013 by incorporating the functions of SERC (State Electricity Regulatory Commission), which included designing and supervising generation markets and implementing reforms in the electricity sector.[12]

[11]Recent years have seen more authorizing rights of plant construction being granted to provincial Development and Reform Commission.

[12]SERC was setup as the independent electricity regulator. It was established in 2003 and dissolved in 2013. SERC led the reforms of the electricity sector, including breaking up monopolies, promoting market competition, and supervising policy implementation. However, its lack of power over setting electricity prices and determining whether firms could enter the market meant that SERC was not able to independently regulate the electricity sector. Recognising that the sector was not yet designed to allow for an independent regulator, the government dissolved SERC and integrated some of its functions into NEA.

MEP issues environmental policies and conducts environmental implementation and supervision. In the context of the electricity sector, MEP assesses the environmental impacts of projects and pollution from electricity production.[13] SASAC is a special commission directly under the State Council which supervises and manages the state-owned assets of the companies controlled by the Central Government. On behalf of the State Council, SASAC appoints the top executives and dispatches supervisory panels to the supervised companies.[14]

The relationship between the various regulatory and policy institutions is illustrated in Figure 1. A crucial feature is the existence of conflicting objectives across different national-level institutions but also between national and local institutions (Zhang, 2015). For example, the main goal of NDRC is to promote economic development, while MEP's objective is to protect the environment. Similarly, in most provinces, large-size power plants are state-owned while the small and medium ones are provincial-level companies. When an energy-saving mechanism such as the ESPD is implemented, large plants gain additional operating hours and thus can generate more energy and, consequently, more revenue. The generation shift from small and medium plants to large units induces a revenue shift from provincial companies to state-owned companies. Not surprisingly, local governments can attempt to reverse such a shift through administrative measures aimed at state-owned companies. In particular, the absence of mechanisms to compensate the small and medium companies means that initiatives such as the ESPD may lead to operating losses and stranded assets (Fredrich et al., 2013) and loss of revenue by local governments.

2.5 Energy Efficiency

Energy efficiency is defined as the physical service provided per unit of energy. Energy efficiency is also often referred to as '*using less energy to provide the same service'*. These two definitions illustrate that the concept and measurement of energy efficiency varies with the context.

In the case of white goods and electronic goods, the most energy-efficient is the one that uses the least energy. In the context of power plants, energy efficiency is commonly measured by the heat rate: the amount of energy used by a power plant to generate one kilowatt-hour (kwh) of electricity. In the transmission and distribution of electricity, energy efficiency is measured by line loss: the disparity between the amount of electricity generated by power plants and the amount that is available for final consumption.

Improvements in energy efficiency are seen by Chinese policy makers as a key component of meeting the increase in demand for electricity in a more sustainable way. As it is common in the development of public policy in China, there are a number of different programs promoting energy efficiency. From the consumers' side, a demand side management (DSM) program was in-

[13]Note that MEP will be dismantled and replaced by the Ministry of Ecological Environment according to the thirteenth National People's Congress held in March 2018. The new ministry will be responsible for the compiling and implementation of China's ecological environment policies, plans and standards, as well as ecological environment monitoring and law enforcement. See http://english.mep.gov.cn/News_service/media_news/201803/t20180314_432393.shtml.

[14]See http://en.sasac.gov.cn/n1408028/n1408521/index.html.

troduced in several cities.[15] In the electricity generation sector, as depicted in Figure 2 , the energy efficiency (i.e., heat rate) of thermal plants with over 6 MW in capacity has improved consistently since 2008. Energy efficiency exceeded 45 per cent for the first time in 2014, with 28 per cent of coal-fired power plants in 2014 applying super-critical and ultra-supercritical technology—which allows pulverized coal combustion systems to achieve higher efficiency than conventional units through operating at increasingly higher temperatures and pressures. China's coal-fired power plants are currently more efficient on average than U.S. coal plants.

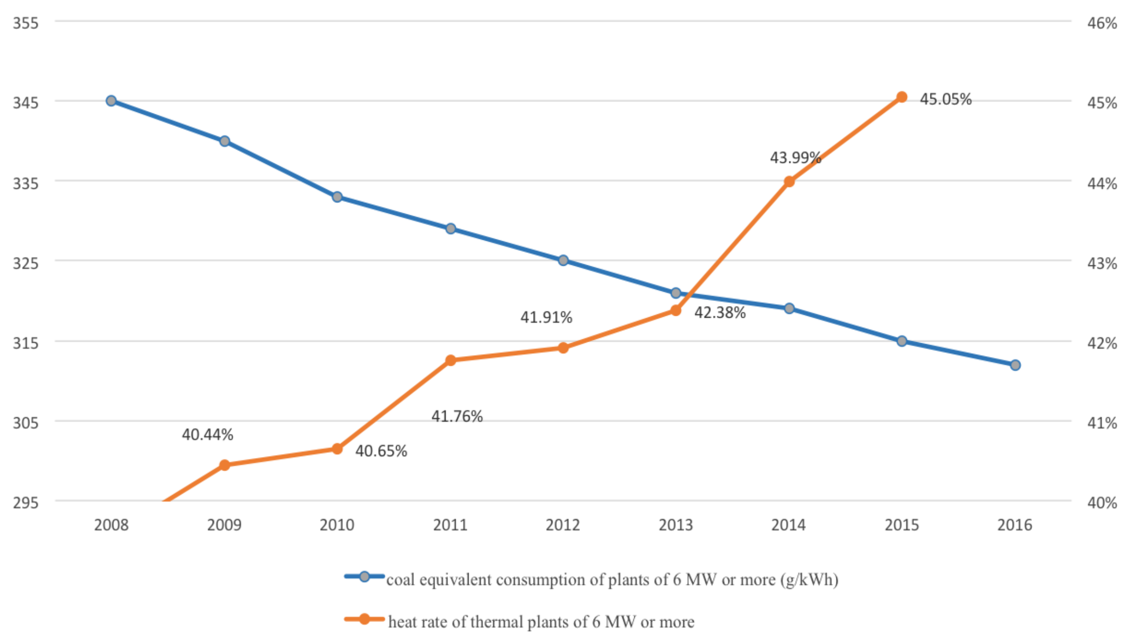

Figure 2: Energy Efficiency of Electricity Generation
Source: China Electricity Council

The improvement in energy efficiency of power plants has been achieved by a combination of different policies and programs. For example, the 'Large Substitutes Small' (LSS) program replaces small and inefficient power plants with large and efficient generators.[16] Along with the LSS program, there is a supplementary generation right trading scheme, under which the small and inefficient thermal-power generation plants are shut down and sell their generation rights to large and efficient generators or renewable generators. The total capacity of small thermal-power-generating units decommissioned from 2005 to 2014 is estimated to be over 95 GW.[17] The LSS program, however, is considered to have already achieved its maximum impact as it will be increasingly difficult to find small, inefficient plants to be replaced.

[15]This program will be described in more detail in subsequent Section 6.2.

[16]This program was launched in the 1990s; however, due to the electricity shortage and the resultant necessity to encourage investment in generation, it had never received adequate attention before 2007. Here small and inefficient generation units include those below 50 MW, those below 100 MW which have been operating for over 20 years, those below 200 MW which have been at the end of their design life, and those that fail to meet environmental standards, laws and regulations. See `http://www.gov.cn/zwgk/2007-01/26/content_509911.htm`.

[17]See China Electricity Council at `http://www.cec.org.cn/yaowenkuaidi/2015-03-10/134972.html`.

Currently, the policy of clean and high-efficient retrofitting in about 500GW existing fleet is important as the LSS reached its limit in terms of impact. In particular, according to the document "Full Implementation of Ultra-low Emission and Energy Saving Transformation of Coal-fired Power Plants" jointly issued by the MEP, NDRC and NEB in December 2015, ultra-low emission retrofitting of coal fired units should be completed by 2017, 2018 and 2020 respectively in the eastern, central and western regions. It required the newly established coal-powered generation plants to use over 600 MW ultra-supercritical (USC) units. Assuming that the heat rate of super-critical (SC) and 1000-MW USC units could reach their theoretical levels by 2020, which are 300 gce/kWh and 284 gce/kWh respectively, Yuan et al. (2017) estimated that the total potential of energy conservation of coal power could reach 15 Mtce and the CO_2 emissions abatement could reach more than 36 Mt.

Finally, energy efficiency in transmission and distribution has also been actively pursued in China, which now has similar levels to those of other geographically dispersed developed countries like Australia and the U.S., as seen in Figure 3. It is worth noting that each point reduction in network losses amounts to a gain of 54.64 TWh, which is nearly equivalent to the amount of the national consumption in some OECD countries such as Greece, Switzerland and Portugal.[18]

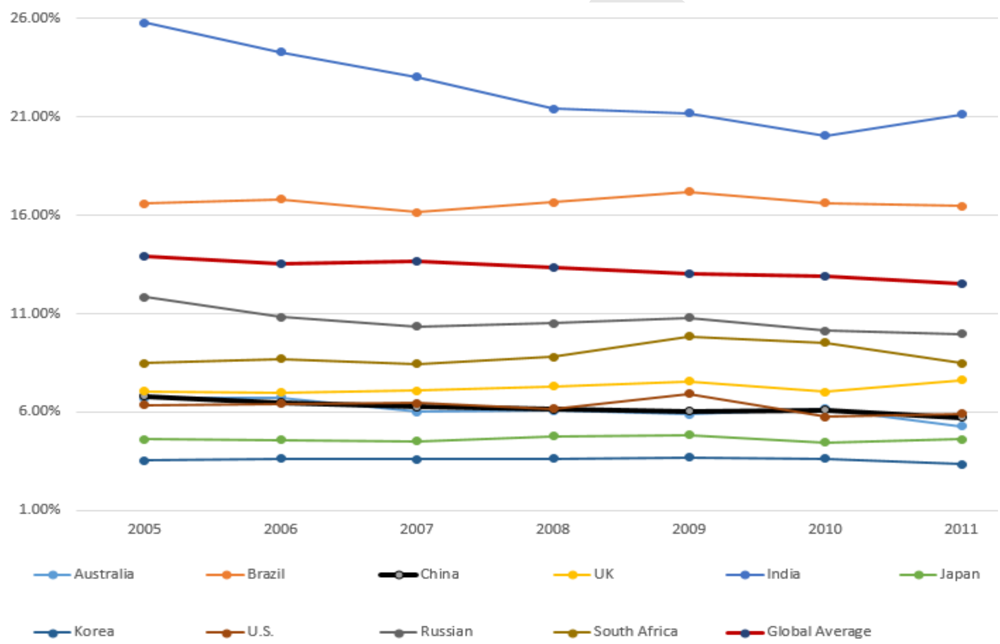

Figure 3: Rate of Line Losses

Source: World Bank. (Note that the global average is calculated based on the data of 165 countries.)

In summary, while energy efficiency has improved recently, it still holds the key for the pursuit of sustainable economic growth. In the following sections, we will review the regulatory arrangements that were designed to promote energy efficiency, including the legislative framework, command-and-control energy plans, pricing mechanisms, and related pilot incentive measures.

[18] See IEA (2014).

3 The Legislative Framework

The laws related to the promotion of electricity sector development, energy saving and emissions reduction include (1) the Electricity Law, (2) the Energy Conservation Law, (3) the Law on the Prevention and Control of Atmospheric Pollution, and (4) the Renewable Energy Law.

3.1 The Electricity Law

The Electricity Law was enacted in 1996 and amended in 2015 with the aim to promote the development of the electricity sector. It establishes the framework to set on-grid tariffs, retail prices, and trading prices between grids.[19]

Prices should reflect costs (including a return on and of capital and taxes) and contribute to the expansion of the electricity sector. The generation price is identical across electricity generated by the same technology and connected to the same grid.[20] Retail prices are also identical across the same category of consumers who have the same level of voltage in the same power network, with prices varying according to the different periods of time that the electricity is used.[21]

The dispatch of electricity by different grids is centralized and administrated at both central and local levels.[22] Interconnection of grids is encouraged and the agreements on grid interconnection should be reached on the basis of fairness and mutual benefits. The request of electricity generators to connect to the grid should be accepted by the grid companies.

As the first law governing the energy sector in China, the Electricity Law is an important milestone. However, the law has failed to keep up with the significant economic and technological changes that have occurred since its enactment. An obvious example is the failure of the law to address environmental concerns. While the Electricity Law states that electricity generation from renewable energy and clean energy should be encouraged and supported, it does not establish a regulatory framework to promote its development.

The Electricity Law has been amended as part of the 2015 reforms. However, more needs to be done. Importantly, the provision that 'only one electricity supplier is allowed in each area' has not been changed, which is a key barrier to competition. As with any reform process, vested interests, including those of the government institutions that regulate the sector, are pervasive in the sector.

3.2 The Energy Conservation Law

The Energy Conservation Law was adopted in 1997 and amended in 2007 to promote energy conservation and enhance energy efficiency. Under its amended version, energy conservation

[19]Note that the T&D prices of electricity are not included under the Electricity Law's pricing regime.

[20]Exceptions can be approved by the State Council.

[21]The criterion for classifying consumers and the method for dividing the period of time is also determined by the State Council.

[22]The dispatch of electricity in China is administered by institutions at five different levels: i) national, ii) multi-provincial regional, iii) provincial, iv) city, and v) county. The institutions at a lower level must follow the direction from the upper levels.

goals are included in the assessment of local governments and leading officials, and more sectors are required to reduce energy consumption with a target set by local governments.

This law prohibits the construction of new oil-burning or coal-burning thermal power plants that do not meet energy conservation standards. Instead, it encourages the development of biomass, solar power, wind power and small-scale hydro-power generation through various measures such as financial subsidies, tax concessions and preferential loans.

The law determines the adoption of peak load prices, seasonal prices and interruptible load prices to adjust loads. Differential prices are implemented across different companies in energy intensive industries based on their energy intensity. Grid companies are required to connect new power plants that comply with the provisions of the law.

Overall, the Energy Conservation Law plays an important role in promoting the development of renewable energy and clean energy by providing a legislative guarantee for grid connection of renewable energy and for the prioritized utilization of clean energy. However, its implementation is compromised by a regulatory system that is still under reform and a market mechanism needing improvement.

3.3 The Law on the Prevention and Control of Atmospheric Pollution

Originally formulated in 1977, then revised in 1995 and 2000, the Law on the Prevention and Control of Atmospheric Pollution was enacted in January 2016. The law requires all firms (including electricity generators) to obtain a license for their emission of air pollutants and the total emission of air pollutants must be controlled.[23] Moreover, the list of air pollutants is expanded from sulphur dioxide and nitrous oxide to include greenhouse gases, volatile organic compounds and other matters. The penalties imposed on firms that discharge more than the allowable amount have also been strengthened compared with the previous version.[24]

3.4 The Renewable Energy Law

Being formulated in 2005 and amended in 2009, this law establishes key mechanisms to develop renewable energy. Under this Law, the central government sets out a national plan for the development and utilization of renewable energy resources. Given this national plan, the provincial-level departments determine the plans for their respective regions.

The 2009 amendment requires grid companies to purchase a fraction of their total demand from renewable energy producers. Grid companies are also required to expand the grid to meet demand, to develop a smart grid and to pursue energy storage opportunities. Any difference in the purchase cost of renewable and conventional electricity will be recovered by additional charges levied on national electricity sales. The additional costs for the grid connection of renewable electricity are included in the transmission cost and passed through to electricity sales prices.

[23]This makes the current version of this law different from the former version—which only requires firms in the acid rain control areas and the sulphur dioxide pollution control areas to do so.

[24]The financial penalty according to the former version is not less than 10,000 CNY but not more than 100,000 CNY.

This law also provides guidance on price setting. Prices should vary according to the types of renewable energy (e.g., wind versus solar) and the conditions (e.g., availability of renewable energy sources) in different areas, and should be set to promote the efficient provision of and investment in renewable energy.

Despite the legal requirements, grid companies find it difficult to connect renewable generators to the grid. One reason is that existing grids are not flexible and smart enough. The geographic mismatch between areas where demand is large and areas where renewable resources are available aggravates this problem. The law itself may also contribute to this problem as it does not explicitly specify the process governing grid connection or the compensation to be paid to the renewable generators for failure to connect to the grid (Hong et al., 2013). The lack of financial incentives for grid companies is another factor. While in principle grid companies can recover connection costs from consumers, the additional charges are not sufficient to allow the companies to recover their investment and additional purchase costs. In addition, local governments lack the incentives to promote renewable energy as sales of renewable energy are exempt from value-added tax, which is retained by local governments.[25]

Table 1 summarizes the key features of legal framework. It is important to note that, when different laws are in conflict, for example, when equal-hour dispatch operates against the full purchase of renewable electricity, renewable energy is prioritized according to the NDRC.[26]

4 FYP on Energy and Command-and-control Energy Policies

The Chinese government sets a number of mandatory targets covering renewable energy generation, energy consumption caps, energy efficiency and technology standards.

4.1 Renewable Energy Targets

The 13th FYP for the electricity sector (13th FYP-Electricity), released in 2016 by the NEA, sets out development guidance and targets for the electricity generation mix for the next five years. In general, the share of coal and non-fossil fuels in generation capacity is targeted at 59% and 39%, respectively. The specified targets are summarized in Table 2.

Compared with the previous FYPs for the electricity sector set by China Electricity Council, the 13th FYP-Electricity is more consistent with the FYP for energy development (FYP-ED) in terms of targets regarding renewable energy. However, there is still disparity between the FYPs and the Energy Development Strategic Action Plan (EDSAP) set by State Council. This implies that companies' investment decisions which are optimized on the basis of the former mandatory targets may become inefficient due to the unexpected changes of targets set by the government.[27]

[25]See the report on the implementation status of the Renewable Energy Law at `http://www.npc.gov.cn/npc/xinwen/2013-08/27/content_1804270.htm`.

[26]See "How to Understand the Supporting Documents of the Power System Reform" at `http://www.ndrc.gov.cn/zcfb/jd/201512/t20151201_761159.html`.

[27]The inefficiency arises if the mandatory targets set by the State Council for installed capacity are lower than those previously set in other plans, as there will be excess investment in transmission (needed to link the new capacity to the

Table 1: Key Legislations Related to the Electricity Sector

	Electricity Law (enacted in 1996, and amended in 2015)	**Energy Conservation Law** (enacted in 1997, and amended in 2007)	**Law on the Prevention and Control of Atmospheric Pollution** (enacted in 1988, and revised in 1995, 2000 and 2015)	**Renewable Energy Law** (formulated in 2005, and amended in 2009)
Aims	promote the electricity sector development	promote energy conservation and enhance energy efficiency	reduce main atmospheric pollutants	promote renewable energy and optimize the energy mix
Electricity Pricing	• reflect cost • identical across the same category of electricity • identical acorss the same category of consumers • varies with time periods	• adopt peak load prices, seasonal and interruptible load prices • differential prices for energy intensive industries		• different feed-in tariffs for generation from different renewables • grid connection costs partly allocated to consumers
Dispatch Principles	centralized and administrated at both central and local levels, encourage grid interconnection, encourage grid connection of generation from renewable energy and clean energy	grid companies compensate generators for financial losses when failing to connect the qualified generation	prioritize the grid connection of generation from clean energy	mandate purchase and grid connection of renewables
Role	milestone: the first law governing China's energy sector	important for promoting the development of renewable energy and clean energy	control atmospheric pollution, protect and improve the environment	establishes key mechanisms to develop renewable energy
Inherent Problems	• fails to keep up with economic and technological changes • fails to to address environmental concerns	• implementation is compromised	• technically difficult to implement	• financial incentives and compensation paid by grid companies are not explicitly specified • difficult to connect renewable electricity due to technological and geographic reasons

Table 2: Installed Capacity Targets during the 13th Five-Year Plan Period (GW)

Sources	**13th FYP-Electricity**			**EDSAP**
	accumulated by 2015	incremental (2016-2020)	accumulated by 2020	accumulated by 2020
Coal	900	200	1,100	
Hydro-power	320	40	340	350
Wind	131	79	210	200
Solar	42	69	110	100
Nuclear-power	27	30	58	58
Natural gas	66	50	110	
Biomass	13	2	15	

Note: All the numbers in column 2, 3 and 4 are obtained from the 13th FYP-Electricity, where the accumulated amount by 2015 (i.e., the number in column 2) is included in the part summarizing the outcomes of the 12th FYP period. However, the accumulated amount by 2020 does not equal the accumulated amount by 2015 plus the incremental amount between 2016 and 2020. This reflects that the targets set by the FYPs are not strictly enforcing, leaving some space for minor adjustment.

4.2 Energy Intensity and Total Energy Use

Mandatory targets for energy intensity and total energy use are also set. In the Intended Nationally Determined Contributions submitted to the Paris Climate Change Summit in 2015, China pledged to decrease its energy intensity by 60 to 65 per cent from 2005 levels by 2030. The 13th FYP-ED also mandated that by 2020, the annual aggregate energy consumption would be kept below 4 billion tCE. Both 13th FYP-ED and 13th FYP-Electricity anticipate that by 2020 annual electricity consumption will be limited to 6.8 to 7.2 trillion kWh. Furthermore, the coal equivalent consumption of thermal-power plants would decline to less than 310 g/kwh, and the overall rate of line loss in electrical networks would decrease to less than 6.5%.

In the EDSAP from 2014 to 2020, a cap on annual primary energy consumption is set at 4.8 billion tCE and annual coal consumption is aimed to be held below 4.2 billion tons by 2020. This implies that the annual increase rate of primary energy use in China must be no more than 3.5 percent by 2020.

4.3 Technological Standards

A number of plans place restrictions on the technologies of construction and operation of power plants.[28] Ma and Zhao (2015) examine the contribution of technology standards and market restructuring to energy efficiency of power plants in China. They find that, from 1997 to 2010, technology standards have contributed at least half of the observed efficiency improvement. They also suggest that technology mandates have short-term effects. This is consistent with the finding

grid). For instance, some electricity generated from renewable energy in remote areas (particularly western China) is eventually wasted due to the lack of grid connection.

[28]Technology standards could be found in the following representative plans: the FYP for National Energy Technology issued by the National Energy Bureau which specifies the targets for technology development in the electricity sector, the FYP for the Development of Wind Power, the FYP for the Development of Solar Power, and the Medium and Long Term Plan for the Development of Nuclear Power.

related to mandated target regulation in the study by Dutra et al. (2016), which shows that mandated target regulation is a relatively coarse instrument and is inferior in incentivizing investment in supply-side energy efficiency.

Targets set in plans can be effective. For example, Wang et al. (2014) found that local governments are diverse in their initial attitude towards energy saving policies, which are reflected in their ex-ante voluntary targets.[29] However, the central government's credible commitment—under which the determination to reduce energy intensity is unambiguously clarified—drove the initially disparate attitudes of provinces to eventually converge.[30]

However, planned targets have limitations. In order to mitigate the strategic responses from local government, a more flexible approach could place more emphasis on the quality and effort of policy implementation and be less rigid in terms of the 5-year plan time frame (Wang et al., 2014). Moreover, the planned targets might be economically untenable and requires radical revision. According to Zhao et al. (2017) which assessed the economics of coal power generation in China, if the capacity installation target for coal power is realized, at 1100 GW as suggested in the 13 FYP-Electricity, by 2020 in most provinces the internal rate of return for coal power will drop below the social average return rate or will even be negative due to the weak demand growth. Another important drawback of command-and-control approaches is that standards may be influenced by rent-seekers. This is particularly the case in China where the process of standard-setting is nontransparent and the final standards are determined to a large extent by the political concern of local officials.

5 Pricing Mechanism

Over the past three decades, China has adopted a complex electricity pricing system.[31] Under the current system, electricity prices, including generation prices (or on-grid tariffs), T&D prices and retail prices, are regulated by governments at various levels.

5.1 Generation Prices

In most cases, generation is sold to grid companies, rather than to end-users, under wholesale contracts at predetermined prices approved by NDRC and recommended by local pricing bureaus.[32] In 2003, the Chinese government introduced a trial of partially competitive wholesale

[29]Some provinces clearly proposed to reduce energy intensity by 20% or more during the 11th FYP period, some plan to reduce by less than 20%, and others do not have voluntary targets.

[30]Given the voluntary targets proposed by local governments, the central government can distinguish the attitudes of different provincial governments and thus can push provinces with lower willingness to ensure overall energy-saving outcomes.

[31]At the early stage of reform, on-grid tariff was used to attract investment into electricity generation. In response to the necessity of market mechanism, it was then applied to create competition in the generation sector. In 2004, in order to reduce energy intensity, a differentiated electricity pricing policy was introduced to energy-intensive industries. In 2007, to phase out aged and small-sized coal-fired electricity generation plants, lower on-grid tariffs are applied to them. In recent years, with the rising concern about environmental protection and the promotion of clean energy utilization, on-grid tariffs have progressively been developed for renewable electricity generation.

[32]Pricing bureaus are the administrative institutions responsible for pricing issues in local areas. In some provinces, a pricing bureau exists in parallel with local NDRC, while in other places it is merged with the relevant local NDRC.

markets in some eastern and southern provinces.[33] These trials were concluded in 2006, and no other subsequent market regime for generation prices has since been introduced.[34] However, under the 2015 electricity reform, competitive bidding was reintroduced to set wholesale prices. The market rules under competitive bidding are yet to be defined.

Under the existing system, recommended benchmark prices are commonly related to the price of coal. Due to the different proximities to coal mines, generation prices for thermal-power plants differ across different regions and provinces. In general, east China has the highest prices, followed by south China, north China and middle China, with northwest China having the lowest. In a specific province, generation prices for thermal-fired electricity vary according to the technology types of power plants. For instance, coal-fired plants with the same desulphurization receive the same price.

While coal prices fluctuate significantly in the market, electricity prices are fixed by the regulator. To address this mismatch, the central government approved a price link between coal and the electricity generated by coal-fired plants in 2004. According to this policy, if the average price of coal increases by five percent or more in a period of six months, the prices of electricity will increase in the next period. However, this policy has not been implemented as anticipated, and only a couple of co-movement adjustments have been made over the whole of the past decade. Regarding the impacts of the coal-electricity price linkage (CEPL) mechanism , through a Stackelberg game model, Fan et al. (2018) assessed its impacts on the profits of Chinese enterprises. They found that CEPL policy is conducive to reducing profits loss when coal price rises for coal-fired power plants, with the profits declining relatively less compared to the increase of coal prices given fixed electricity production.

The price of hydro-power-generated electricity is based on costs and can differ from project to project. Factors influencing prices include the hydrological and geological condition of plants, water adjustment capabilities of reservoirs, and specific requirements for possible resettlement during construction. The prices of large hydro-power plants are approved by NDRC and those of smaller ones are determined by provincial governments. Compared to the electricity generated from coal, wind and nuclear, the price of hydro-power-generated electricity is lower by 30 per cent, 60 per cent and 44 per cent respectively. This is despite the accepted notion that 'the electricity connected to the same grid should receive the same unit price.'

The generation prices for nuclear power plants built after mid-2013 are set on the basis of a nation-wide benchmark price, which is set at 0.43 CNY/k.[35] The nuclear power benchmark price is lower than the prices of thermal-power or renewable power. According to the regulatory rules set by NDRC, in those places where the nuclear power benchmark price exceeds the local thermal-

This is contrasted with the case at the central government level, where the Pricing Department which takes charge of pricing issues is part of NDRC, as we showed in subsection 2.4.

[33]A maximum of 10 to 20 per cent of the electricity generated by participating power plants could be transacted through the market.

[34]The need for electricity generation to support the rapid economic growth in the last decade has likely influenced the decision to retain a centralized approach to price making. Such an approach could ensure that investment was undertaken in a timely manner rather than remain subject to the vagaries of market forces.

[35]This contrasts with the previous method in which the price of nuclear power was based on the costs of individual plants.

power price (with costs for desulphurization and denitration included), the newly built nuclear power plants will follow the local thermal-power price standards. This benchmark price is adjusted according to changes in supply and demand in the market, generation costs, and technology.[36]

As nuclear power creates externalities, its price should reflect social attitudes to nuclear power development (Sun and Zhu, 2014). However, in China the value of public concerns about nuclear power has not been considered in prices.[37]

For electricity generated from renewable energy such as wind, solar and biomass, feed-in tariffs (FITs) are applied. The benchmark prices of coal-fired electricity is added to FIT to constitute the benchmark price of electricity from renewable energy, which differs across different technologies, geographic locations, and availability of resources.

As for biomass plants, a subsidy of 0.25 CNY/kWh is added to the benchmark price of desulphurized coal-fired plants. Under this pricing mechanism, only a few biomass power projects are profitable in China due mostly to the rapid rise of biomass material costs (Zhou et al., 2012), the scattered and seasonal supply of resources for biomass fuel (e.g., crops), and the lack of financing channels for biomass projects (Liu et al., 2014).[38]

The benchmark price for electricity from wind or solar is regionally fixed. China mainland is divided into four different wind energy areas and in each area there is one fixed benchmark price, ranging from 0.40 CNY/kWh to 0.57 CNY/kWh from 2018.[39] The price of solar-generated electricity is also set contingent on regionally fixed benchmarks, and three categories of prices have been created, i.e., 0.9 CNY/kWh, 0.95 CNY/kWh and 1 CNY/kWh. A subsidy of 0.42 CNY/kWh is added to the distributed generation from solar. While prices do vary across regions, the current FIT scheme is too rigid to fully take into account that resources vary greatly in different areas (Zhang and He, 2013).[40]

In general, the downward adjustment of generation prices for renewable electricity can be partly explained by technological advancement that reduces marginal generation costs. Another reason is the decline of fossil fuel prices (particularly the relatively low price of oil) witnessed in recent years, which imposes crowding-out stress on the adoption of renewable energy. Taking the pricing of onshore wind power as a case, with previous price levels, the FIT policy is attractive to wind power investors, but it does not fit the target to introduce market mechnism to the deployment

[36]See http://www.gov.cn/zwgk/2013-07/08/content_2442397.htm.

[37]As shown by He et al. (2013), decision-making on nuclear power in China is dominated by national governmental agencies, state-owned nuclear enterprises, and scientific experts. By contrast, the public are hardly informed and involved in nuclear power developments.

[38]Given the unfavourable situation for biomass power projects, there are sitll many biomass projects that have been constructed. This is mainly because that investors expect that the government will increase the biomass electricity by a large magnitude due to the social benefits of such projects. When they make their investment decisions, the main factor they consider is the technical feasibility rather than profitability. See `http://paper.people.com.cn/zgnyb/html/2014-06/16/content_1442228.htm`.

[39]This is the recently updated price level since January 2018. Before this round of price depreciation, the regions with the richest wind energy in northwest Inner Mongolia and northwest Xinjiang have a fixed tariff of 0.51 CNY/kWh, the regions with modest wind resources in east Inner Mongolia, north Hebei and west Gansu are given a price of 0.54 CNY/kWh, the regions in southern Xinjiang, southern Gansu, whole of Ningxia and parts of Jilin and Heilongjiang are priced at 0.58 CNY/kWh, and the rest comprising the vast majority parts of China with relatively less wind resources have a fixed tariff of 0.61 CNY/kWh.

[40]For instance, although the average solar radiation in China is 4 kWh/(m^2/day), the resources vary greatly across different areas, ranging from less than 2 kWh/(m^2/day) to over 9 kWh/(m^2/day). See Zhang and He (2013).

of wind power. Hence, with the lowered prices of turbines and fossil fuels, it makes sense to reform the FIT policy for newly commissioned wind farms (Yuan et al., 2016).

5.2 Transmission and Distribution Prices

The T&D prices are not set independently on the basis of T&D costs. Instead, they are calculated indirectly, as the difference between generation prices paid to power plants and retail prices charged to end-users by the grid companies. According to the most recent reform launched in 2015, T&D prices will be separately set based on a regime akin to cost-of-service regulation (i.e., on a cost-plus-return basis).

Following the trials in Shenzhen and Western Inner Mongolia, other provinces (e.g., Anhui, Hubei, Ningxia, Guizhou and Yunnan) have reformed T&D prices. In the case of Shenzhen, the first special economic zone in China, both total revenue of the grid company and electricity T&D prices are regulated through a revenue cap. In essence, total revenue, which consists of allowable costs and a permissible return on capital and taxes, is capped to decouple the grid company's revenue from sales volume. T&D prices, which are determined by the level of voltage, are calculated as the quotient of total revenue divided by total T&D volume.

T&D price reform is a particularly difficult task in China, as a large state-owned enterprise, the grid company SGCC shoulders many responsibilities, ranging from making profits to political and social purposes. This makes it difficult as economic regulation requires a focus on costs and revenues that are specificity to the activity of transporting electricity.

5.3 Retail Prices

Retail prices of electricity comprise the on-grid tariff, the embedded T&D charges, and various taxes and surcharges. Overall, energy purchasing costs account for 65 to 70 per cent (Teng et al., 2014), and combined taxes and surcharges amount for about ten to 15 per cent (Edwards, 2012).[41] In theory, retail prices are regulated on the basis of the cost-plus principle (Teng et al., 2014), which is similar to the cost-of-service regulatory regime.[42] However, due to the lack of an independent pricing mechanism for electricity T&D, the actual T&D costs in China's electricity sector are not known and, as a result, NDRC takes existing prices as the starting point rather than reviewing the costs in detail.[43]

[41]Examples of surcharges at the national level include: 1) construction of the Three Gorges Dam; 2) migration subsidies related to the relocation of those affected by the Dam project; 3) rural power grid maintenance; 4) urban public utility services; and 5) subsidies for renewable energy projects.

[42]Under the cost-plus principle, unit price = unit cost + markup, where the unit cost is calculated as the total cost divided by the number of units, and the markup is the product of unit cost and a percentage that provides an acceptable profit for the firm. Note that the total cost refers to total generation cost (including social costs). See http://paper.people.com.cn/zgnyb/html/2013-10/28/content_1316574.htm. In contrast, under the cost-of-service regulation, firms receive a rate of return on their investment, and a firm's total revenue is calculated as: revenue requirement = (rate of return)×(rate base) +operating costs+depreciation+taxes, where the rate base is the capital and assets utilized to provide services.

[43]Usually, the retail prices are based on guidance provided by NDRC and are ultimately determined by local governments and vary across different provinces.

There are three categories of retail prices (households, agriculture production, and industry/services) which are applied to different types of consumption based on the voltage requirements.[44] The prices for households and agricultural production are lower than the average price level.

In general, the retail prices for the same type of consumers are identical regardless of their location in each province. However, to encourage energy saving and to protect those with lower incomes, progressive electricity tariffs have been introduced to households nationally since 2013. Under this mechanism, consumers who use more electricity need to pay a higher unit price if the total electricity consumption exceeds a threshold level. The progressive tariffs vary across different provinces in terms of tier definition and the level of unit price for each tier. Although the tierd pricing mechamism contributes to moderate electricity demand growth, additional policy reform and tools are needed as this pricing mechamism alone may not be effective in energy conservation (Khanna et al., 2016; Zhang et al., 2017; Zhang and Lin, 2018), particularly after a period of time when the psychological pressures perceived by consumers decay (Wu and Zhang, 2017). Studies such as Yu and Guo (2016) even found that rural Chinese households show no response to current electricity pricing as most of their electricity use is for basic need.

In the industrial sector, differentiated prices have been implemented for energy-intensive industries since 2004.[45] Efficient companies in these industries receive a price that is set for their industry, while the less efficient companies need to pay a surcharge in addition to the basic electricity price. In retailing, China's electricity pricing is featured with cross-subsidy from industrial sectors to households, as the retailing prices of electricity is relatively lower for households and higher to industries compared to other parts of the world.

While retail electricity prices have remained stable, fostering economic development and protecting low income consumers, the pricing mechanism distorts behavior away from efficient outcomes. For instance, retail prices do not reflect the price changes of coal, nor do they reflect the costs of connecting electricity generated from renewable energy to grids. To introduce market mechanisms, the 2015 reform allows large end-users to transact directly with generators. Moreover, private firms meeting retailing standards are able to buy electricity from generators and sell it to final consumers.

Aside from pricing mechanisms, there are other financial measures to incentivize energy efficiency and renewable energy development, including subsidies, preferential loans and tax incentives. These financial incentives contribute to increase the share of renewables in energy consumption, to improve energy efficiency, and to address the problem of electricity generation centres located far away from main load centres (Ouyang and Lin, 2014). However, these effects are offset by the existence of substantial subsidies and low-interest loans provided to fossil fuel industries to alleviate energy poverty and promote economic growth.[46]

[44] See `http://www.gov.cn/zwgk/2013-06/09/content_2423501.htm`.

[45] In 2004, six industries (i.e., aluminium, ferroalloy, calcium carbide, caustic soda, cement, and steel) were chosen as energy-intensive industries. In 2006, industries such as phosphorus and zinc smelting were also included. To encourage provincial authorities to apply this policy, revenues collected through this pricing mechanism were allowed to be retained by local governments in 2007.

[46] Through the price-gap approach – which quantifies the gap between world energy prices and domestic (subsi-

Another concern about financial incentives is the timing of support taking into account the life cycle of an industry. Government supports provide advantageous condition to gain profits for an industry during the start-up periods, and contribute to encourage R&D investment during the industry expansion period (although in a diminishing rate). However, continuous government intervention may attract too many firms to enter into the market, leading to production over-supply at the later stage (Zhou et al., 2015). Currently China is reducing the over-capacity of industries in the supply-side structure reform, and the electricity generation sector is included.

6 Pilot Incentive Measures

In addition to the measures undertaken nationally, there are a number of pilot programs in particular areas. These include the energy saving power dispatch (ESPD), demand side management (DSM) and an emissions trading scheme (ETS). In this subsection, we will describe and review the main features of these programs.

6.1 The Energy Saving Power Dispatch (ESPD)

The electricity dispatch system has been characterized by the average dispatching principle implemented in the 1980s. Under this principle, equal operating hours are allocated to generating units of the same type despite their size, energy efficiency and pollutant emission levels. That is, this dispatch model allows inefficient generating units to operate as many hours as efficient ones.

While it encourages investment in electricity generation by guaranteeing investors' revenue, this dispatch method is neither economically efficient nor environmentally sound. As a response to these concerns, the ESPD was introduced in 2007.[47] It prioritizes the use of renewable energy and fossil-fuel-generating units with higher energy efficiency and less pollutant emission. Thermal-power-generating units within each class are ranked according to their energy efficiency, with the more energy-efficient given priority. For the units with the same energy efficiency, pollutant emission level determines their order of dispatch. Lower ranked units are dispatched only when the higher ranked units are operating at full capacity.

To date, five provinces (i.e., Henan, Jiangsu, Sichuan, Guizhou and Guangzhou) and China Southern Power Grid have conducted ESPD pilot programs. The on-grid tariffs are set according to the pricing mechanism described in Section 5.

The ESPD has achieved remarkable energy saving and emissions mitigation (Ding and Yang, 2013). For instance, from 2008 to 2011, the accumulated saving of standard coal reached 341 mil-

dized) end-user prices, Lin and Jiang (2011) estimates that energy subsidies in China amounted to CNY 356.73 billion in 2007, equivalent to 1.43% of GDP.

[47] With the ESPD, generation dispatch is scheduled according to the dispatching list, which place all types of generating units into the following order: i) single-sourced generators using renewable energy such as wind, solar, tidal and hydro-power; ii) flexible units fired by renewable energy like hydro-power, biomass and geothermal power and solid waste-fired generators meeting environmental protection requirements; iii) nuclear power plants; iv) coal-fired co-generation units running in terms of 'electricity upon heat' and units with comprehensive use of resources including residual heat, residual gas, residual pressure, coal gangue and coal bed/coal mine methane; v) natural gas and coal-gasification-based generation units; vi) other coal-fired generators, including co-generation units without heat load; and vii) oil and oil products-fired generation.

lion tons in Guizhou, which resulted in a reduction of carbon dioxide emissions of 10.48 million tons. In 2009, through the ESPD, Guangdong saved 0.9 million tons of standard coal, which reduced carbon dioxide emissions by 1.98 million tons (Dong, 2011). However, with the increasing share of large units that have low heat rates in the total thermal generation, the impact of ESPD is diminishing.

Although the 2015 reform has signalled the desire for a dispatch mechanism that favours more environmentally-friendly and efficient units, the nation-wide rollout of the ESDP faces institutional, technical and financial obstacles. Being a centralized dispatching mechanism, the ESPD is not compatible with market mechanisms (Chang and Wang, 2010; Gao and Li, 2010). The ESPD is technically challenging for grid companies and raises reliability and stability issues for the whole power system. The resultant re-allocation of financial resources between central and local governments, as illustrated in subsection 2.4, also hinders the full implementation of the ESPD. To the extent that local governments prioritize direct local economic benefits, rather than environmental benefits, which may accrue to a broader region, they may also hinder the implementation of policies such as the ESPD.[48] This distorts outcomes away from those that are socially optimal.

6.2 Demand Side Management (DSM)

DSM refers to measures that aim to decrease consumers' overall energy demand or to shift demand from peak to off-peak. DSM has been conducted as a pilot program in five cities.[49]

DSM measures include energy efficiency management, load management, and utilization order management (Zeng et al., 2013). Energy efficiency management is achieved through consumers using more efficient energy-intensive appliances (e.g., refrigerators, air conditioners and water heaters). Load management is carried out through price signals and load-shaping technology to reduce the maximum load on the grid. Utilization order management is implemented with administrative means to deal with electricity shortage by meeting the demand of some consumers while limiting the use of the others.[50]

Non-pilot provinces have also embarked on DSM programs. They have established facilities and systems to supervise businesses related to energy-saving services, to assess the achievement of DSM projects, and to manage energy utilization order.[51] Pricing mechanisms such as time of use prices, peak and off-peak prices, and seasonal prices have been employed by more than 20 provinces, and a DSM-specific fund has been developed in ten regions (Zeng et al., 2015).

[48] For instance, as the allocation of the dispatch hours is not transparent, local governments may be able to avoid complying with ESPD and instead prioritize the dispatch of less-energy efficient plants under their ownership. See `http://www.chinapower.com.cn/newsarticle/1205/new1205841.asp`.

[49] The five cities are Beijing, Suzhou, Tangshan, Fuoshan and Shanghai. See `http://www.sdpc.gov.cn/zcfb/zcfbtz/201504/t20150409_677004.html`.

[50] The efforts for DSM in China can be dated back to 1990s when electricity supply was tight and load adjustment was needed several times a day. Before the electricity sector reform launched in 2002, load management instruments include direct-load-control, load-adjustment, peak-load pricing and time-of-use pricing. But at that time these approaches were different from the ways they are applied currently. For instance, consumers were not free with their choices; instead, they had to accept the implementation.

[51] For instance, Qinghai, Shandong, Sichuan and Liaoning. Take Liaoning as a case, and see efforts undertaken there at http://www.sdpc.gov.cn/fzgggz/jjyx/dzxqcgl/index.html.

DSM plays an important role in energy saving and emission reduction in China. It is estimated that, from 2007 to 2009, the amount of electricity saved through DSM was around 90 to 100 TWh, avoiding the use of 54 million tons of coal, and resulting in a reduction of as much as 900 thousand tons of sulphur dioxide emissions. Over 70 per cent of national electricity shortages were solved by DSM, mainly through utilization order management, and as much as 16 million Kwh of electricity usage had been shifted across different times of the day.[52] In 2014, electricity savings achieved through DSM were 13.1 TWh, which avoided the need to add 2,950 MW of installed capacity.[53] During the 12th FYP period (2011-2015), the potential of accumulated savings could amount to 46.334 TWh of generation, thus achieving a saving in installed capacity of 18,356 MW (Zeng et al., 2013). Yuan et al. (2016) also estimated that, if China can utilize the market mechanism to implement DSM, it can reduce at least 3% of the total electricity demand (or 243 TWh) by 2020, which is equivalent to 76 Mtce primary energy.

The nation-wide rollout of DSM programs also face many challenges. Pricing is obviously an issue (Cheung, 2011; Zhou and Yang, 2015). Due to the lack of real market price or real-time price for electricity, there is limited scope for price signals to motivate demand changes. For example, the peak-load price is only two to three times the off-peak price, while in developed countries this ratio is eight to ten. To incentive consumers to shift their peak demand, it is necessary to increase this ratio (Zeng et al., 2015).

The lack of powerful economic incentives for DMS also limits its implementation (Zeng et al., 2013, 2015). DSM projects usually lead to a decline in electricity sales, which reduces the revenue of grid companies. Hence, in the absence of adequate economic compensation, grid companies, who are responsible for implementing DSM, will not do so. The lack of sufficient DSM-specific funds is another constraining factor (Yu, 2012; Zeng et al., 2015) with only a limited number of regions introducing such funds (Yu, 2012).[54]

In addition to the above discussion about the barriers for ESPD and DSM, there are also some institutional problems, including: (i) the relationship between electricity system flexibility and the guarantee for the grid connection of renewable energy. Given the intermittent attribute of renewable energy, it is difficult to achieve both goals, and thus it is essential to achieve good balance between electricity demand and supply, generation and T&D, and the share of electricity generated from traditional energy and renewable energy; (ii) the trade-off between economic efficiency and environmental protection. As thermal energy enjoys relatively lower cost, the use of thermal energy is more economically efficient. Hence, to promote the development of renewable energy, it is necessary internalize the environmental cost of thermal energy through economic measures such as tax or quota trading; and (iii) the development of capacity market, which could make renewable energy more competitive.

[52]See http://yxj.ndrc.gov.cn/dlxqgl/201011/t20101130_383703.html.

[53]See National Development and Reform Commission (NDRC) at http://www.jsdsm.gov.cn/dsmsite/info/1215.jhtml.

[54]This fund can be financed from sources such as budget allocations, multi-lateral donors, CDM revenues, etc (Yu, 2012). Taking Shanxi Province as an example, the DSM-specific fund is raised through taking 20% of the surcharge for public utilities. See http://www.sxfzb.gov.cn/Article/ShowArticle.asp?ArticleID=1974.

6.3 Emission Trading Scheme

An emissions trading scheme addresses the environmental externalities of carbon emissions through a market mechanism. Under this scheme, companies are assigned an emissions quota and are allowed to sell excess permits to other firms if their carbon emission is lower than the quota. China's pilot carbon emission trading system was initiated in 2008, and has been launched nationally since December 2017 after having been piloted in seven provinces since 2013.[55] In 2015, about 37.86 million tons of carbon dioxide equivalent, with a value of CNY 1 billion, were traded under these schemes.[56] Despite the emissions reduction achievements, quotas are over supplied. Consequently, the price of carbon emission right is low and permits are not traded as often.

As a main emitter of greenhouse gases, the electricity sector is covered by the compulsory carbon trading scheme and plays a crucial role in China's carbon pricing system in both direct and indirect ways. However, the highly regulated electricity wholesale and retail prices, as well as the equal share dispatching principles, represent formidable challenges for the successful implementation of a national emissions trading scheme (Teng et al., 2014).

A national emission trading scheme, which will be the world's largest, is planned to start in 2017. The national carbon market will be administrated by both central and local governments, with the central government setting standards and the total amount of carbon emissions, and local governments allocating quotas to firms. A unified national market will contribute to limit regional protectionism, which resulted from the tournament system under which the local official with the best economic performance is more likely to benefit from political promotion. However, given the differentiated economic development level and economic structure across provinces, it is difficult for the central government to allocate quotas fairly, and thus the allocation scheme that depends on report data from local governments may result in a new type of regional gaming.

Pilot programs have been extensively used in China. Nevertheless, a robust evaluation of their performance in achieving energy efficiency and lower emissions is yet to be carried out. A perfunctory analysis suggests that results have been mixed, and there has been little opportunity for learning from them.

7 Conclusion

Given the size of China's electricity sector and its dependence on coal, energy efficiency and renewable efficiency will necessarily play a significant role in achieving its emissions reduction targets and to ensure that economic growth follows a sustainable path.

In this paper, we have reviewed evidence that the various programs designed to replace less efficient with more efficient power generation units have already produced impressive results. In addition, there has been steady progress in reducing line losses. All in all, supply-side energy efficient initiatives have been, at least, moderately successful.

[55] The emissions trading scheme was implemented in Beijing, Tianjin, Shanghai, Chongqing, Guangzhou, Shenzhen and Hubei, covering 2,000 businesses in energy-intensive industries.

[56] See `http://www.tanpaifang.com/tanguwen/2017/0117/5830.html`.

In contrast, demand-side energy efficiency initiatives seem to have gone nowhere. For example, the trials of demand-side initiatives that were initiated across a number of cities have either been discontinued or have not produced significant effects. This is not surprising given that the prices faced by final consumers bear little relationship to the actual costs of production, but instead, reflect a myriad of objectives, including inflation control. This is a common flaw across developing economies that pursue a modern, efficient electricity system to support sustainable development, but are often tempted to control final electricity prices to achieve other goals. To solve this problem, market mechanism in the electricity sector should be steadily promoted, particularly the pricing of electricity in each segmentation.

While renewable generation capacity has also increased significantly over the last decade, the increase in actual renewable generation has been less significant. This follows from both the intermittent nature of renewable energy, such as solar and wind, and the location of the energy resources often away from existing transmission and distribution lines. However, it also follows from the limitations and incentives embedded in the dispatch system and the lack of financial incentives and a stable regulatory regime to promote the connection of renewables to the grid. The multitude of targets, and the conflicting signals they send to grid companies, also explain the somewhat more limited increase in renewables generation. Hence, the government is recommended to shape the market for renewable energy generated electricity, and pay more attention to the grid access and dispatch priority for renewable energy.

Above all, the biggest challenge to promote energy efficiency and renewable energy in China is the lack of a coherent regulatory regime. China lags much behind developed countries (and even peer developing countries such as Brazil), which have reformed their electricity sectors by unbundling generation, transmission, distribution and in some instances retail, and introduced competition for generation and retail. In some instances, capacity markets were introduced, with spot markets to clear differences between contracted capacity to actual dispatch and demand, while in other instances, energy-only markets were introduced. In addition, markets are also used to price energy efficiency opportunities such as demand-side management and distributed generation. In the monopolized segments of transmission and distribution, independent regulators were established with a mandate to set prices in a way that would ensure the long-term interest of consumers. While the 2015 electricity law can be credited with initiating the reform process in the Chinese electricity sector, there is still a long way to go as the law does not provide sufficient guidance, and existing institutions may have too many vested interests to develop the regulatory and institutional framework that is needed. That is, to better support the decision-make process, much work needs to be done.

Finally, the dominant role played by state-owned enterprises can undermine the reform process. More often than not, the investment in the development of energy efficiency and renewable energy is undertaken to fulfill a political or social objective rather than as a response to appropriately designed economic incentives. This explains why electricity reform in other countries was undertaken at the same time as privatization and the reform of government-owned enterprises to effectively insulate them from political pressures and also to introduce competitive neutrality principles. Furthermore, considering the "new norm" of China's economic situation, overcapacity and over-investment in Chinese electricity also calls for concerns.

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- Reviews the regulatory framework governing energy efficiency in China's electricity sector.
- Identifies the incentives embedded in the complex Chinese electricity market design.
- Explores options aimed at striking a better balance between markets and direct regulation.