ENVIRONMENT & NATURAL RESOURCES PROGRAM

The Challenges and Promises of Greening China's Economy

Jinqiang (JC) Chen

HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

DISCUSSION PAPER 2017-01
JANUARY 2017

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Cover photo: A satellite view of the Gansu Wind Farm Project under construction in China's western Gansu province. Construction began in 2009 toward a planned total generation capacity of 20,000 MW. ©2016 Google Earth, DigitalGlobe. Used with Permission.

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The Environment and Natural Resources Program (ENRP)

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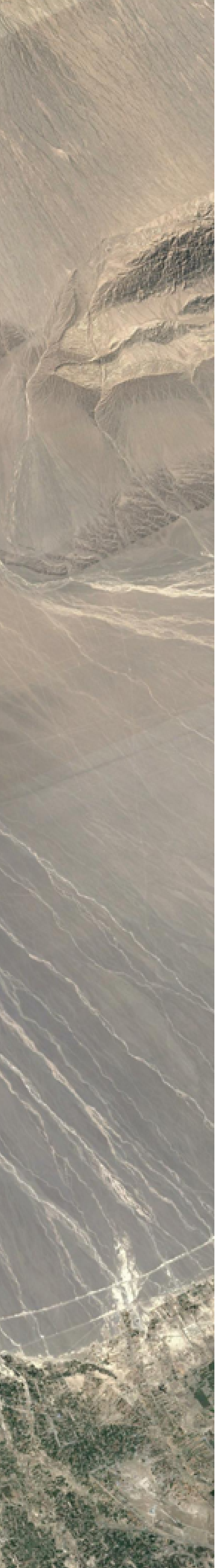


Introduction

In the 2014 joint U.S.-China climate announcement, China pledged to peak carbon emissions by 2030, with at least 20% of its primary energy consumption coming from sources other than fossil fuels, up from about 10% today. To reach its ambitious goal, China has been acting quickly to design and implement economically prudent energy policies such as a national cap-and-trade program. The U.S.-China announcement represented strengthened bilateral cooperation between the top two carbon emitting countries and injected momentum into the global climate negotiations at the 2015 United Nations Climate Change Conference in Paris. In addition to its non-fossil fuel goal, China made another serious pledge to lower carbon dioxide emissions per unit of GDP by 60-65% from 2005 levels in its Nationally Determined Contributions (NDC). This paper shows the compatibility between the non-fossil fuel share pledge and carbon intensity target and summarizes key challenges China has been facing (and will face) in scaling up non-fossil fuels as promised in its NDC. Non-fossil fuels typically include all energy sources except coal, oil and natural gas. In this research, only energy sources with an expected installed capacity larger than 100 GW in China (such as solar, wind, hydro, and nuclear) are considered. Research approaches include literature reviews, financial modeling, and interviews with senior executives from state-owned enterprises (SOEs), government agencies, non-government organizations (NGOs), and private sector companies specialized in energy and environment.

Compatibility

The Chinese government has made two important commitments in its NDC: one is its non-fossil fuel target, in which shares of non-fossil fuels in primary energy consumption will be increased to around 20%; the other is its carbon intensity target, in which carbon dioxide per unit of GDP will be lowered by 60-65% from the 2005 level. Those two pledges are not mutually exclusive, and the carbon intensity target is inclusive of the non-fossil fuel one.

The carbon intensity target requires an annual reduction rate of approximately 4.18%. This reduction can be further partitioned into two components: carbon intensity per unit of energy and energy intensity per unit of GDP. Based on the major assumptions in its pathway shown in Fig. 1, the annual reduction in energy intensity per GDP is around 3.32%, which is achieved mainly in two ways: one is technological energy conservation, i.e., improvement in technology efficiency of energy conversion and use; the rest is structural energy conservation, meaning the adjustment and upgrading of industry structure and the promotion of high-end development.[1] Empirically speaking, this reduction rate is consistent with middle-income countries. The difference between those two metrics is carbon intensity per unit of energy, which is 0.89%.[2] By definition, this factor can be formulated as

$$\frac{\alpha\beta E}{\beta E + (1-\beta)E} = \alpha\beta,$$

where α, β, and E indicate carbon emission factor, percentage of primary energy consumption related to carbon emission, and total primary energy consumption, respectively. Assuming no improvement in technologies or adoption of alternative energy sources that result in carbon emission reduction, α will not change over time. Therefore, when comparing the future milestone, i.e., 2030, with the baseline year 2005, reduction in carbon intensity per unit of energy can be expressed as

1 He, Jian-Kun, 2015. China's INDC and non-fossil energy development. *Advances in Climate Change Research*, 6(3), 210-215.

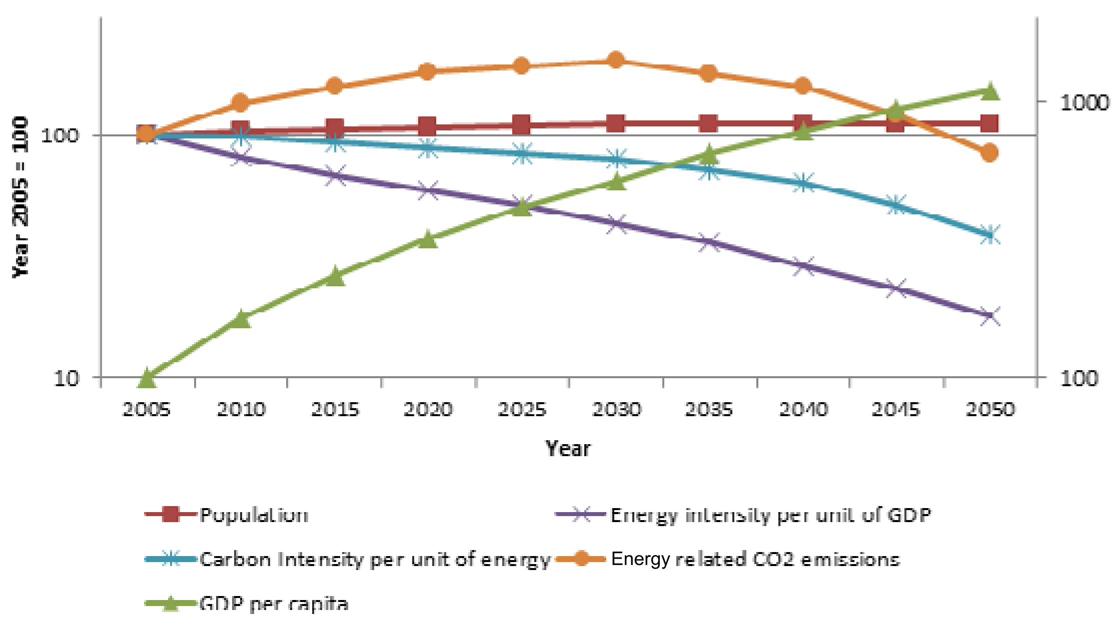
2 0.89% is calculated directly from data in Fig. 1. The difference between the carbon intensity per unit of GDP and the energy intensity per unit of GDP is 0.86%, slightly different from the direct result of 0.89%. The slight difference is due to approximation made in the logarithmic calculation. For more information regarding the relationship between logarithm and rates of change, please refer to http://www.uio.no/studier/emner/sv/oekonomi/ECON4150/v13/undervisningsmateriale/loglinearnote-.pdf.

$$\frac{\beta}{\beta_0} = (1 - 0.89\%)^{25} = 80\%,$$

where subscript 0 indicates the baseline year 2005. This result shows that in order to realize the carbon intensity target, the percentage of conventional energy in year 2030 has to be 80% of that in year 2005. Statistical data indicate that shares of conventional energy in the year 2005 were 92.3% of total energy consumption, i.e., β_0 equals 92.3%.

The relationship expressed above indicates that β has to be equal to 73.8%, which means that if there is no reduction in carbon emission factor through technological improvements or substitution of heavy polluting energy sources with less polluting ones such as natural gas, 26.2% of primary energy consumption from non-fossil fuels is required. This conclusion is consistent with and inclusive of the 20% target, and it implies that the rest (6.2%) of the target has to be achieved through improvements in technological innovation such as carbon capture and sequestration or through wider adoption of natural gas that results in a lower carbon emission factor.

Figure 1[3] Major assumptions used in China's NDC. Data sources: Data for 2005 and 2010 is from China Statistical Yearbook, China Energy Statistical Yearbook, and China's official review of target completion. Data after 2015 is developed based on NDC scenario study results calculated by the PECE model of NCSC and Renmin University of China.



3 Reproduced from Fig. 2 in "An Analysis of China's INDC". Available at http://www.chinacarbon.info/wp-content/uploads/2015/07/Comments-on-Chinas-INDC.pdf

Capacity

The portfolio of renewable energy sources has grown rapidly in China's energy market in recent years and has become a significant element in the electricity mix. Based on China's energy consumption trajectory, the 20% goal implies that non-fossil energy supplies by 2030 will be 7-8 times that of 2005, and the annual rate of increase will be more than 8% within those 25 years.[4] By then, the projected installed capacity of non-fossil fuels will reach 1,350 GW, which is more total installed capacity than the United States had in 2012.[5] Expected installed capacity for hydro, solar, wind, and nuclear will reach 450 GW, 400 GW, 350 GW, and 150 GW by the end of 2030, from 320 GW, 120 GW, 43 GW, and 60 GW[6] in 2015, respectively.[7] This escalation of energy capacity will require the installation of one 2 MW-sized wind turbine per hour and 8-10 GW-sized nuclear power plants annually. This is a relatively aggressive estimate since capacity factors of non-fossil fuels are expected to increase as integration of renewables becomes easier to achieve.

Large-scale introduction of power from intermittent renewable energies (wind and solar) creates challenges for the stability of the electricity grid, as unexpected changes in local meteorology can significantly alter solar and wind power production. This problem, however, can be mitigated as the proportion of renewable energy sources increases in the total energy portfolio. Renewables become more predictable as more renewables are connected to the grid system due to the benefits of geographic diversity[8] and the Law of Large Numbers. However, realization of those benefits has been challenged by the management of grid systems, as discussed in the next section.

4 He, Jian-Kun, 2015. China's INDC and non-fossil energy development. Advances in Climate Change Research, 6(3), 210-215.

5 Equals 1,063 GW, according to EIA data.

6 25.5 GW in operation and 32.0 GW in construction.

7 In He's research, estimates of expected installed capacity for non-fossil fuels are based on the partial substitution method, in which the primary energy equivalent of the sources of electricity generation represents the amount of energy that would be necessary to generate an identical amount of electricity in conventional thermal power plants, with a range of thermal efficiency from 38-41%. Operating hours for hydro, solar, wind, and nuclear are prescribed as 3500h, 1400h, 2400h, and 7800h, respectively.

8 Geographic diversity benefits mean that as more and more renewables are installed in a wide range of geographic locations, the uncertainties associated with electricity generation are reduced. It can be achieved through the negative correlation in weather patterns among different locations when the concerned region is large enough.

The next section discusses the existing challenges in integrating renewables into grid systems, which is expected to provide lessons for the future policy design of China's electricity sector or other developing countries facing similar problems.

Integration of Renewables

Grid Connection

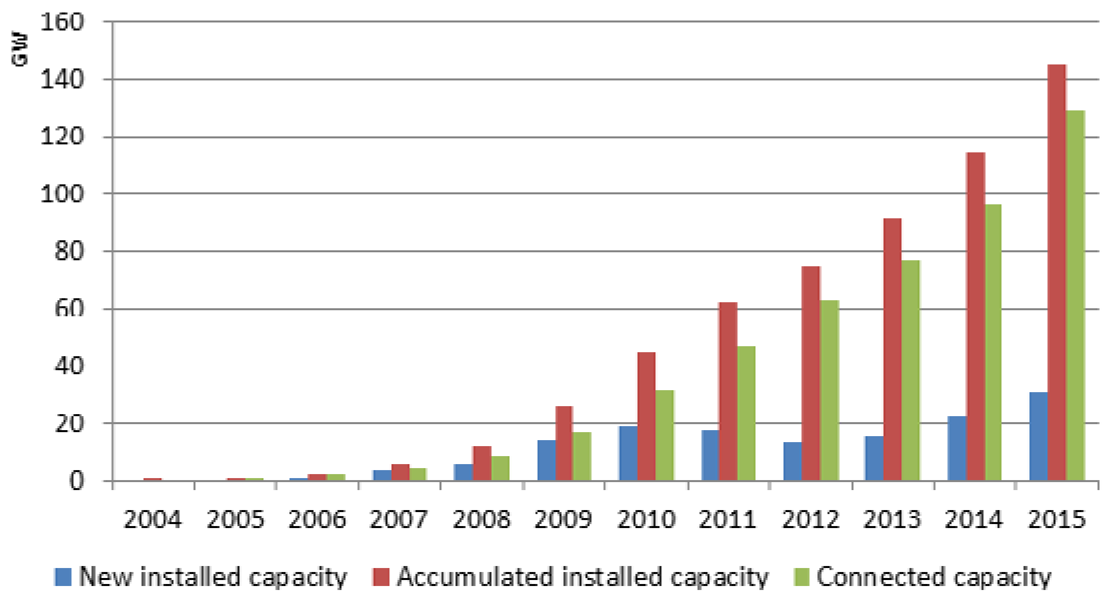
A rapid increase in the capacity installment of renewables requires grid connections. Take wind energy for example. In the past ten years, accumulated installed wind capacity increased from 743 MW in 2004 to 145,362 MW in 2015, with a geometric-averaged annualized increase of 65.5% (Fig. 2). However, only 70-80% of installed capacity was connected to the grid and the rest is due to lack of physical accessibility (Fig. 2). Because of concession programs, wind farm and solar panel developers rushed to occupy some of the best locations, but overly rapid installment of wind and solar capacity (often driven by these rent-seeking activities) is not synchronized with the time-consuming procurement of land permits to build grid connection. For example, it takes around one year for renewable energy developers to get permits and jump into operation, but it takes more than two years for grid companies to get permits from the central government and to build local grid facilities. It takes even longer to build ultra-high-voltage transmission lines.[9] This time lag directly leads to a significant amount of energy wasted in situ. In 2015, the power to approve all thermal plant projects and a portion of grid projects was distributed to local governments and central and local planning have both been redefined; the central government is in charge of regional grid projects that are at least 500 kV and above transmission lines, and local governments are in charge of grid projects at the city and county levels.[10] This decen-

9 The major reason for delays in the process of building an ultra-high-voltage transmission line is that experts cannot reach a consensus on DC vs. AC. As a result, the Grid Development Plan cannot get approved from the National Energy Administration. (http://finance.sina.com.cn/chanjing/gsnews/20140108/132217883540.shtml)

10 http://www.sdpc.gov.cn/gzdt/201512/t20151210_762078.html

tralization of power to local governments was expected to expedite this time-consuming process; however, feedback from the State Grid Company indicates that lack of knowledge among local government officials adds significant communication costs that compromise the positive expectations around decentralized power.

Figure 2 Installed wind power capacity in China from 2004 to 2015. Sources: Chinese Wind Energy Association, National Energy Administration.



Curtailment

Even when clean sources are physically connected, not all of the energy they generate can be absorbed by the grid. This phenomenon is called curtailment. To accommodate the rapid growth of renewables, the Chinese government has put favorable policy and legislation in place, such as the Renewable Energy Law in 2005. Under this law, power grid operators are required to buy all the grid-connected power produced with renewable energy within the coverage of their power grid and provide grid-connection service for the generation of power with renewable energy.

In reality, implementation of this specific clause has been inconsistent. When local consumption is limited, or the electricity surplus cannot be easily transmitted through to adjacent grids, grid companies typically curtail electricity generated from wind and solar sources. In 2015, the wind curtailment rate in China peaked at its historical record, at rates of 18%, 39%, 32%, and 32% respectively in Inner Mongolia, Gansu, Xinjiang, and Jilin,[11] four large provinces in the northern part of China, where there is abundant wind energy potential and a large amount of installed wind capacity (Fig. 3). The total wind curtailment amounts to a direct economic loss of 16 billion RMB, accordingly to statistics from the National Energy Administration. Factors that contribute to this curtailment include lack of local consumption, price competitiveness, reliability concerns, and a rigid electricity dispatching system, which will be elaborated upon in the following paragraphs. In addition, grid companies are forced to shoulder part of the costs of physically connecting wind farms. As a consequence, they have little incentive to integrate power sources that augment unpredictability and net variability of their power systems. Even though a revised law now "obliges" grid companies to guarantee the purchase of a minimum amount of electricity from renewable energy, the details of how this obligation can be achieved and what percentage of electricity from renewables is mandatory vary across different provinces and are not well defined. For example, in some cases, as a condition to provide grid facilities to solar developers, grid companies require solar developers to pledge to assume losses related to solar curtailments.[12]

Starting in 2015, the National Energy Administration began refusing to approve any new wind projects for regions with an existing wind curtailment rate higher than 20%, and established a renewable energy quota system that requires a certain percentage of electricity consumption to be purchased from non-hydro renewable energy sources—primarily wind, solar, and biomass. Provinces that are unable to meet their quotas may have to suspend or reduce their fossil fuel power generation projects.

However, in some places, the quota is set at a very low level and local governments have developed policies through which the electricity surplus of renewables can be consumed through direct electric power purchase from large users or power generation rights exchange with factories' self-owned power plants. Through power rights exchange, power plants can opt out of electricity generation and sell their operating hours to renewable developers. Normally self-owned power plants' generation cost is lower than

11 Review of development of the wind power industry in 2015. http://www.nea.gov.cn/2016-02/02/c_135066586.htm

12 http://zfxxgk.nea.gov.cn/auto92/201407/P020140718634498745605.pdf

the local benchmark price, so renewable developers need to bid an ask price lower than the cost of self-owned power plants, or a much lower than market price to secure a buyer and complete a power exchange agreement. Once the power generation rights are delivered to renewable developers, they can provide power directly to the end users, and consequently, the renewable curtailment problem is alleviated. Because of the limited supply of generation rights in the auction market, renewable developers do not have much negotiation power. Some renewable developers even bid a "0" price, with a hope to earn only subsidies rather than being curtailed.[13] Policies that allow for power generation right exchanges or direct purchases from large users have often been eliminated because they challenge the Renewable Energy Law. Under these policies, there is little guarantee that renewable power will be purchased; instead, it is often sold at a lower price, with a portion of payments and subsidies essentially "passing through" the renewable developers and flowing directly into heavily polluting power plants in exchange for power generation rights.

Lack of Local Consumption

Once connected, energy from renewable sources should ideally be locally consumed. However, local consumption of renewables is limited for a number of reasons. First, in some places, the installed capacity of renewables is far higher than the required load capacity. For instance, in Gansu Province, the total annual electricity consumption in 2014 was 109.5 billion kWh,[14] equivalent to an average load capacity at 12.5 GW. Installed renewable energy capacity, however, had already reached 17 GW. This overcapacity had significantly limited the potential for local consumption of renewable energy, especially when combined with an existing 16.6 GW of installed capacity of coal power plants. Second, conventional coal power is primarily used as base load because it is relatively inflexible and can take up to ten hours to reach full production from a cold start. Accommodating dynamic electricity generation shifts from coal plants to local renewable power generation can be technically difficult and economically unfavorable because of the high costs of ramping up and down. Third, the use of com-

13 http://finance.sina.com.cn/energy/industrydynamics/20160215/223524288734.shtml

14 http://www.gstj.gov.cn/www/HdClsContentDisp.asp?Id=29343

bined heat and power prevails in regions where wind power is high. This is not coincidental, because high wind power exists in the northern part of China, and temperature can drop to negative degrees for fairly long periods of time. Units must run during heating seasons and passively generate electricity even when plenty of wind power is available. Even though in some provinces, local governments have already limited the number of coal power plants in their yearly plan, developers still build combined heat and power plants and sell electricity as their primary business.[15] All of these factors can lead to limited local consumption of renewables.

Transmission

China's most abundant wind and solar energy sources are in the northwest, while high electricity demand is primarily in the southeast. Because of that, large renewable capacities have been installed in the northern regions of China (Fig. 3). Since electricity generated from renewable sources cannot be totally consumed locally, electricity surplus has to be exported to other regions. High capacity transmission lines are being built to accommodate that need. There are several lines operating and several being built that are expected to be completed by 2020[16] (Fig. 3). For example, the Jiuquan-Hunan ultra-high-voltage line linking Jiuquan in western Gansu province to Xiangtan in central Hunan province is the longest line of its kind to be built in China, stretching 2,383 kilometers and involving a total investment of RMB 26.2 billion ($4 billion). In China, long-distance power transmission is often cited as an important factor in power sector decision-making by the government. It is an essential element in the idea of Global Energy Interconnection, a concept proposed by Liu Zhenya, the former Chairman of the State Grid Corporation of China.[17]

One caveat is that it was not the primary motivation to transmit renewable energy from the northwest to the southeast when the National Energy Administration approved large-scale renewable projects in the northern part of China. For example, local consumption was an important

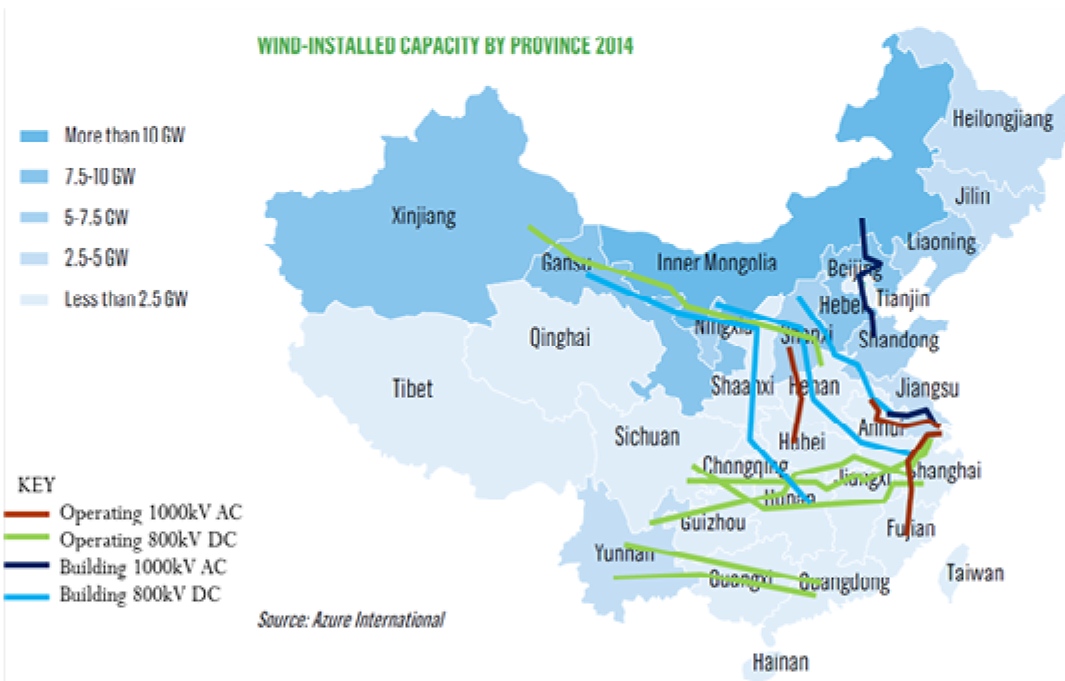
15 Communication with economists at the State Grid Corporation of China.

16 http://www.windpowermonthly.com/article/1361466/analysis-china-adds-uhv-network-transfer-surplus-wind-energy

17 http://www.sciencedirect.com/science/book/9780128044056

requirement when the National Energy Administration approved the large-scale wind power plan in Gansu Province in 2008. Apparently, grid companies are often blamed for curtailing wind capacity. In response, they point out that they are constrained by the time-consuming process of permitting and approval from the National Energy Administration. The tension between the National Energy Administration and grid companies still exits.

Figure 3 Ultra-high voltage transmission lines (Source: State Grid 2020 UHV Transmission Plan) and wind-installed capacity by province in 2014 (source: Azure International).



However, building transmission lines alone cannot solve the problem. For example, the electricity surplus in Gansu Province is expected to be transmitted to Hunan Province through an 800kV DC line (Fig. 3). State Grid Hunan Electric Power Company claims that it will prioritize hydropower within its province over wind and solar power from Gansu. This implies that when hydropower is abundant in Hunan Province, the company must use it and will not purchase power from Gansu Province, because hydropower is cheaper and is generated within the province itself. In addition, company officials believe that the responsibility to consume power from Gansu Province should not be assumed solely by Hunan consumers, but by all neighboring provinces, so more ultra-high AC lines should be constructed to accommodate that need.

In 2015, Hubei, a neighboring province, approved six coal-fired plant projects, with total installed capacity up to 7,980 MW, equivalent to one third of the installed capacity of the Three Gorges Dam. Hubei and other provinces in southeast China are deficient in coal, oil, and electricity. In order to relieve their energy shortage, a railway, called Menghua Railway, was constructed to bring coal from Inner Mongolia, passing Hubei Province, to Jiangxi Province. In order to maximize the use of the railway, coal-fired plants were planned and built. These plants have boosted the local economy and increased employment, and due to the continually decreasing coal price, electricity from coal power plants has become more price competitive. The added capacity from coal power plants leaves the local electric power company less interested in purchasing power from outside provinces. Jiangxi Energy Administration, however, doubts the safety of long distance transmission lines, arguing that because of the supply volatility inherent in renewable power, intermittent power flows may cause system instability and major power outages.

In addition, power sectors in China are characterized by long-term contracts and fixed prices. This rigid structure provides no incentive for system operators to accommodate inter-provincial and inter-regional exchanges or for utilities to release capacity. For example, in the case of Hunan Province, if the system operator decides to purchase power from Gansu Province, she has to sell any surplus power to other provinces, even at a lower price, which is not economically favorable. Otherwise, she has to reduce operating hours of either hydropower, whose price is significantly lower than that from Gansu Province, or of coal power plants. The former is economically unfavorable because a rational operator does not purchase power at a higher price from other provinces while lower price energy source is readily available; the latter results in lower revenue for coal power plants because revenue is proportionally linked to operating hours in the context of a fixed benchmark price for coal-generated electricity. Therefore, significant local resistance exists in pursuing inter-provincial power exchange.

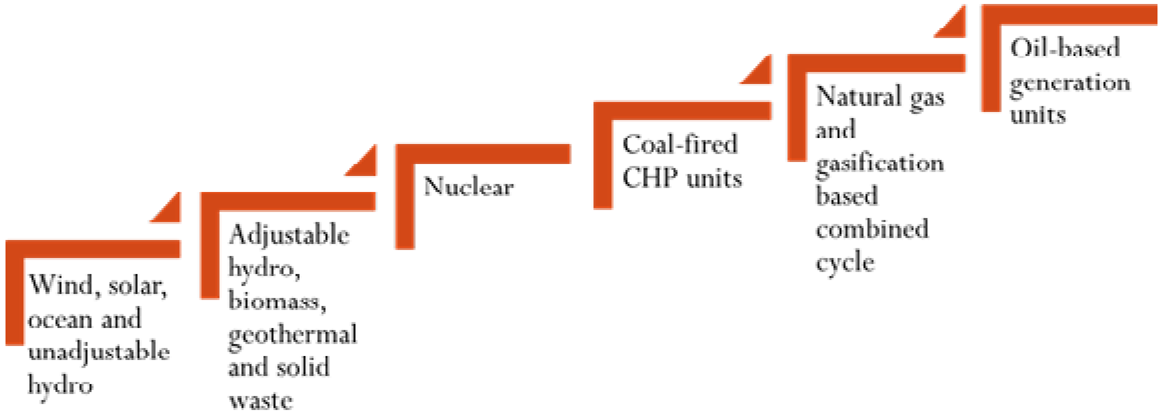
Although grid companies in different provinces are collectively responsible for achieving targets set by the central government, including requirement of the Renewable Energy Law that obliges them to guarantee the purchase of a minimum amount of electricity from renewable energy, they appear to be driven by local needs and demands when implementing policies and achieving targets.

In summary, there are two major reasons that inter-provincial power exchanges are difficult to implement. First, renewable power prices from other provinces are often not price competitive, in addition to their high volatility. It is not rational to purchase power at a higher price while giving up readily available power at a lower price because this decreases revenue for local power suppliers. Second, coal power is cheaper and can significantly increase the local employment rate as well as GDP, which is an index directly linked to promotion benchmarks for government officials. Regulatory uncertainties due to the establishment of a national carbon market and the implementation of China's electricity sector reforms will potentially remove some of the barriers to renewable integration. Difficulties in integrating renewable energy into the grid system and transmitting the surplus of renewable supply to other provinces significantly reduce the geographic diversity benefits of renewable source aggregation.

Dispatch

Unlike other countries, dispatch in China is neither economic nor environmental. System operators in China allocate a fixed number of operating hours to power generation technologies, regardless of costs. The dispatch system is planned in advance to meet the target of allocated operating hours. This system was designed to incentivize investment from public, private, and foreign sectors in power generation by ensuring that generators could recover all of their investment costs. Because of that, when supply exceeds demand, electricity coming from variable sources such as wind, solar, and hydro is curtailed first. This is particularly true when the combined heat and power units must provide heating. As a result, this policy leads to less efficient competition between electricity sources with lower operating costs, such as nuclear and hydropower, and coal-fired plants, and among coal-fired plants with different levels of efficiency.

Figure 4 Dispatching order.



In order to reduce wind and hydropower curtailments, the National Development and Reform Commission, the State Electricity Regulatory Commission, and the Ministry of Environmental Protection launched a pilot system to promote energy efficient dispatch in five provinces, namely, Guangdong, Guizhou, Henan, Jiangsu, and Sichuan Provinces.[18] This system specifies the order in which plants are dispatched, as seen in Fig. 4, with renewables, hydro, nuclear, and combined heat power given priority over conventional sources, and conventional thermal units within each category dispatched based on their efficiency and emission rate. Theoretically, this new rule prioritizes renewables, and thereby ensures that they will run at their full capacity. However, experience has shown that the specified order leads to insufficient operating hours for coal-fired plants or forces them to run at less than full load. This increases the cost per unit of electricity generation, reducing utility revenue in the five provinces, which is directly linked to the number of operating hours their plants run per year. In addition, a fixed benchmark price allows no financial compensation for owners of low merit order plants (old and smaller units) with less efficiency and higher emission rates and no incentive to encourage utilities to retain them as ancillary reserves. Smaller plants offer an attractive option for flexible dispatching, but they are being replaced by larger ones (at least 600 MW) because of the Chinese government's efforts to improve overall plant efficiency and to reduce emissions. For example, from 2006 to 2009, 54 GW of small coal-fired plants were closed, which contributes 0.11 billion

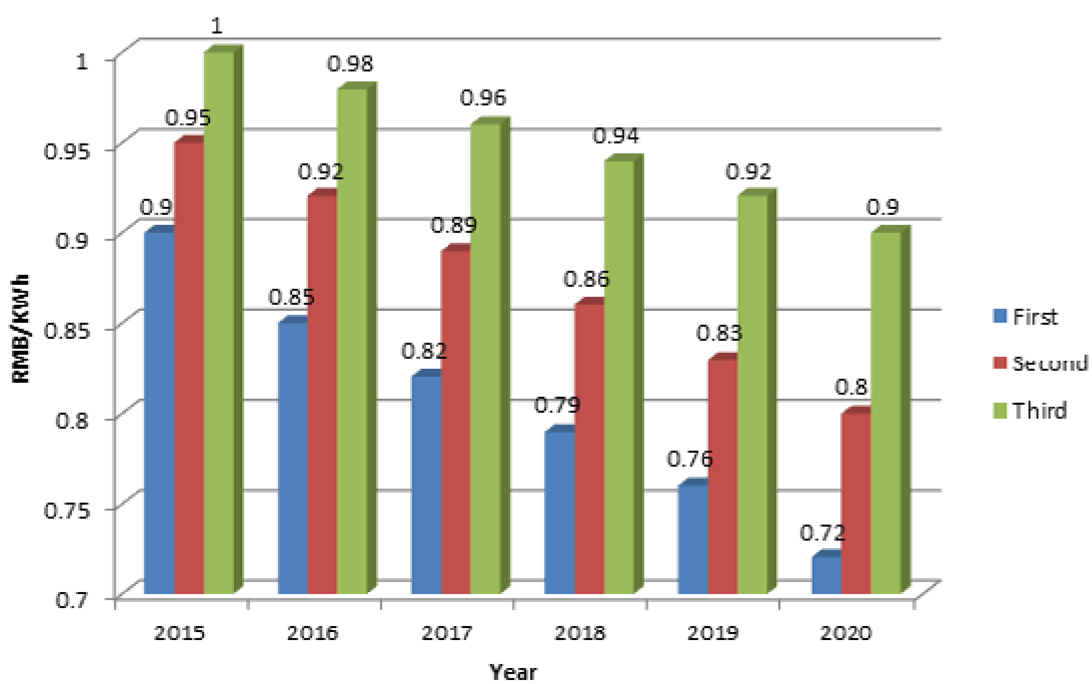
18 Analysis and policy recommendation for energy efficient dispatch. http://www.efchina.org/Attachments/Report/reports-20110501-zh/reports-20110501-zh

tons in CO_2 reduction annually.[19] However, this move reduces the number of smaller plants that can be dispatched in a flexible way.

Subsidy Policy

China has been the engine for the global renewable industry for the last decade and has soared from almost nothing to one of the top installed capacity countries in the world. This fast escalation of renewable installment is largely due to the subsidy policy the Chinese government has developed to incentivize investments in solar and wind power industries. However, continuous unrealized subsidy payments may discourage the renewable industry and cause serious problems in operating cash flow for some private companies. Reducing this type of credit risk is vital in addressing the challenges of scaling-up renewables in the coming years.

Figure 5 Solar subsidies with utility scale at national level for first category (left, h>1600), second category (middle, 1400<h<1600), and third category (right, h<1400), where h is annual operating hours.



19 http://www.greenpeace.org/hk/Global/hk/planet-2/report/2009/7/climate-change-ranking-of-china-power-corps.pdf

Fig. 5 shows the subsidy policy from 2015 to 2020 for solar power with utility scale at the national level for three categories. Because of geographic differences and local climate conditions, insolation received at different regions varies significantly. Solar power, which is heavily dependent on the available sunshine, can over-perform in sunny regions but under-perform in cloudy regions, resulting in a wide range of operating hours. Therefore, provinces are categorized into three categories—the first category with annual operating hours greater than 1600 h, the second between 1400 h and 1600 h, and the third with less than 1400 h for solar power with utility scale. The discriminative treatment of regions with different solar energy is intended to balance the development of the solar power industry nationwide. For example, solar farms in the first category, in which regions receive higher insolation, receive lower subsidies per unit of electricity generated. If subsidies were uniform across the whole country, solar developers would rush to regions of the first category and cause an imbalance in the development of the solar power industry. The decreasing trend of government subsidies reflects two facts—one is the deficit of subsidy reserves and the other is the government's intention to improve the efficiency of subsidization, which has been hindered by high curtailment rates and poor grid connections.[20]

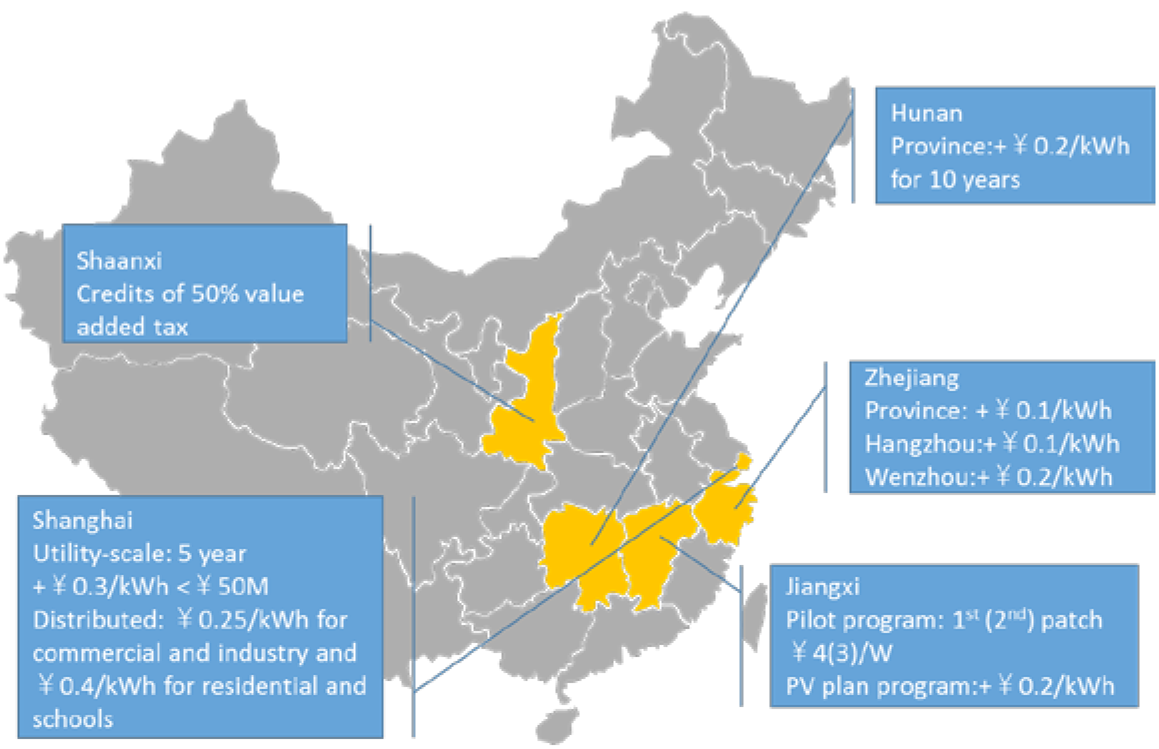
For distributed solar panel, the ideal adopters are commercial and industrial enterprises. The current subsidy for distributed solar panel at the national level is 0.42 RMB/kWh, and generated electricity surplus is priced with the local on-grid power tariffs from coal power plants, which is around 0.38 RMB/kWh. The electricity price for end users is around 0.5 RMB/kWh for residential users, different from the approximate 1 RMB/kWh for commercial and industrial users. Therefore, for commercial and industrial enterprises, building solar panels and using generated electricity can help them save 0.62 RMB/kWh compared to building solar panels to sell the electricity to the grid. For residential users, the cost saving is less.

In addition to national subsidies, each province develops their own policies to incentivize adoption of solar energy (Fig. 6). The most straightforward scheme is to offer additional subsidies on top of national ones, such as

20 Subsidies to renewables are categorized mainly in two types: one is based on installed capacity and the other is based on generated electricity. Because of high curtailment rates and poor grid connection, subsidized capacity is not able to generate electricity that is eventually consumed by users, which leads to a waste of money and low efficiency of subsidization.

those offered by Zhejiang Province. Some local governments, however, offer additional subsidies based on types of solar power and categories of consumers. For example, Shanghai offers awards to utility-scale solar power at 0.3 RMB/kWh for five years, with a cap of 50 million RMB per single project. For distributed solar power, the local subsidy is 0.25 RMB/kWh for industrial and commercial users and 0.4 RMB/kWh for residents and schools. In addition to subsidies based on electricity generation, provinces also subsidize capacity installment. For example, Jiangxi Province offers 3 or 4 RMB/W capacity installment subsidies, depending on the phase of projects; after put into operation, those projects can enjoy an additional 0.2 RMB/kWh subsidy. Unlike other regions, Shaanxi Province offers tax credits equal to 50% of value-added tax to solar panel adopters. Those regional subsidy policies create a favorable environment for solar power investment.

Figure 6 Regional subsidies for solar power.



Renewable developers receive payments equal to the local benchmark price of coal power from grid companies, and the difference between national and local benchmark prices and the subsidies are paid from the central government. These payments are funded from a surcharge imposed on consumers excluding residential and agricultural customers. The surcharge used to be 0.015 RMB/kWh and was raised to 0.019 RMB/kWh in 2016 because of large deficits in subsidy reserves. These deficits are largely due to an overly rapid increase in renewable capacity installment and a low amount of surcharge. The subsidy program was managed by the National Development and Reform Commission but was taken over by the Finance Ministry in 2012. The transition left it unclear as to which agency was responsible for paying any previous shortfall between the subsidies promised and the money raised from the surcharge.

Based on a report from Bloomberg,[21] approximately 30-40 billion RMB in unpaid subsidies may be owed by the government to developers. Some developers have been waiting for over four years for payments they have yet to receive. Longyuan, the biggest wind farm developer in China, had about 2 billion yuan in subsidy receivables at the end of 2014, mainly from overdue payments in 2011 and earlier. If we argue that most wind farm developers in China can afford any late subsidy payment because they are state-owned, the situation is not optimistic for solar farm developers, since most of them are private companies. It is estimated that the Chinese government owed more than 10 billion yuan to operators of Chinese solar farms by the end of June 2015. Increasing the amount of subsidy receivables might pose a threat to the continuation of operating cash flow and developers will have to either sell their assets at a discount or eventually claim bankruptcy. This will undermine Chinese renewable developers' efforts to raise financing and will discourage this engine of growth in the global renewable industry. Without a doubt, renewable curtailment worsens developers' financial status.

This situation may also crawl towards renewable manufacturers. The table below shows the aging analysis[22] of the current portion of the gross amount of trade receivables as of the end of the reporting period for China Ming Yang Wind Power Group Limited, one of the five largest wind turbine

21 http://www.bloomberg.com/news/articles/2015-08-20/china-s-wind-and-solar-developers-hit-by-subsidies-short-of-plan

22 Aging analysis is a periodic report that categorizes a company's accounts receivable according to the length of time an invoice has been outstanding. It is used as a gauge to determine the financial health of a company's customers. If an accounts receivable aging analysis demonstrates that a company's receivables are being collected at a much slower than normal rate, this is a warning sign that business may be slowing down or that the company is taking greater credit risk in its sales practices (definition from Investopedia).

manufacturers in China with a market share around 7% in 2015. A significant outstanding balance of past-due amounts exists in both years and keeps increasing, which indicates either that the business is slowing down or that the company is taking greater credit risk in its sales practices. As disclosed in the financial report, the past-due amounts of trade receivables as of December 31, 2014 and 2015 are mainly attributable to two reasons:

1. A majority share of the Group's customers are state-owned enterprises in the PRC, the gross trade receivables due from which accounted for 64% of the total gross balance as of December 31, 2015, and payments made by these enterprises are subject to complex internal application and approval procedures, which normally take several months from the time when payment applications are initiated until the payments are finally approved and processed.

2. The Group's customers usually finance wind farm projects from their internal resources or loans from financial institutions, which may not be obtained or drawn down as originally planned. If the financing is postponed, agreed payment schedules in the relevant wind turbine sale agreements are affected.

The first reason is hard to justify because of limited available information, but the second reason might be the channel through which renewable manufactures get paid overdue since renewable developers could not get subsidies in time.

Table 1 Aging analysis of current portion of gross amount of trade receivables as of the end of the reporting period for China Ming Yang Wind Power Group Limited.

	31 Dec. 2015 RMB'000	31 Dec. 2014 RMB'000
Not past due	4,448,848	2,853,494
Less than 1 month past due	118,760	74,062
1 to 3 months past due	412,258	120,380
More than 3 months but less than 12 months past due	588,653	429,445
More than 12 months but less than 24 months past due	280,239	451,858
Amount past due over 24 months	584,958	314,335
Amount past due	1,984,868	1,390,080
Total	**6,433,716**	**4,243,574**

Discussion

In its Nationally Determined Contributions, China has made an ambitious commitment to achieve a green economy. It has created a series of targets including increasing non-fossil fuels in its primary energy consumption, reducing its carbon intensity, and increasing its forest coverage. In this paper, I analyzed the efforts China will need to make in order to fulfill its energy sector goals and reviewed the challenges China has faced in promoting renewables in the past years. Over the last decade, China's installed capacity of solar and wind power has increased from almost nothing to the largest wind power and second largest solar power capacity in the world. Rapid growth of wind and solar industries, however, is not coupled with growth of grid facilities. As a result, part of the installed capacity is idle because of lack of physical connection. Even connected, a significant portion of generated power is curtailed, causing a large economic loss. Several reasons lead to renewable curtailment, including lack of local consumption, lack of long-distance transmission lines, lack of cooperation among grid companies, protectionism, rigidity of electricity market, price competitiveness, stability concerns, as well as a dispatch system. Some of those factors are intrinsically connected—for instance, because of the fixed price, the system operator has to allocate a fixed amount of operating hours to thermal plants in order to fulfill the guaranteed revenue for utilities.

Because of the complex situation and inter-supportive structure, it is extremely difficult to solve the curtailment issue. High expectations are placed on the pending reforms in the power sector and the new carbon market. These two initiatives are expected to force the power sector to internalize carbon costs and to reformulate its economic structure. Coal power has the advantage of significant price competitiveness, as well as a low level of risk, and additional "co-benefits" such as employment and increases in local GDP, which is directly linked to government officials' promotion. This creates barriers in persuading local governments to adopt renewable energy, which is not only expensive, but also unstable. Even though some local governments have set regulations to reduce renewable curtailments, it has often been achieved by exchanging generation rights with coal power plants with an aim to solve their financial difficulties. As a result, renewable developers are forced to bid at a lower price than the supposed benchmark price and pay thermal plants at the benchmark price. Subsidy policy was developed to incentivize investments in the renewable industry, but a current subsidy deficit leads to late payments to renewable developers, which might eat into their operating cash flow and poses a question mark on the sustainability of some of the private renewable companies.

In addition, the Chinese government needs to balance the following two factors in its energy sector.

1. Renewable vs. fossil fuel. In China's NDC, expected installed capacity of non-fossil fuel in 2030 will be even higher than that of the total installed capacity in the US in 2012. Significant growth of non-fossil fuels requires an intelligent infrastructure to insure their stability and safety concerns. Geographic diversity benefits can be compromised by the barriers of inter-regional and inter-provincial power exchange. Climate change poses a threat on long-life capital intensive and inflexible energy infrastructures (particularly hydro) because their performance largely relies on future weather patterns, which are rife with uncertainties. China is abundant in coal, which is a secure and cheap energy source and can be turned into a clean one with existing technologies. Hence, from an energy security perspective, renewables lose competitive ground to coal power. But

the current practice of coal use has generated two serious problems: coal mining accidents and air pollution. Co-benefits of retiring coal use include improvements in public health and the alleviation of social disturbances. With those in mind, it is worthwhile to deliberate on whether China should focus on solely scaling up non-fossil fuels or advance coal and renewables in tandem.

2. Integration of renewables vs. existing power structure. China has become one of the top renewable power countries in the world; however, in somewhat embarrassing contrast to other top renewable power countries, the percentage of renewables in its overall electricity generation profile remains low. Not all power generated from renewable resources can be brought to grids and consumed by users—significant renewable curtailments prevail. In addition to the lack of physical connection, local protectionism, rigidity of electricity market, price competitiveness, and the dispatch system leave renewables less welcome. Thermal plants have a pledged share of the power sector because of the fixed benchmark price. The introduction of renewables in the context of a decelerating Chinese economy is destined to be challenging and difficult. Overcoming these challenges requires China to develop prudent policies and to continue to raise its efforts in their implementation. It is an energy problem, but solutions cannot come solely from the energy industry itself. Removing political impediments and liberalizing energy markets will play a key role in the achievement of China's green economy goal.

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