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China as a Low-Carbon Energy Leader: Successes and Limitations

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Abstract

China has come to be seen as a global clean energy champion on account of its success in building the world's largest fleet of renewable energy - wind power and solar photovoltaics (PV), as well as hydro-electricity. In addition, it has become a major player in international renewable energy markets. In other words, it has shown a remarkable ability to adapt to environmental challenges and market opportunities. In this way, China provides a counter-example to the neo-institutional argument that limited-access social orders possess less adaptive capacity than open-access orders. This paper briefly examines the central government's efforts to promote the manufacture and installation of renewable energy capacity and the consumption of renewable energy since 2005, with a focus on wind power and solar PV. The strategies that have underpinned this success have relied on the deployment of massive political and financial capital, as well as the availability of human capital. Nevertheless, the many features of the institutional environment continue to undermine the efforts of the central government. These include the government's continued efforts to maintain economic growth and the ability of local governments and enterprises to emasculate central government policies.

Keywords: China, clean energy, wind, solar PV, institutions

1. Introduction

Since the beginning of the twenty-first century, China has become a major actor in the international energy arena. It is the largest consumer of commercial energy in the world, accounting for 23% of annual global consumption in 2016. In 2016, coal accounted for 62% of primary commercial energy consumption, with the balance provided by oil (19%), natural gas (6.2%), hydroelectricity (8.6%), other renewables (2.8%) and nuclear (1.6%). The size and mix of its energy consumption makes the country the largest emitter of carbon dioxide, accounting for an estimated 27% of the world's carbon emissions from energy [1]. At the same time, air pollution had worsened to such an extent that its mitigation has become a high political priority for the government.

Set against these challenges is China's success in building the world's largest installed capacity of hydro-electricity, wind power and solar photovoltaic (PV; Table 1), as well as the fastest growing

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fleet of nuclear energy plants. The government has combined this massive investment in clean energy infrastructure with measures to constrain the production and consumption of coal and to drive down energy intensity. The simultaneous slowing and rebalancing of the national economy led to coal consumption and carbon emissions from energy to peak over the years 2013 and 2014, and subsequently decline [2]. Furthermore, Chinese manufacturers have taken the world by storm to become the largest suppliers of renewable energy equipment, notably solar PV (Tables 2 and 3), as well as the dominant constructors of hydroelectric dams. This rapid expansion of manufacturing capacity has been a key factor in driving down the cost of solar PV across the world.For these and other reasons, China has been seen as one of the leading countries in the low-carbon energy transition.

Such achievements were not foreseen during the period 2003-2006 when energy consumption was rising at an annual rate of more than 10%. Between 2003 and 2011, national energy consumption and carbon emissions doubled [1]. Drawing on neo-institutional theory, a previous prognosis on China's low-carbon energy transition was distinctly pessimistic. That analysis argued that the nature of the institutions governing China's energy sector and their resistance to change would strongly constrain the pace of transition, and that only a dramatic economic slowdown would allow carbon emissions to peak before 2020 [3]. The rate of increase of annual GDP did decline, from 10-14% between 2004 and 2011 (after a dip in 2009) to 6-8% after 2012. This 'new normal' also encompassed a changing economic structure to one in which the service sector played an increasingly important role, at the expense of heavy industry. These changes to the economy set China's energy sector on a new path and greatly enhanced the impact of the government's clean energy strategies.

Nevertheless, China's low-carbon trajectory has come at a high cost and continues to encounter obstacles. Constraints in the electrical power sector include a high level of curtailment of wind and solar energy and the continued dominance of coal. As a result, wind and solar energy only contributed 6.7% of China's electricity supply in 2017. Other low carbon sources of electricity included hydro at 19% and nuclear at 4%.

These observations raise a number of inter-related questions concerning the governance of China's energy sector:

1. How were these successes in clean energy development achieved?
2. Did these successes rely more on traditional governance styles and institutions, or on new approaches?
3. What have been the sources of the costs, unintended consequences and failures of these policy approaches?
4. What are the implications for China's low-carbon energy transition?

This paper briefly addresses these questions by examining the development of wind energy and solar PV in China through the lens of neo-institutionalist theory. In addition, the evidence from China challenges propositions from this family of theories which imply that adaptive capacity is highly constrained in hierarchical societies in which conformity is perceived as the norm and where access to political and economic power is restricted.

2. Transitions and institutions

Much of the theoretically-based literature that addresses contemporary socio-technical, low-carbon or sustainability transitions has its roots in Western academic traditions. Many of these accounts emphasise reflexivity [4], societal participation and discourse [5] and democratic processes [6].

Table 1: *Wind and solar PV in China:installed capacity, capacity growth and global significance [32]*

	GW	World rank	Share of global
Wind energy capacity, end 2017	164	First	32.0%
Wind energy capacity additions, 2013-2017	102	First	53.2%
Solar PV capacity, end 2017	130	First	33.3%
Solar PV capacity additions, 2013-2017	123	First	42.1%

Table 2: *Chinese wind energy manufacturers in the global market [33]*

	Volume of sales (GW)	Share of global sales	Rank
Goldwind	5.6	10%	3^{rd}
Envision	2.9	5%	6^{th}
Guodian	1.4	2.5%	10^{th}

Note: data are rounded.

Table 3: *Chinese solar PV manufacturers in the global market [34]*

	Volume of sales (GW)	Share of global sales	Rank
JA Solar	6.4	7%	1^{st}
Zhongli Talesun	4.6	5%	3^{rd}
Jinko Solar	4.6	5%	4^{th}
Trina Solar	4.6	5%	5^{th}
LONGi Solar	4.6	5%	6^{th}
Tongwei	3.7	4%	8^{th}

Note: data are rounded.

While such approaches have value, they place insufficient weight on two key factors: power and institutions. Meadowcroft [7] and others have critiqued the transition literature for ignoring the role that political power can play in supporting, obstructing or distorting a transition. The distribution of power in any society depends, in part, on its institutions - the term 'institution' being used to cover the formal and informal rules of a society, as well as the beliefs, expectations and behavioural norms. Much of the literature on transitions has emerged from scholars in what North et al. [8] would term 'open-access social orders'; that is to say, in the more or less liberal democracies of North America and Europe. However, most nations, including China, fall into the category of 'limited-access social orders' in which power is relatively concentrated. Enlightenment ideas, such as those of David Hume, John Locke and Jean-Jacques Rousseau, have arrived only relatively recently, if at all, and are not always welcomed by national governments.

For these reasons, the study of transition must take into account the institutional context within which actors assess situations, make decisions and interact with other actors. Two complementary approaches can yield useful insights to transitions. The first has its roots in sociological or organisational institutionalism and focuses on institutional logics with a specific organisational field [9, 10]. This framework can be applied to a particular industry or supply chain or to a sector of society. A second approach looks across the whole of a society or nation, at embedded institutions and the institutional environment [11, 12] to identify the factors that assist or constrain the transition [13, 14]. One of the key issues addressed in neo-institutionalist analyses is the causes and nature of institutional change [10, 15, 16]. Most applications of neo-institutionalist concepts to analysing the low-carbon transition have been directed at states which are more or less democratic and relatively strong. Relatively few have focused on states which are more corporatist or dominated by a single party [3, 17] or those which are weak [18].

3. Support for renewable energy in China

China's central government continues to rely on the development of strategic plans, the setting of targets, the provision of financial support and implementation by local governments and by enterprises, many of which are partly state-owned. This traditional policy approach has allowed the central government to support the manufacture and deployment of renewable energy and to promote other aspects of clean energy.

The *Renewable Energy Law* of 2005 marked a turning point for China's renewable energy industry. The new law was reinforced by a number of subsequent policies such as the establishment of a *Special Fund for Renewable Energy Development*, successive five-year plans for renewable energy development with targets for capacity, the *Medium and Long-Term Plan for Renewable Energy Development 2007* and an update of the *Catalogue of Chinese High-Technology Products for Export*. The *Renewable Energy Law* itself was revised in 2009 [19].

Together, these and other policies provided a wide range of incentives for actors along the full supply chains for wind energy and solar PV [19, 20]. The Special Fund provided support for research and development and for manufacturing. The Ministry of Science and Technology targeted their funding at the development of progressively larger wind turbines, from 600 kW in Ninth Five-Year Plan (1996-2000) to 2-3 MW in Eleventh Five-Year Plan (2006-2010). Targets were set for installed capacity. Subsidies were available to project developers for constructing wind farms and to the grid companies for integrating renewable energy. The Renewable Energy Law introduced the concept of mandatory market share for any generating company with more than 5 GW of total capacity. Grid companies were mandated to provide wind power and solar PV access to the grid, not just connection but also dispatch and ancillary services. In return, additional costs could be shared between the grid and end-users. The initial scheme for on-grid tariffs allowed the

tariffs to set by the NDRC or through concession bidding.

The *Renewable Energy Law* of 2009 paved the way for the National Development and Reform Commission (NDRC) to issue a notice on improving the price policy for wind power generation through the introduction of feed-in-tariffs. These tariffs varied from 0.51 RMB/kWh to 0.61 RMB/kWh, depending on the quality of the regional wind resources. The government introduced feed-in-tariffs for solar PV in 2011, once the costs of the equipment had declined sufficiently. Finally, this period saw an increasing use of the Clean Development Mechanism which had been applied to 568 wind power projects in China by end of 2010 [21].

The generous availability of state funds, together with the support of local governments has led to China becoming a world leader in the manufacturing and installation of wind energy and solar PV capacity. These incentives attracted a large number of local state-owned enterprises and private entrepreneurs into the manufacturing of renewable energy equipment, leading to China in 2016 gaining a 46% share of the global market for solar PV and a 24% share of the market for wind energy equipment [22] China's installed capacity of wind energy increased almost tenfold between 2009 and 2017 to reach 163 GW, and the capacity of solar PV grew twenty-fold from 2012 to reach 130 GW by the end of 2017 [23].

4. Challenges facing renewable energy

This same institutional framework has provided actors the opportunity to undermine or distort key policies, for example, by curtailing wind energy or continuing to build coal-fired power stations. Likewise, local governments and enterprises have invested in an unconstrained manner which has led to a waste of state funds, as has been seen in the vast overcapacity and bankruptcies in solar PV manufacturing.

The sources of these deficiencies are multiple and lie in the policy and planning processes, in certain characteristics of the national electricity sector, and in the interests of the various actors. At the most basic level, the nationwide data on wind resources has remained inadequate, resulting in the poor siting of many wind farms [24]. Although planning is carried out by central government, final project approvals are issued at local level, and local economic interests leading to wind farm construction outstripping grid capacity [25]. This problem was especially prominent when plants with a capacity of less than 50 MW did not require the approval of the NDRC. These challenges were exacerbated by the focusing of planning targets on installed capacity rather than electricity delivered, and by the low level of coordination between the grid companies and the project developers, with the NDRC failing to exert their authority [19].

Two fundamental features of China's power industry contributed to the high level of curtailment. The first was the paucity of flexible power to match the intermittency of wind energy, arising from the shortage of gas fired power stations and pump storage hydro, and the lack of incentives for coal-fired stations to increase their flexibility [24,26,27]. Secondly, it is difficult to trade power across the country between balancing areas, as planning and dispatch tends to be carried out at provincial level [25].

These deficiencies have been accentuated by a number of technical issues, some of which have their origins in the interests and abilities of key actors. The technical standard of the turbines remains below what is required, the major problem being the tolerance to the large quantity of sand and dust in the air. Manufacturing companies have been spending insufficient funds on research and development because their profits are being squeezed by the highly competitive market. As a result, some companies buy drawings from foreign companies, but lack the quality of research staff to absorb and adapt the designs to Chinese conditions [24]. Project developers try to build wind farms as fast as possible in order to occupy prime land and secure future market

position. To keep up this level of investment, they require manufacturers to supply at low cost and so often end up purchasing low quality equipment [24]. At government level, the development and enforcement of technical codes for grid connection and the requirement for Low Voltage Ride Through equipment has been slow [19].

Arguably, it is the local governments which have played the most active role in the implementation of wind energy policy on account of their prioritisation of local economic development, employment and tax revenues. They have provided over-generous support for manufacturing and installation but have given too little backing for grid connection and dispatch. The overcapacity in wind turbine manufacturing has arisen from local protectionism, as wind farm developers tend to buy from local manufacturers to obtain project approvals from local governments [24].

Local governments have also played a central role in the curtailment of wind power as they tend to give preference to dispatching thermal plants over wind farms. The number of hours of generation for thermal plants is still determined by local governments after negotiation to create annual plans which are then implemented by local system operators. Thermal power stations lose out if the local grid operator dispatches wind energy preferentially, as is required by the central government, for a reduction of operating hours raises the breakeven price [25]. Recent years have seen the emergence of local overcapacity in power generation. As a result, in 2016, the average coal-fired power station in China was operating at a capacity factor below 50% [28]. Thermal plants employ more people and generate more local tax revenue than wind farms [24]. As a result, wind energy has been dispatched first in only a few provinces [25].

5. The implications of the ongoing power sector reform

The slowdown in the economy since 2010 has been accompanied by a decline in the rate of growth of electricity demand and a consequent surplus of potential supply over demand. This provided the opportunity for the State Council to revitalise its reform efforts which had been suspended since 2003, by issuing *Document Number 9* in March 2015. The reform has been progressing faster than expected. By the end of October 2016, comprehensive pilot reform schemes in 18 provinces (municipalities and autonomous regions) and pilot electricity retail reform schemes in 8 provinces (municipalities and autonomous regions) had been approved by the NDRC.

This new round of reform is characterised as 'control the middle, deregulate the two ends'. This means that while competition will be gradually introduced into the upstream (generation) and downstream (retail) segments, the middle stream (transmission and distribution) will be regulated [29]. The three main elements of the reform are to establish transparent transmission and distribution tariffs for the first time, to open up the retail business to competition gradually, and to establish independent power trading bodies. At the very least, these measures, combined with third-party access, will allow large power users to purchase directly from generating companies.

The new policy programme also seeks to promote renewable energy by [30]:

- Prioritising renewable energy in generation planning and dispatch;
- Increasing the proportion of renewable energy in inter-provincial and inter-regional power trading;
- Establishing ancillary services markets and cost-sharing mechanisms;
- Regulating captive power plants to improve the flexibility of the power system and promote the engagement of such generators in wider electricity ancillary services;
- Allowing distributed renewable generators to engage in retail business.

Together, these measures hold the promise of substantially reducing the curtailment of wind power and solar PV. Further support will come from other instruments such as compensation

mechanisms for curtailment, and a green certificate scheme. Nevertheless, a number of obstacles threaten to undermine the benefits intended [31]. First and foremost, some local governments continue to subvert national policy by directly determining which generation plant sells to which consumer, and at what price, as well as ignoring the required guaranteed hours for renewable energy dispatch. Second, the green certificate scheme cannot operate effectively if the power market itself is being distorted. These and other features of China's power sector are also likely to threaten the effectiveness of the new national carbon emissions trading scheme.

6. Conclusions

China's strategies to support a low-carbon energy transition since 2005 have met with a high degree of success as measured by the installed capacity and consumption of renewable energy. Much of this success has been achieved through the deployment of the government's traditional administrative policy instruments supplemented by substantial financial support. Such an approach is consistent with the wider political institutions of governance as well as the institutions that govern the electrical power sector. Critical to the success of these strategies has been the deployment of both political and financial capital. The leaderships of both Hu Jintao and Xi Jinping devoted considerable political capital towards constraining the rise of carbon emissions and reducing air pollution. In addition, they directed tens of billions of dollars of state funds to drive forward these policies. Further support has comes from the availability and mobilisation of human capital in the form of a relatively strong cadre of technologists and a dynamic entrepreneurial spirit in the private sector and parts of the state-owned sector.

In this way, China can be seen as a mature, limited-access order (applying the terminology of North et al., [8]) that has shown remarkable adaptive capacity in relation to the low-carbon energy transition. The availability of financial and human capital has compensated to some degree for the relatively weak adaptive capacity of its governance institutions. In other words, the government has tackled the challenge of cleaning up the energy sector through the deployment of mainly traditional, administrative policy instruments with few changes to the main governance institutions. This contrasts with western scholarly preferences and, to a lesser extent, western government strategies to rely on market-based instruments and more bottom-up governance institutions. Whilst this approach has yielded substantial benefits to China in terms of the manufacturing, export and domestic deployment of renewable energy equipment, it has been hugely inefficient use of resources in terms of curtailment of energy capacity and industrial overcapacity.

It would be dangerous to be overconfident on the future trajectory of China's carbon emissions. First, the leadership could decide to boost economic growth, a measure that would boost coal consumption, at least in the short term. This seems to have happened in the latter part of 2017. Second, the institutions governing the power sector might prevent sustained emissions reduction, even at low levels of economic growth. Evidence for this second possibility can be seen in the continuing obstacles facing the central government as it tries to overcome resistance from actors with different agendas and to react to unanticipated events. So, whilst China may be close to reaching peak carbon emissions, it is too early to tell how soon the trajectory will take a sustained downward turn.

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