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Catching up through green windows of opportunity

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Renewable energy and sustainable development

There is worldwide attention on environmental innovation as concepts and political agendas focus on challenges related to green growth, low-carbon technology development and sustainability transition. Central to meeting these challenges is the need to address the tensions between the environment and the current (unsustainable) economic regime. However, achieving the political goal of building green economies requires a holistic perspective that links economic policy with controlled carbon emissions and enhanced energy and resource efficiency. A reorientation of investments to greener industries and businesses relies largely on green technological innovation and the creation of new sectors, with both elements driven by policy initiatives (Schot and Steinmueller 2018; Geels et al. 2017; Borel-Saladin and Turok 2013).

Conceptually, the transition to sustainability consists of "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al. 2012: 956). Given its relative immaturity, this transition often relies on the scaling up of innovative 'niches' in green technologies (Geels 2007). Research focused on advanced economies has shown that the rolling out of green technologies typically requires protected experimental and learning spaces for the nurturing and empowering of innovation. These spaces have nurtured the development of renewable energy technologies in many countries, promoted by domestic environmental policies that seek to promote sustainable solutions for the incumbent fossil fuel-based energy system (Sachs et al. 2019; Hayashi et al. 2016).

Recently, scholars have analysed how the green transformation influences latecomer development in emerging economies. Green windows of oppOrtunity (GWOs) refer to favorable but time-bounded conditions for catching up, arising from changes in institutions, markets, or technologies, associated with the green transformation (Lema et al. 2020). They are specific specific windows of opportunity (Perez and Soete 1988; Lee and Malerba 2017) that emerge in the context of global challenges of climate change and the response from governments and companies indicate that some of these green windows of opportunity are linked directly to sustainable transition. Windows of opportunity can result from domestic policy and institutional windows, demand (Landini et al. 2020) and major shifts in technology (Dai et al. 2020). In general, open windows allow companies to catch up by pursuing one of three paths: Following the developments of other industrial actors; skipping stages in industrial evolution; or creating new technological paths for the global industry (Lema et al. 2020). In China, a unique environment for renewable energy industries has been driven by windows of opportunity related to government policy, access to technology and company responses (Urban 2020 and Zhou; Lema et al. 2020; Dai et al. 2020).

This chapter addresses the transition to sustainable energy sources and innovative solutions in China. It shows how the Chinese response to the sustainability challenge is dependent on both technological and institutional innovation. The cornerstone of the country's transition of its energy system towards green energy sources is founded on diffusion, combination and adaptation of renewable energy technologies. While diffusion is an innovative process in its own right, combination facilitates the development of green energy technology. Meanwhile, adaptation of this technology relates to the dynamic capabilities of the industry. All three elements are processes dependent on technological and institutional innovation. Indeed, combining technological and institutional innovation has been key in the transformation towards sustainable energy production and consumption in China (CNREC 2018; Lewis 2012).

In some of the technological areas related to renewable energy presented in this chapter, the catch-up of China has been supported by Sino-Danish research collaboration. This is the case for wind power (see Chapter 4, 5 and 6), solar thermal energy (see Chapter 7) and district heating (see Chapter 8).

This chapter is organized as follows. Section 2 looks at the bigger picture, outlining the environmental challenges and the policy responses initiated by central, provincial and urban governments in China. Sections 3 to 7 focus on renewable energy and offer insights from the trajectories of key renewable energy technologies. Finally, Section 8 discusses the wider global implica-

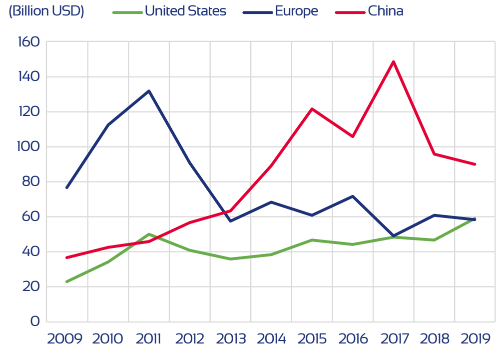

Figure 1 New renewable energy investments in the United States, Europe and China (2009 to 2019) (Source: Renewables 2020 Global Status Report)

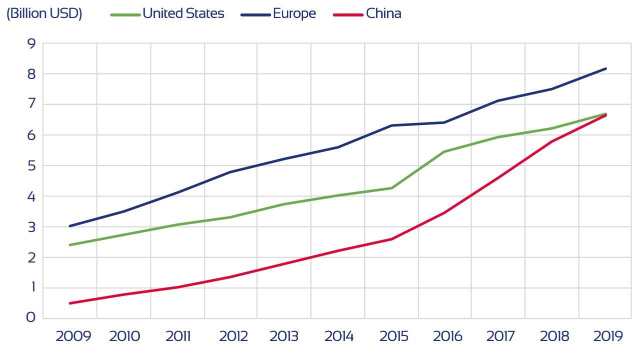

Figure 2 Renewable energy consumption in power generation (excluding hydro power) of the United States, Europe and China (2009 to 2019) (source: BP 2020)

tions of China's growing innovation capacity in green technologies, both in terms of global competition and collaboration in renewables.

The significance of China in renewables

The intense pressure to green China's economy has led to a host of ambitious initiatives. Whereas the prior section sought to shed light on the motivation driving these initiatives, this section aims to show how this is translated into renewable energy diffusion on the ground. We start by providing an overview, before moving onto specific sectors of renewable energy technology.

China has made remarkable strides in both consumption and production of renewable energies and the country aims to become a global technology leader, particularly after the United States announced its decision to withdraw from climate change initiatives. International organizations, such as the International Energy Agency (IEA), predict that China will continue to lead the world in renewable energy development (IEEFA 2017a). Among the 30 leading global science and engineering hubs in 2020, seven are in China, the centre of gravity for patents and publications within biotech, pharma, food and climate tech (ATV, 2020). Denmark is not on this list.

Influential policy initiatives have seen financial resources channelled to the industry. As shown in Figure 1, since 2013 new renewable energy investments in China have exceeded both the United States and Europe. Despite a significant drop in 2016, China still leads in global renewable energy investment, acounting for 29.84% of new investment in 2019 (REN21 2020). Meanwhile, China is also positioning itself as a global leader in overseas clean energy investment, operating alongside the country's Belt and Road Initiative (IEEFA 2017b).

China dominates global growth in renewables. Central milestones in its industrial development - stimulated by institutional windows of opportunity - were the local content requirements introduced in 2003 and the Renewable Energy Law implemented from 2006. The Renewable Energy Law set long-term targets and prioritized renewable energy in the national grid system, leading to unprecedented growth of the domestic market and industrial catch-up. In 2016, China surpassed the United States to become the largest producer of renewable power. Total renewable installed capacity reached 570 GW, with hydro power providing 332 GW, wind 149 GW, Solar PV 77 GW and bioenergy 12 GW (NEA 2017b). In 2016, the total global renewable capacity addition amounted to 165 GW of which 68 GW was installed in China (IEEFA 2017a; see also Zhou et al. 2020).

Figure 2 shows power consumption in China, the USA and Europe between 2009 and 2019 from renewable sources such as wind, geothermal, solar, biomass and waste. China has made significant progress in its use of renewable energies, rising from only 0.52 exajoules[1] in 2009 to 6.63 exajoules in 2019 (BP 2020). China's share in global consumption increased from 6.31% in 2009 to 22.88% in 2019.´

China is increasingly taking a leading role in renewables. Rapid expansion of the renewable energy sector is not only a result of sizable government financial support and extensive regulatory measures, but also relies on China's increasing innovation capacity in many renewable technologies, such as solar PV and wind. Since 2000, a substantial amount of science and technology funding in China has been allocated to the renewable energy sector (Huang et al. 2012). A growing number of clean energy research centres are being established, and more funding is being provided for the R&D of early-stage and high-risk new energy technologies. Building on the country's political agenda to support transformative and indigenous innovation, technological innovation capacity is seen as key in increasing China's global competitiveness and securing its leading role in the renewable energy technology sector. Indeed, as this capacity has been generated in only two decades, it represents a remarkable catch-up by the renewable energy industry.

1 1 exajoule = 10^{18} joules, approx. 23.9 mtoe

Table 1 China's share of patents of selected renewable energies (2005-2016, cumulative).
Source: IRENA INSPIRE based on data from EPO PATSTAT. The EPO Climate Change Mitigation Technology classification was also used.

Technology	Percentage (%) 2005-2010	Percentage (%) 2011-2016
Solar Thermal	32.78	40.75
Solar PV	10.95	19.19
Wind Energy	15.94	25.05
Biofuels	14.54	19.12

With strong governmental support for technological innovation, the past decade has seen the rise of innovation capacities across multiple green sectors in China. Consequently, the sector has transformed itself from a follower to a world leader in certain technologies. This is illustrated in Table 1 which shows China's share of patents for four renewable energy technologies. Before 2006, China possessed relatively weak innovation capacities within these four technology sectors, while from 2006 to 2010, patent applications significantly increased. In 2011, China became the country with most patents in solar thermal, wind energy and biofuels (Helm et al. 2014). Taking biofuel as an example, before 2001 there were less than ten biofuel inventions in China annually, but by 2011 this number had shot up to 931 (Albers et al. 2016).

Wind energy

Since 2009, China has been the largest market for wind power in the world. Over ten years, China has maintained its leadership position in new installations. Figure 3 shows the new and cumulative installed capacity of wind energy in China from 2006 to 2018. In 2018, China installed an additional capacity of 21.1 gigawatts of wind energy and maintains its position as the world's wind power leader, with a total wind capacity of 210 gigawatts (CWEA). Figure 4 illustrates the trend of electricity generation from wind energy in China, in which a significant and steady increase can be observed.

To understand the reasons behind this success in wind, it helps to examine how China was able to increase its share of the global market. Historically, the sector mainly focused on on-shore technologies and relatively small turbines. More recently, wind turbine manufacturers have developed partnerships for offshore technology and digital solutions for system integration (Dai et al., 2020). We can identify four interrelated sources of wind energy competitiveness that have created the windows of opportunity for the domestic industry to develop (Schmitz and Lema 2015; Haakonsson 2020).

The first is the strength of the home market. The Chinese government, understandably concerned with energy security, has fostered the production of renewable energy. The 2005 Renewable Energy Law was the institutional disruption that opened different windows of opportunity across new energy industries (Lema et al 2020). It translated sustainability-induced pressures into legislation that has since been implemented and incorporated into sector specific political plans across Chinese ministries. Along with other complementary policies, the Renewable Energy Law initiated the rapid development and expansion of a domestic market for wind turbines. Foreign enterprises were not directly prevented from competing in this market, but Chinese enterprises were favoured, as they received government support through various means, some visible (e.g. local content requirements

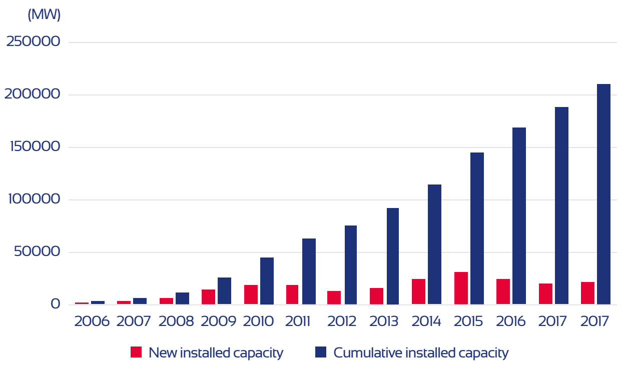

Figure 3 New and cumulative installed capacity of wind energy in China (2006-2018) (source: Chinese Wind Energy Association)

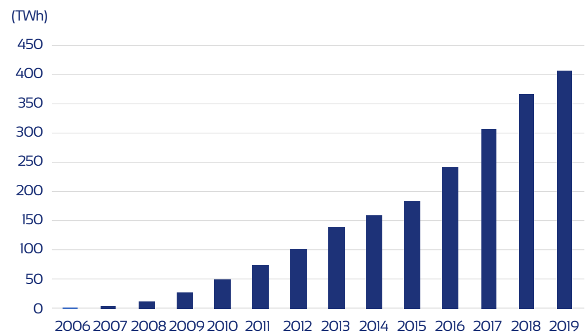

Figure 4 Electricity generation from wind energy in China (2006-2016) (source: National Energy Administration statistics, 2009-2019)

in place between 2005-2009), others less visible (e.g. the difficulty experienced by foreign enterprises in winning competitive bidding for state-funded projects). Since the Chinese market was large and growing rapidly, success in this market had a major impact on global market shares at the company level (Lema, Sagar and Zhou 2016).

The second source of Chinese competitiveness is producer power and capacity. The size and rapid growth of the domestic market enabled Chinese wind turbine manufacturers to adopt a model of industrial organisation geared towards economies of scale. A turbine is a complex product typically comprising more than 10,000 parts. While leading European firms - such as Vestas of Denmark and particularly Enercon of Germany - produced many of these parts in-house (seeking to constantly improve design and quality), their Chinese counterparts to a much greater extent relied on buying components from suppliers who also supplied other turbine makers and were thus able to achieve economies of scale and reduce costs. This was possible as many of the European component suppliers were developing spin-offs of their specialised components by designing plug-in solutions that would function as modules for highly specialised parts, such as control systems and blades. Simultaneously, international standards and certification agencies were evolving (Haakonsson et al. 2020).

The third source of competitiveness is financing power. This is as yet little explored in the literature but is of increasing importance. Crucially, Chinese firms can offer supplier credit, while this is much more difficult for Western firms. This is hugely significant for their customers since investment requirements for wind farms are high and time frames are long. Project finance is particularly important for competing in export markets. Compared with their Western counterparts, Chinese companies have deep financial pockets. Sinovel, for example, which is no longer among the leading firms, had a 6.5 billion USD line of credit from government-owned banks (Schmitz and Lema 2015), while China Exim Bank has injected capital into Goldwind and Ming Yang to support foreign expansion. This type of support facilitates an export model that has not been directly exploited by European companies – the pulling together of wind farm project finance and turbine exports, a full package solution integrated in industrial policy. Many new projects undertaken abroad by Chinese turbine firms have been implemented with tag-along finance.

The fourth pillar of competitiveness is the strength of innovation. The extent of China's development of innovation capabilities in wind energy is contested and difficult to accurately specify. Some analysts question China's ability to achieve high utilisation efficiency from their turbines (Physics World 2018) and critics point out that key innovations, such as Goldwind's permanent magnet Direct-Drive (PMDD) technology, was in fact invented in Goldwind's German subsidiary, Vensys.

Although it is clear from patent analysis that Chinese turbine firms have less advanced innovation profiles than their European and North American counterparts (Zhou et al. 2016), it is clear that the pace of learning is unprecedented, with significant advances from production to innovation capabilities within a ten-year time span (Hansen and Lema 2018; Dai et al. 2020).

Solar photovoltaics

Development in the solar-photovoltaic (Solar-PV) industry has been very different from the wind energy industry, as the domestic Chinese market only became a significant factor very recently. The Solar-PV industry started out as an export-oriented industry catering almost exclusively to the international market. Through 'learning from exporting'strategies, Chinese manufacturers have upgraded their position in the value chain in a short time-span, moving from supplying components to building complete solar panels under their own brands. Rapidly, we witnessed Chinese Solar-PV companies undercutting European and American manufacturers, leading to major job losses and prompting a trade war (Fischer 2012).

Chinese companies, backed by the government, caused a major disruption in the market and drove down costs in the solar panel industry. These dynamics were markedly different from how the wind sector evolved from the domestic market. In Solar-PV, Chinese companies managed to build up manufacturing potency by catering to the world market, while the domestic market – and policies for reducing greenhouse gas emissions domestically – played a minor role, if any. Solar-PV production was driven by exports during its 'take-off' phase. Exports from Chinese companies enabled China to replace the EU as the leader in the production of Solar-PV equipment (Fischer 2012; Lema and Lema 2016). Indeed, in contrast to the wind sector, in which Chinese manufacturers still produce predominantly for the Chinese market, the Chinese Solar-PV sector has partially emerged on the basis of policy support for solar-energy deployment schemes outside China, mainly in Europe. This sector has relied on demand-led and institutional windows of opportunity abroad.

The development of China's Solar-PV sector originated from the production of PV cells and modules. By focusing on these elements, enterprises concentrated on the steps in the Solar-PV value chain in which they enjoyed a competitive advantage due to low labour costs, economies of scale and comparatively weak environmental standards applied to production processes. The development of the Chinese Solar-PV sector and exports to key markets have also been facilitated by modularization and comparatively low transportation costs.

Although the industry has been growing since the turn of the century, securing a share of the domestic market share was not a priority until around 2010 when the industry faced restrictions in international markets due

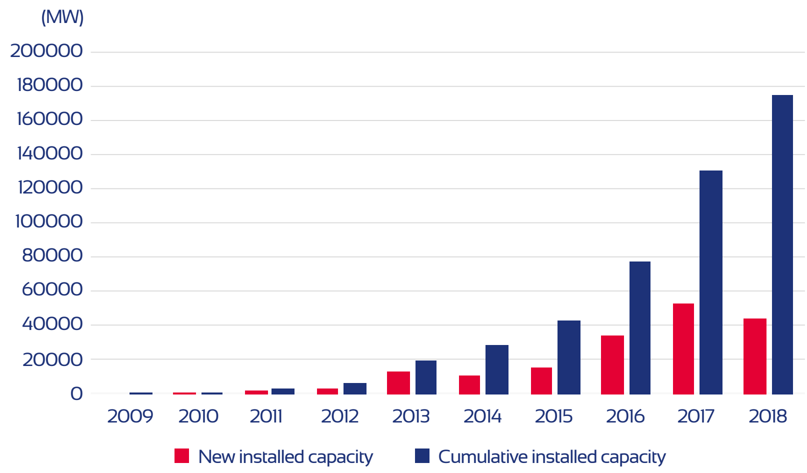

Figure 5 New and cumulative installed capacity of solar PV in China (2009-2018)
(source: European Photovoltaic Industry Association, National Energy Administration of China)

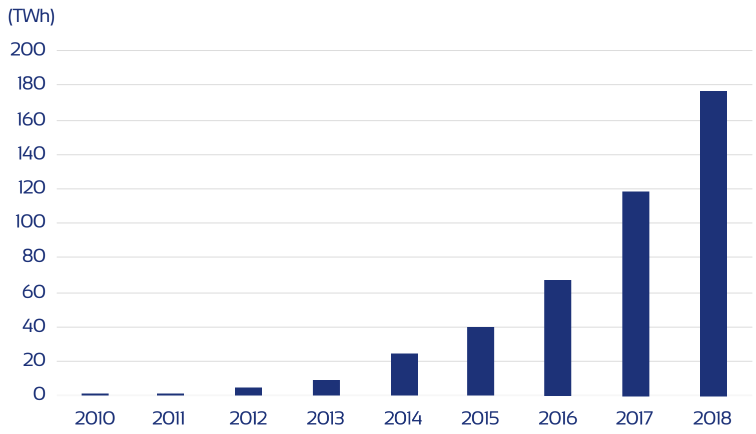

Figure 6 Electricity generation from solar PV in China (2010-2016)
(source: China Electricity Council statistics from 2011 to 2019)

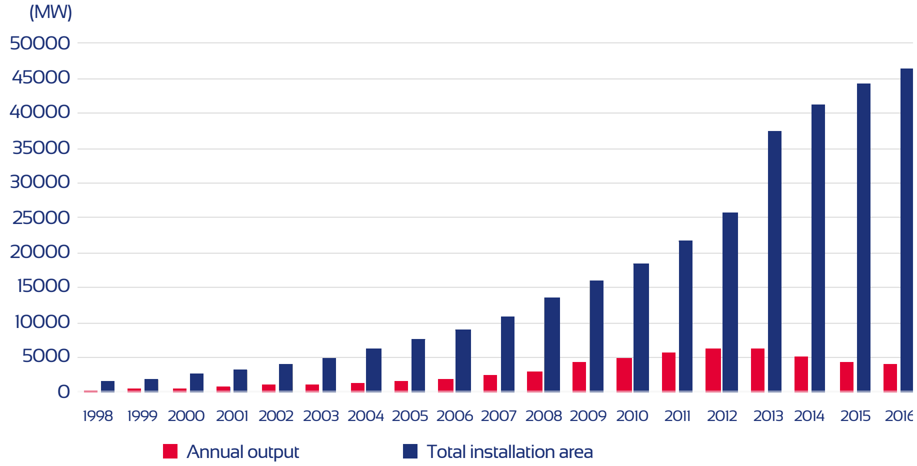

Figure 7 Annual output and total installation area of solar water heaters in China (1998 to 2016)
(source: Solar Vision)

to the financial crisis and anti-dumping measures. In China, government support for the industry was driven by local economic considerations and by the backing given by local government to other export-oriented industries (Iizuka 2015). Hence, a domestic market developed on the back of support schemes initiated to foster the use and deployment of PV energy technology in China, precisely when export-oriented manufacturers of Solar-PV cells and modules faced falling external orders, particularly in Germany. In essence, when central government started to support PV energy use within China in 2009, the Chinese PV industry was already a highly capable manufacturer and a strong competitor in global markets. Figures 5 and 6 show the increase of solar PV energy applications in China since around 2009.

Solar thermal energy

China is leading the global solar thermal market (Islam et al., 2013). At the Copenhagen Conference in 2009, Premier Wen Jiabao referred to China as leading the world in the application of solar water heaters. In 2019, China accounted for 69% of total global installed capacity, followed by the United States, Germany and Turkey (REN21, 2020). Figure 7 shows the annual output and total installation area of solar water heaters in China from 1998 to 2016.

Though the drivers behind China's dominance in the global solar thermal market are multiple, three factors stand out.

First, during the early stage of creating a pathway, key indigenous innovations made large-scale industrial production of solar water heaters possible. Together with huge domestic demand for hot water use, a niche market was successfully opened up. In 1984, Professor Zhiqiang Yin at Tsinghua University patented evacuated glass tubes, marking the start of large-scale industrial production of water-in-glass evacuated tube solar water heaters in China. Since then, the market has steadily grown.

Second, leading enterprises in solar water heaters placed technology innovation at the centre of their development strategy, dedicating substantial financial and human resources to R&D activities. In addition to R&D capacity building within enterprises, cooperation with research institutes and universities was another important mechanism for the establishment of innovation capacity. For instance, in 2007, a research centre was jointly established by Linuo Paradigma, a leading solar thermal enterprise in China, and Tsinghua University. Later in 2010, another solar research institute was formed by Linuo Paradigma, together with Shanghai Jiao Tong University. Cooperation between enterprises and universities advanced R&D in solar thermal technologies. It is estimated that Chinese enterprises have patented more than 95% of global solar water heater technologies (Chinadialogue 2014).

Third, government support played a significant role in further deployment of solar water heaters in both rural and urban China, generating demand and windows of opportunity for the industry to grow. In 2009, solar water heaters were included in the national *Home Appliances to the Countryside (HATC)* scheme, which sought to exploit the unexplored rural market to offset the impacts of the 2008 global financial crisis by providing rural residents with government-subsidized home appliances. The HATC scheme prompted the opening up of the large rural market. Simultaneously, from 2005 mandatory policies for the installation of solar water heaters in buildings have been enforced in many Chinese cities. Initially implemented in low- or multi-storey buildings, the mandatory policy was later extended to high-rise buildings, which created a new market segment for solar water heaters, the 'construction project market' (Huang et al., 2018b). Contracts are often signed directly between real estate developers and manufacturers to install solar thermal products for an entirely new-built neighbourhood. This mandatory policy has boosted market expansion in urban areas, though a number of problems emerged. For instance, in order to meet government requirements and at the same time control construction costs, many real estate developers chose to purchase low-cost, low-quality solar water heater products, resulting in poor user experiences and thus jeopardizing the development of the industry as a whole (Yu and Gibbs 2018).

Bioenergy

Bioenergy refers to energy generated from the conversion of solid, liquid and gaseous products derived from biomass. Biomass is organic matter available on a renewable basis, such as feedstock derived from animals or plants, and organic waste from municipal and industrial sources (source: IEA). In China, the use of biomass resources was officially encouraged by the 2005 Renewable Energy Law. Bioenergy has been used in a number of sectors including electricity generation, transportation and heating. While the biomass power and liquid biofuel (mainly bioethanol and biodiesel) industries have reached a significant scale, other biofuel industries, such as biomass briquettes, are still in the early stages of development.

China has a long history of biofuel innovation and utilization. As early as the 8th Five-Year period (1991-1995), some research institutes started to conduct experiments in biodiesel (Yuan et al. 2009). Later, during the 10th Five-Year period (2001-2005), biodiesel technology was included in the National High Technology R&D Program of China (863 Program), funded by the Ministry of Science and Technology (MOST). In 2006, the National Development Reform Commission (NDRC) established approximately 30 demonstration projects for bioenergy technology nationwide. In the *12th Five-Year Development Plan for Biology Technology* and the *13th Five-Year Special Plan for Biology Technology Innovation*, published by MOST, bioenergy technology was included as a key strategic area. The focus was placed on supporting and promoting R&D in key bioenergy technologies, such as non-grain fuel ethanol, biodiesel, biogas and specialized equipment for production processes of bioenergy products (Chen et al. 2016). Two national R&D centres, the National Energy R&D Centre for Liquid Biofuel and the National Energy R&D Centre for Non-food Biomass, were established in 2010 and 2011 respectively.

In October 2016, the National Energy Commission (NEA) announced the *13th Five-Year Plan for Bioenergy Development*. Specific targets were set for the development of different biofuels up to 2020 (Table 3). For instance, the total installed capacity of biomass power was expected to reach 15 GW, and the annual production of liquid biofuel 6 million tons.

To promote the application of bioenergy, the Chinese government has deployed a number of policy instruments, including subsidies and tax reductions. For instance, since 2010, new agricultural and forestry biomass power generation projects have been able to benefit from a feed-in tariff of 0.75 RMB/kWh. Similarly, subsidies have been provided for bioethanol production. In 2012, subsidies for grain ethanol and non-grain ethanol were 500 RMB/ton and 750 RMB/ton, respectively. Government support has significantly driven the diffusion of bioenergy technology and the expansion of the biofuel industry. However, a number of challenges remain, such as low levels of specialization, marketization for biomass briquette and biogas technology, and a lack of comprehensive standards, including testing and certification standards.

Emerging renewable energy sectors

In addition to conventional renewable energy sources, such as wind and solar, China is also exploring other new energy technologies.

A must-mention technology is the new energy vehicle (NEV). According to the State Council of China, NEVs include plug-in hybrid electric vehicles, battery electric vehicles and fuel cell vehicles. As early as the *8th Five-Year Plan* (1991-1995), central government started to support the development of NEVs in China. Ever since, the significance of the NEV industry has been articulated in multiple national plans and strategies. Targets have been set for each phase of technology development from basic and applied R&D to demonstration and commercialization. After nearly three decades, China has established a relatively comprehensive technological system, with more than 3000 patents and 30 energy-saving and NEV-technology innovation platforms (MOST 2012). The rise of leading NEV enterprises, such as BYD, demonstrate China's growing technology capacity. NEVs produced by BYD are now operating in more than 200 cities across 48 countries, including Japan, the USA and the UK (IEEFA 2017b).

China has also made significant progress in smart grid development. In China's *13th Five-Year Plan for Power Sector Development* (2016-2020), accelerating the development of the smart grid is specified as a main task. The smart grid is also listed as one of the major projects in *Science and Technological Innovation Report 2030*. The period between 2011 and 2015 saw the widespread construction of smart grids (H3C 2010), led by major power grid corporations. By the end of 2014, the State Grid Corporation of China (SGCC) had initiated a total of 358 smart grid projects, of which 305 were complete (State Grid 2017). In the next stage, China aims to further enhance the smart grid system, a process that will involve the development of smart power transmission and transformation technology, and the improvement of grid connection and integration technology for large-scale renewable energy resources (Han et al. 2017).

The building sector is another focal area. In the *12th Five-Year Plan for Economic and Social Development*, the introduction of green buildings was formally proposed (Zhang et al. 2018). In 2017, the *13th Five-Year Plan for Building Energy Efficiency and Green Building Development* was published, including the requirement that by 2020 50% of all new urban buildings would be certified green buildings. China has paid special attention to the improvement of innovation capacity in green building and the government has supported a number of scientific projects on green buildings. The technology behind energy saving buildings is also a major focus of the *13th Five-Year Plan on Scientific and Technological Innovation*. This development is being driven by a combination of innovations – a bricolage of technological solutions that together have the potential to develop houses that generate more energy than they use (WinDoor City). Partnerships have been formed with European and US companies that employ more advanced technologies in this area (MHURD 2017). These partnerships are re-

Table 2 Targets of bioenergy development in China by 2020

Bioenergy	2020 Target	2015 Level
Biomass power installed capacity (GW)	15	10.3
Biomass briquette annual consumption (million tons)	30	8
Bioethanol annual production (million tons)	4	2.1
Biodiesel annual production (million tons)	2	0.8

markable in the sense that many of these companies would not have collaborated in their home markets, in which competition is fierce.

Compared to other technologies, the development of concentrated solar power (CSP) is relatively new in China. CSP denotes technologies that 'use mirrors to focus and concentrate sunlight onto a receiver, from which a heat transfer fluid carries the intense thermal energy to a power block to generate electricity' (U.S. Department of Energy, 2014: p. 34). Although CSP was listed as a key technology in both the *Summary of National Mid & Long-Term Science and Technology Development Plan (2006–2020)* and the *Mid & Long-Term Development Plan for Renewable Energy*, China is still in the early stages of CSP commercialization. By the end of 2012, only six demonstration CSP stations had been constructed, three were under construction, and 14 other projects were in the preparation stage (SGERI 2013).

In September 2016, the NEA published the *Notice on the Construction of Solar Thermal Power Demonstration Projects*. This marked the beginning of large-scale demonstration CSP projects in China, under which a first round of 20 projects were selected as national demonstration projects. However, the implementation of these projects did not run smoothly, and four were eventually terminated (Economic Daily 2018). To address the situation, in May 2018, the NEA released the *Notice on Promoting the Construction of Solar Thermal Power Demonstration Projects*, extending the deadline for completion of demonstration projects from the end of 2018 to the end of 2020, and establishing, in th mean time, a clawback mechanism for subsidized electricity prices. Overall, the development of CSP is still at an early stage in China. The success of national demonstration projects will be key for the commercialization of this technology and the channelling of private financial resources.

Conclusions: Upgrading renewables in China

Over a remarkably short time span of only two decades, Chinese researchers and companies have not only been able to catch up, but also take a leading position in renewable energy industries. A number of green windows of opportunity facilitated industries to move from path-following towards market or technological take-over. This paper has shown how Chinese industries have caught up in wind turbines, Solar-PV, thermal solar power and biomass. This industrial 'catch-up' can be directly linked to green windows of opportunity, rooted in national policy, the development of technological capabilities, and the creation of domestic and international markets. These windows were both domestic and international, and in the case of the latter were linked to changes in foreign markets (e.g. solar-PV in Europe) or to opening up new networks and alliances with foreign actors, such as lead companies and universities (e.g. wind turbine industry). Chinese companies have demonstrated high levels of adaptability and creativity in devising solutions to issues of up-scaling and mass production. These solutions are based on a combination of three core elements that are opening new green windows of opportunity - access to technological solutions, domestic markets and, not least, the support of domestic policies. Chinese actors are playing an important role in further developing renewable energy.

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