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Title:
Low-carbon (Re-)Industrialization: Lessons from China

Date:
2017

Citation:
Lo, K. & Wang, M. (2017). Low-carbon (Re-)Industrialization: Lessons from China. Nawratek, K (Ed.). Urban Re-industrialization, (1st), pp.149-158. Punctum Book.

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Chapter 14

# Low-Carbon (Re-)Industrialization Lessons from China

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## Intoduction

The difference between (re-)industrialization in the past and present is that energy security and climate change now increasingly frame the space in which such processes take place. Therefore, there is an urgent need to rethink (re-)industrialization as part of a low-carbon future, rather than as something that perpetuates the current carbon-intensive mode of production and consumption. The aim of this chapter is to explore the concept of low-carbon industrialization, which has recently gained significant traction in China as part of the rethinking process. More specifically, this chapter seeks to clarify the meaning of low-carbon industrialization, supported by examples from China. The chapter also seeks to transfer lessons from China's experience with low-carbon industrialization to the context of (re-) industrialization. To anticipate the conclusion, this paper argues that both top-down and bottom-up initiatives can be important in low-carbon (re-)industrialization and that their appropriateness depends on the market structure and technological characteristics of the industry.

Following this short introduction, this chapter discusses energy security and climate change, which are the key challenges to (re-)industrialization. Next, it defines low-carbon industriali-

zation and illustrates the concept with the development of photovoltaic, wind turbine and solar water heater industries from China. This chapter concludes with a discussion of the lessons learnt from China's experience with low-carbon industrialization.

## Key challenges of re-industrialization: energy security and climate change

Improving energy security and tackling climate change are two of the greatest challenges of the twenty-first century. One of the key energy security concerns is peak oil, which refers to the peaking or plateauing of the production of petroleum. Although the timing of peak oil remains the subject of heated debate, mainly due to uncertainty over the size of ultimate recoverable reserves (especially in unconventional, but often controversial places such as the Arctic), there is an increasing consensus that high-quality, low-cost conventional oils are declining and beginning to be substituted by low-quality, expensive sources such as Alberta's tar sands and heavy oils in the Orinoco Delta.[1] Coupled with the increasing demand from developing countries, oil prices are more than likely to continue to rise. Another energy security concern is energy dependency upon politically unstable territories.[2] Such concern has driven governments to implement policies to reduce dependency on imported energy by increasing the domestic supply of energy (which may or may not be renewable) and reducing demand through energy conservation measures.

Climate change refers to significant and long-term changes in the average weather patterns caused by the emission of greenhouse gases (e.g., carbon dioxide and methane), mainly from the combustion of fossil fuels but also from non-combustion

1 Gavin Bridge. 'Geographies of Peak Oil: The Other Carbon Problem', *Geoforum* 41 (2010): 523–30.

2 Erica S. Downs. 'The Chinese Energy Security Debate', *China Quarterly* 177 (2004): 2–41.

sources such as non-energy industrial processes and agriculture, forest, and other land use (AFOLU). It is now generally accepted that the adverse effects of climate change include global warming, an increased likelihood and intensity of extreme weather events, and rising sea levels.[3] The internationally institutionalized climate change target, first established by the Copenhagen Accord (UNFCCC, 2009)[4] and subsequently ratified in the Cancun Agreements (UNFCCC, 2010),[5] is to constrain global temperature change to two degrees above the pre-industrial level. This temperature target could be achieved by a 450 ppm [parts per million] $CO_2$ stabilization level. The long lifetime of greenhouse gases, particularly $CO_2$, means that to achieve this target carbon emissions need to peak as soon as 2014.[6]

The two carbon problems are curiously contrasted, as noted by Bridge (2010), because energy security takes the form of flow constrictions and resource constraints, whereas climate change is fundamentally a problem of abundance and unrestrained flow. Nonetheless, energy security and climate change are connected by their relationships to the carbon-intensive mode of production and consumption. Prima facie, the two carbon problems appear to have made (re-)industrialization less desirable and viable as an urban development strategy due to the perceived energy intensity and carbon intensity of industrial activity. Using a general equilibrium model developed by the World Bank,

3 J. Houghton. *Global Warming: The Complete Briefing* (Cambridge: Cambridge University Press, 2004).

4 UNFCCC, Conference of the Parties (COP), *Report of the Conference of the Parties on its Fifteenth Session, Held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action Taken by the Conference of the Parties at its Fifteenth Session* (Geneva: United Nations Office, 2010), https://unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600005735.

5 UNFCCC, Conference of the Parties (COP), *Report of the Conference of the Parties on its Sixteenth Session, Held in Cancun from 29 November to 10 December 2010. Addendum Part Two: Action Taken by the Conference of the Parties at its Sixteenth Session* (Geneva: United Nations Office, 2010).

6 Chris Huntingford et al., 'The Link between a Global 2°C Warming Threshold and Emissions in Years 2020, 2050 and Beyond', *Environmental Research Letters* 7 (2012): 014039.

Mattot et al. (2011) estimated that even modest carbon control depresses industrial output by 3 to 3.5 percent and industrial exports by 5.5 to 7 percent for carbon-intensive countries such as China and India.[7] Arguments have been made that developing countries should bypass industrialization in pursuit of a service-oriented economy. However, it has also been argued that if the right path is taken, industrialization can contribute to the building of a prosperous, low-carbon future.[8] Zhang calls for a rethinking of industrialization as part of this future. As the world's largest carbon polluters, the concept of low-carbon industrialization is rapidly gaining currency in China as part of the rethinking process. This paper now turns to examine this concept.

## Low-carbon industrialization in China

There are in fact three meanings of low-carbon industrialization: (1) the decarbonization of existing carbon-intensive industries through energy conservation or carbon capture and sequestration; (2) the development of high-tech, high value-added and low-emission industries (e.g. biomedicine and information technology) and (3) the development of industries that manufacture low-carbon energy systems and infrastructures, such as products in energy efficiency (e.g. building insulation materials), renewable energy (photovoltaic and wind turbines) and climate adaptation. Because of the limitation of space, this chapter focuses on the third dimension of low-carbon industrialization, although it acknowledges that all three types are significant and useful responses to climate change. To further illustrate the level of complexity and variety even within this narrow definition of low-carbon industrialization, this chapter divides the abstract discussion into three examples: the photovoltaic industry, the

7 Aaditya Mattoo et al., 'Can Global De-Carbonization Inhibit Developing Country Industrialization?', *The World Bank Economic Review* 26 (2011): 296–319.

8 Zhang, L.-Y., 'Is Industrialization Still a Viable Development Strategy for Developing Countries under Climate Change?', *Climate Policy* 11 (2011): 1159–76.

wind turbine industry and the solar water heater industry. These examples are carefully chosen to demonstrate the diverse pathways through which low-carbon industrialization develops and evolves.

### *The photovoltaic industry*

Photovoltaic (PV) units convert sunlight into electricity by means of silicon-based materials. The PV production chain consists of upstream production (i.e. purification of silicon, casting silicon into ingots, and slicing ingots into wafers), which is capital- and technology-intensive and downstream production (i.e. assembling silicon wafers into cells and modules), which is energy- and labour-intensive.[9] Barriers to entry are high in upstream production but relatively low in downstream production, where entire turnkey production lines can be purchased and run without much prior experience. This provides a suitable entry point for Chinese start-ups such as Suntech, Yingli and Trina, which entered the downstream PV industry in the early 2000s. These private companies have been able to compete aggressively in the global market on a price basis, and have very quickly propelled China to be the world's largest PV cell and module manufacturer. However, China's position in upstream production remained weak until 2007, when China produced just 2.5 percent of the world's silicon.[10]Recently, Chinese firms have accumulated sufficient capital and technological know-how to venture upstream. By 2010, China had gained substantial market share in almost every step of the PV production chain: 33 percent of silicon processing, 52 percent of ingots and wafers, 50 percent of PV cells, and 28 percent of PV modules.[11] China's PV industry is export-oriented, with less than 10 percent of output

9 Arnaud De La Tour et al., 'Innovation and International Technology Transfer: The Case of the Chinese Photovoltaic Industry', *Energy Policy* 39 (2011): 761–70.

10 Ibid.

11 Alim Bayaliyev et al., *China's Solar Policy: Subsidies, Manufacturing Overcapacity & Opportunities* (Washington, DC: GW School of Public Policy and Public Administration, 2011), http://solar.gwu.edu/research/

absorbed domestically.[12] The export orientation of the PV industry reflects the lack of domestic installation — by the end of 2009, the cumulative installation of PV in China was 300 MW, equal to 3.3 percent of that in Germany.[13]

The development of the PV industry in China is largely a bottom-up affair. Until recently, Chinese authorities have done little to support the industry.[14] Rather, success is attributed to local entrepreneurialism, the recruitment of skilled executives from the Chinese diaspora, low energy and labour costs, and the subsidy of PV in Europe through generous feed-in tariffs.[15] The 2008 global financial crisis and the reduction in PV feed-in tariff and installation subsidies among European countries created problems with overcapacity and diminished profits. In response, the Chinese government introduced a series of supportive policies such as subsidized credit from state-owned banks.[16] Moreover, the government introduced direct subsidies and feed-in tariffs to boost domestic PV installation. Consequently, the cumulative PV installation in China skyrocketed from 300 MW at the end of 2009 to 3300 MW at the end of 2011, an increase by a factor of 11 over two years.[17] In 2012, the government promised to invest a further 15 billion RMB to increase PV installation by 5200 MW.[18] These policies have been instrumental in protecting the PV industry in China from collapse.

china%E2%80%99s-solar-policy-subsidies-manufacturing-overcapacity-opportunities

12 Bernardina Algieri et al., 'Going "Green": Trade Specialisation Dynamics in the Solar Photovoltaic Sector', *Energy Policy* 39: 7275–83.

13 Mo-Lin Huo and Dan-Wei Zhang, 'Lessons from Photovoltaic Policies in China for Future Development', *Energy Policy* 51 (2012): 38–45.

14 De la Tour et al., 'Innovation and International Technology Transfer'.

15 Ibid.; Bayaliyev et al., *China's Solar Policy*.

16 Jailu Liu and Don Goldstein, 'Understanding China's Renewable Energy Technology Exports', *Energy Policy* 52 (2013): 417–28.

17 Sufang Zhang and Yongxiu He, 'Analysis on the Development and Policy of Solar PV Power in China', *Renewable and Sustainable Energy Reviews* 21 (2013): 393–401.

18 Eric Savitz, 'China Solar Stocks Soar; Chinese Government Vows $2B in Subsidies', *Forbes,* December 12, 2012.

### *The wind turbine industry*

A wind turbine generation system (WTGS) generates electricity by capturing kinetic energy from wind to power a generator. Unlike the PV industry, the WTGS industry is vertically integrated and highly concentrated. In the early 2000s, four companies from Europe and the United States controlled the WTGS market: Vestas, Gamesa, Enercon and GE Wind.[19] Technical barriers to entry are high because the production of competitive WTGS requires specialized labour skills and technical know-how.[20] China forayed into the WTGS industry at approximately the same time as the PV industry, but through very different means. Foreign direct investment played a crucial role in the early days, with almost all leading companies investing in China.[21] Foreign WTGS makers were attracted to China because of the rapidly growing wind-power market driven by supportive policies, including direct subsidies and feed-in tariffs. Moreover, the requirement that at least 70 percent of the materials be sourced locally to be eligible for subsidies and feed-in tariffs practically forbade foreign companies from exporting components and turbines directly from China.[22] In short, the government created a condition that strongly incentivized foreign companies to establish production lines in China. In contrast to the PV industry, the WTGS industry in China is domestic-oriented, with very little export. The growth of the industry is thus inseparable from the strong, policy-driven growth in the domestic deployment of

19 Liu and Goldstein, 'Understanding China's Renewable Energy Technology Exports'.

20 Zhen-Yu Zhao, et al., 'Comparative Assessment of Performance of Foreign and Local Wind Turbine Manufacturers in China', *Renewable Energy* 39 (2012): 424–32.

21 Liu and Goldstein, 'Understanding China's Renewable Energy Technology Exports'.

22 Yuanchun Zhou et al., 'Joint R&D in Low-Carbon Technology Development in China: A Case Study of the Wind-turbine Manufacturing Industry', *Energy Policy* 46 (2012): 100–108.

WTGS, which became the world's largest in terms of cumulative capacity in 2010.[23]

Another interesting feature of the WTGS industry in China is the rapid rise of domestic manufacturers, which surpassed foreign-owned companies in China's WTGS market share in 2007 and secured a market share of 87 percent in 2010.[24] Joint research and development (R&D) projects are a key strategy of fast-track learning on the part of domestic manufacturers. Whereas the leading foreign companies invest directly in China to protect proprietary information, small-scale design and consulting firms usually collaborate with Chinese WTGS manufacturers in joint R&D. The acquisition of human capital is crucial to the process of technological transfer through joint R&D. For example, when the Shanghai Electric Company (SEC) and Aerodyn collaborated to design two MW wind turbines, SEC sent 30 engineers to Germany to receive professional training for one year.[25] Through the training, the engineers obtained a basic capacity to design wind turbines and gained knowledge about Aerodyn's technological foundation, such that they can collaborate with Aerodyn experts to design WTGSs that would satisfy local climatic requirements.

### *Solar water heaters*

Solar water heating (SWH) is a type of solar thermal technology used to heat water from direct sunlight. China's SWH industry has grown rapidly in the last decade. The annual SWH production increased from 6.1 million square meters in 2000 to 42 million square meters in 2009, making China by far the largest SWH manufacturer in the world.[26] A complete production chain has formed from raw material processing to final product assem-

23 Global Wind Energy Council, *Global Wind Report — Annual Market Update* (Brussels: Global Wind Energy Council, 2011), http://gwec.net/wp-content/uploads/2012/06/Annual_report_2011_lowres.pdf.

24 Zhou et al., 'Joint R&D in Low-Carbon Technology Development in China'.

25 Ibid.

26 Hu Runqing et al., 'An Overview of the Development of Solar Water Heater Industry in China', *Energy Policy* 51 (2012): 46–51.

bly. Vacuum-tube SWH, which relatively is less technologically intensive, dominates the market. Because the technological barriers are low, the industry is highly fragmented and competitive. There are over 5,000 SWH manufacturers in China, most of them limited in production capacity and product quality.[27] Nevertheless, a batch of large and influential enterprises has emerged in the sector, including four enterprises with an output value of 2 billion RMB.[28]

The most striking feature of the development of the SWH industry is that it is an entirely local initiative, with little reliance on the foreign market (unlike PV), foreign investments (unlike WTGS) and government intervention (also unlike WTGS). The key to success is that the SWH industry is able to produce products that can compete with traditional fuel-based water heaters on a price basis without the help of government subsidies. Using a life-cycle cost analysis of vacuum-tube SWH, Han et al. (2010) found that a household can save 342–3321 RMB in fuel costs annually, depending on household water use. Considering that SWHS are approximately 800–1,000 RMB more expensive than traditional water heaters, their payback period can be as brief as a few months. This economic competitiveness has led to a large domestic demand, with a 33 percent average annual growth rate of sales from 2006 to 2009.[29]

## Conclusions: lessons from China

The key lesson learnt from the present analysis of China's low-carbon industrialization is that there are many pathways of development. The PV industry was developed using the export-oriented model, primarily targeting the European market, which was booming thanks to generous feed-in tariffs. The development of the PV industry is mainly a bottom-up initiative,

27 Jingyi Han et al., 'Solar Water Heaters in China: A New Day Dawning', *Energy Policy* 38 (2010): 383–91.

28 Runqing et al., 'An Overview of the Development of Solar Water Heater Industry in China'.

29 Ibid.

with little involvement from the government until recently. The WTGS industry in China was developed with the help of direct foreign investment, either as wholly foreign-owned companies or as joint R&D projects. In either case, there has been a successful technology transfer to domestic companies, which now dominate the domestic market. The development of the WTGS industry is a top-down initiative, as government intervention is central, particularly in creating the conditions to attract foreign companies to China. The SWH industry was developed as a pure bottom-up initiative, with little involvement from foreign markets, foreign companies and government intervention. The success of the SWH industry lies primarily in its ability to outcompete traditional water heaters without the help of government subsidies.

To conclude, this chapter made two contributions to the discussion of (re-)industrialization in industrialized countries. First, it highlighted the imperative of rethinking (re-)industrialization in face of the two carbon problems; that of energy security and climate change. Second, this paper argued that low-carbon (re-)industrialization can be achieved through multiple alternative pathways. Both top-down and bottom-up initiatives can be important, and the appropriateness of the model depends on the market structure and technological characteristics of the industry.