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China's Energy Industrial Revolution (Part 2) 中国におけるエネルギー革命（第2部）

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This is part II of China's Industrial Energy Revolution: Renewable targets just became even more demanding by John Mathews and Hao Tan (The Asia-Pacific Journal, Vol 10, Issue 52, No. 2, December 24, 2012.)

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China's energy strategies have attracted a huge amount of attention, precisely because they have been so effective. Chinese energy companies – from global oil and gas giants, to new wind and solar power success stories as well as electric grid operators, not to mention rising Electric Vehicle (EV) producers – have all had an impact on the industry, and sometimes shaken it up. In solar Photovoltaic (PV) cells there are aggressive counter-moves being made by both the US (and potentially the EU) against Chinese subsidized exports. These threaten to spill over into related sectors, and could trigger an all-out trade war.

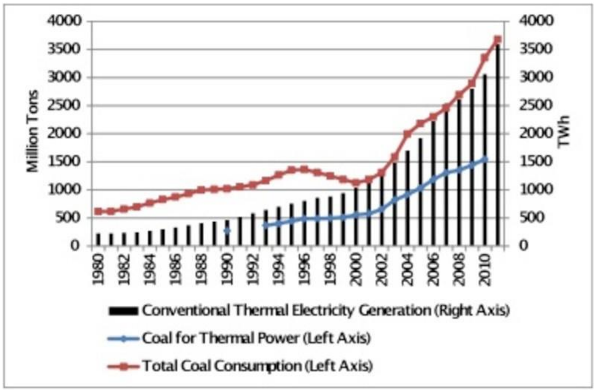
In such a setting, it is important we argue to understand just what the aims of the Chinese strategies and associated policies might be. Of course China is offering all kinds of subsidies, both direct and indirect, to its nascent renewable energy and nuclear power industries, which are viewed in China as essential guarantors of energy security and export platforms for the future. The fact that they can deliver lower carbon emissions is a convenient side effect. We make this point not to belittle the efforts of those who take seriously the environmental threat (after all, we count ourselves as amongst them) but to emphasize the primacy of 'growth' in China's 'green growth' strategies.

The fact is that China is undergoing an astonishing energy transformation that underpins an industrial revolution that is making it the workshop of the world. It is building its 'black' energy system at a prodigious rate – building the equivalent of a 1-GW thermal power station every week [1], and burning vast amounts of coal in doing so. But at the same time it is building a 'green' energy system based on non-fossil sources (renewables and nuclear) faster than any other country on earth. China's green revolution is reflected in its targets for building renewable energy systems, which are being expanded as fast as is humanly and technically possible – in the name of energy security and nation-building infrastructure as much as for decarbonizing the economy. Which wins in this close race between black and green development is a matter of the highest importance, for China and for the world.

There are two facets to China's energy revolution. There is a **black side**, where the focus is on China's relentless mining and burning of coal – billions of tons of it – and building new coal-fired power generators, on a scale that dwarfs efforts in the rest of the world. China's coal production and consumption moved rapidly into a new gear after the country's accession to the WTO in 2001 – and it has been on a steep upward curve ever since, as shown in Chart 1.

Fig. 1 – China's black face: Chinese power

generation and rising coal consumption

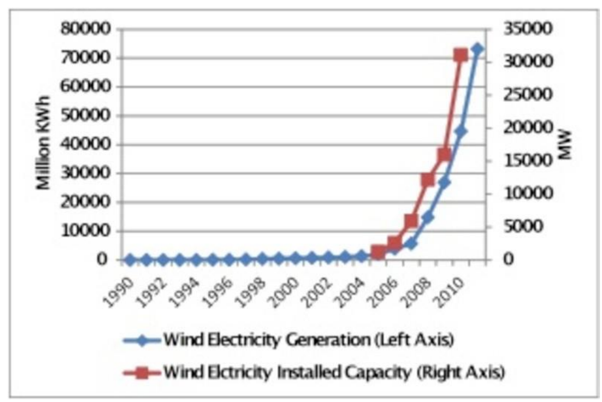


Source of primary data: the data of total coal consumption and electricity generation is available from US Energy Information Agency US EIA); the data of coal consumption for thermal power is available from National Bureau of Statistics of China

China consumed 3.4 billion tonnes of coal in 2010, doubling its consumption over just six years – and burnt 1.5 billion tonnes of this coal in power stations (46%). In the face of predictions of coal's falling away as an energy source, China's rise has put it back at the centre of the world energy industry. The steep upward curve in coal consumption and energy production since 2001 is clearly evident.[2

But China also has a **green face**, where it is building new renewable energy industries also on a scale that dwarfs efforts in the rest of the world. Renewable energies had been a 'plaything' of the West, ramped up in the 1970s in response to the 1973 OPEC oil price increase and the subsequent price increase following the Iranian Revolution in 1979, but fading away until their resurgence in the last decade with growing realization of the consequences of global warming. China's adoption of renewables, by contrast, has been serious, dedicated and relentless. It was as if China viewed the events of Sep 11 2001 as a warning of what total dependence on fossil fuel imports might mean – endless war and terrorism. A future based on renewable energies by contrast could be taken to mean one based on new technologies, the building of new export industries, and massive infrastructure development to accommodate the new, fluctuating sources. And this is precisely what we observe in China, after a lag of a couple of years. From 2005 the wind power sector, for example, has grown from being insignificant to become the largest in the world, doubling every year, and based on a substantial value chain now supplying all components needed. This green facet of China is shown in Chart 2.

Fig. 2 – China's green face: Chinese build-up of wind power



Source of primary data: U.S EIA International Energy Statistics Database

Which tendency wins – the green or the black face of China's energy development – is a matter of huge importance, for China and for the world. If China's vast fossil fuel sector becomes dominant (as it is in most of the West) then we can anticipate a century of vicious resource wars, fought through disputes over access to oil fields not just in the Middle East and Persian Gulf but also in the Caspian Basin and Central Asia, in Africa and in the territorial waters off the coasts of China and Southeast Asia, as well as continued and growing dependence of China's power and industrial sector on coal and all its attendant problems of air pollution and deaths from mining. If on the other hand the green sector wins out, and fossil fuel dependence declines, up to 2020 and beyond, then China's industrialization and modernization would proceed and promise to make China a 'normal' nation, interested in peace, preoccupied with its own technological development – and dramatically reducing its carbon emissions and setting a standard for the rest of the world.

And there are strong indications that **it is the green tendency that may indeed be winning**. In October 2012 China's State Council released its *Energy Policy* white paper, locking in some stringent goals prior to the leadership transition that moved ahead in November, and updating previous targets that had been spelt out in the 12th Five Year Plan, covering the years 2011 to 2015. In the White paper, China committed itself to achieving by 2015 no less than 30% of its electric power generation coming from non-fossil fuel sources – mainly hydro, wind and some solar, as well as nuclear (after a period of close examination of the industry's safety, post-Fukushima). Semi-official projections (not idle 'scenarios' but signposts for the industry pointing to investment behavior and financing by state-owned banks) up to 2020 indicate that renewables (or at least non-fossil sources, which include nuclear and hydro) could be accounting for as much as 40% of electric power generated, and coal and fossil fuels for just 60% -- and falling.

These projections are given more weight by new data on investment in new electric power capacity being built, released in 2012. There are indications that the significance of coal in China's electric power sector may be declining faster than the official projections indicate. The current projected increase is for 223 GW of coal-fired power to be added over the four years 2011-2015, or a rate of 55 GW per year (i.e. a 1-GW power station being built every week). But in March 2012 the China Electricity Council (CEC) issued a report stating that it expected coal consumption in 2015 to be below the 2011 level – thus reversing a long-standing pattern of growth. The CEC also indicated in early December that for the first 11 months of 2012 **investment in new capacity additions** in power generation was following a new trajectory, with coal accounting for only 26% of investment in new capacity additions, while non-fossil sources – hydro, wind, nuclear – made up 72%.[3] Data from the same source for the actual installation of electricity capacity for the first 11 months of 2012 support this: they indicate that addition of capacity of coal-fired power stations dropped by 28% from the level of the last year, accounting for 62% of new capacity additions, while hydro and wind on their own accounted for 23% and14% of new capacity.[4] Indeed, investment in coal-fired power stations has been falling for the last six years, while that for non-fossil sources has been rising.[5] If capacity additions themselves follow these new trends in investment, then this would represent a decisive shift towards clean energy in China. This is certainly very good news for China, and for the world.

China's regulation of the price of coal

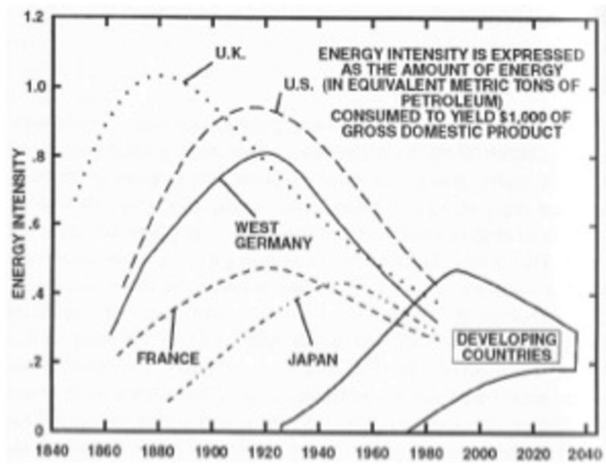
The reductions reported in investment and capacity additions in coal-fired power have not been brought about by a carbon tax or by a cap-and-trade system – the most popular instruments favored by western neoclassical economists. Instead in China the National Development and Reform Commission (NDRC) seems intent on deregulating the price of coal as far as is feasible – as a means of restraining growth in coal consumption. Prices have traditionally been set by direct negotiation between large coal producers (like Shenhua) and large power companies. But soaring prices led the NDRC to step in and impose a limit, setting a band within which contract prices were allowed to float by no more than 5 percent in 2012 over the 2011 level. This moderating of price increases had the desired cooling effect, and the price controls were removed at the end of 2012.[6] So by 2013 China is forcing power generators to pay the world price for thermal coal – which is proving to be far more effective in limiting production than any carbon tax.

These reductions in thermal coal capacity additions are feasible because of the complementary additions in renewable energy capacity, allowing wind, solar, geothermal etc. to take up the slack. This too is a feasible strategy in China because of the extraordinarily rapid take-up of renewable energy options. The swing away from coal is also 'fuelled' by the increasingly stringent controls over coal consumption in the power sector, requiring power companies to utilize the most recent and efficient technologies.

China's projected energy intensity reductions

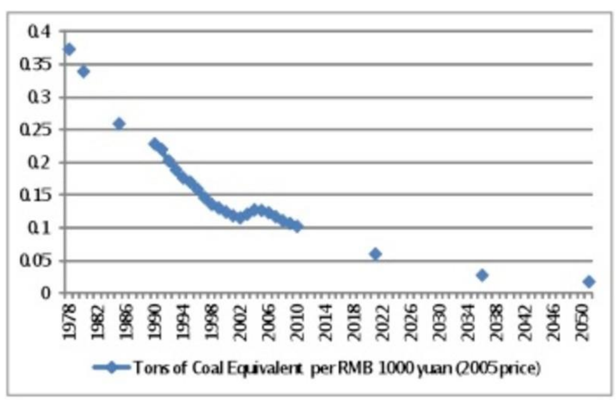
All countries as they industrialize have followed a characteristic trajectory, during which their energy intensity (energy consumed per unit GDP) rises, peaks, and then falls. Great Britain was the first to chart this pathway, peaking in 1880; then the US peaked in around 1920, and Germany around 1930; then in the post-war period, Japan peaked around 1960. Countries are less energy-efficient as they industrialize, and then become more energy-efficient as they grow wealthy. Moreover, the successive peaks are lower for each country. There are good theoretical reasons for observing such a pattern, based on secular improvements in the efficiency of energy technologies being deployed. The characteristic patterns are exhibited in Fig. 3. Through the history of industrialization, the peaks in energy intensity of 'follower' countries have been always lower than their forerunners, suggesting that less energy-intensive industrialization paths become available to the latecomer.

Fig. 3 -- Historical trends in energy intensity



Source: Adapted from Wallace (1996) p.18

Fig. 4 -- China's energy intensity, 1980-2008, and projected to 2050



Source of primary data: historical energy intensity data are calculated based on National Bureau of Statistics of China data; the energy intensity data for the period 2010-2050 are based on projections of researchers at the Energy Research Institute of China[8]

China however has been following a quite different pathway in terms of its energy intensity. In Fig. 4 we plot its energy intensity since 1980, and project its energy intensity forward based on projections of researchers at China's official Energy Research Institute.[7] Since the growth of GDP is expected to be substantially higher than that of energy consumption in the next decades, the estimated energy intensity can be anticipated to decline quickly after 2010.

We interpret this chart to mean that China was able to accomplish the quite unprecedented feat of quadrupling GDP from 1980 to 2000 while 'only' doubling energy consumption – thus accounting for the continuing decline in energy intensity (admittedly from a very inefficient starting point). Then in the early 2000s China experienced the full force of its nascent 'energy revolution', when there was a big swing back to coal as primary fuel and the dominance of energy-intensive heavy industry. But then in 2003 it 'peaked' – at an energy intensity of 0.128 tce per RMB yuan (Year 2005 level) – and since then it has been declining, just as the earlier industrializing countries experienced. But China's period of rising energy intensity has been greatly compressed; it is as if it 'tunnelled' through the rising and then falling energy intensity pathway, as discussed by some commentators in the context of the more general setting of the Environmental Kuznets Curve. China has thus been reducing its energy intensity as a matter of national policy – rather than relying simply on markets and technology as happened elsewhere. Of course China is using these tools to bring about the intensity reductions; in the electric power sector, all efforts are being made to introduce more energy-efficient generation technologies.

This provides the background to China's well known commitment made at Copenhagen to reduce energy intensity by a further 16% between 2011 and 2015, after having almost achieved the goal of reducing it by 20% over the previous five years 2006-2010. (The actual achievement in 2006 to 2010 was a reduction in energy intensity of 19.1%. The first year of the new period of the 12^{th} Five Year Plan (2011-2015) saw a further reduction in energy intensity of 2%, down to 0.79 tons coal equivalent (tce) per unit GDP.[9]

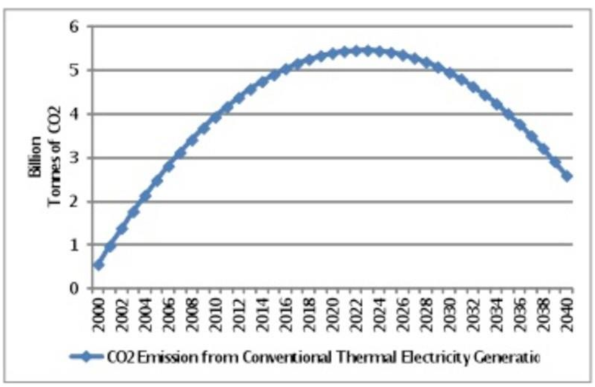
China's projected carbon emissions

But it is the carbon intensity of China's energy industrial revolution that gives rise to most concern. What emissions are likely to be generated from China's massive burning of fossil fuels – before the substitution by renewables reduces their consumption? Using Chinese data on carbon emissions, we can now sketch the actual carbon emissions likely to be generated by China's electric power revolution. We exclude potential carbon emissions from renewable and nuclear-based electric power stations in this calculation as we assume those would be minimal compared with those from the coal-fired power stations.[10]

In 2010, China burned around 3.4 Gt coal, of which 1.5 Gt were burnt in thermal power stations to generate 3,000 TWh of electricity. Based on Chinese estimates for carbon emissions from thermal power generation, we would expect this level of power generation to result in 3.1 Gt carbon dioxide -- or 0.84 Gt carbon. (Multiply level of CO_2 by 12/44 to get the level of carbon; or the level of carbon by 44/12 to get the level of carbon dioxide.) The approx. 1.5 Gt coal thus produce around 0.84 Gt carbon emissions, or 3.1 Gt CO_2.

Now let us add up **all the anticipated carbon emissions** from China's future generation of electric power (accounting currently for no less than 50% of China's total carbon emissions). (We do not include emissions from agriculture, transport and other industrial activities because we do not have reliable data or projections for such sources. But our focus on power generation is certainly justified since it accounts for 50% of carbon emissions at the moment.) According to our estimate, we expect the carbon emissions from China's electric power sector will continue to grow till around 2025, and then start to decline thanks to the take-off of the renewable energy used in the sector. This means that, for all its efforts to reduce energy intensity and carbon intensity, China is likely to be increasing its total carbon emissions from generating power for another decade or more.

Figure 5. China: Projected carbon emissions from thermal power generation, 2000-2040



Source: Authors' calculation

This chart 5 tells a remarkable story. We can read off the level of CO_2 emissions for 2000 (around 0.5 Gt CO_2) rising to more than 3 Gt CO_2 by 2010 and an anticipated level of 5.3 Gt CO2 by 2020 from conventional thermal power stations. By integrating under the curve, we estimate that total CO_2 emissions due to China's fossil-fuel-based electric power generation over the next three decades between 2011 and 2040, **would be about 140 billion tonnes**. Yes, China's carbon emissions from electric power generation will continue to rise – but we anticipate that they will plateau in the 2020s and then start to decline – steeply, as thermal power generation declines.

What will be the impact on carbon dioxide levels of these extra gigatonnes of carbon emitted as a by-product of China's industrialization? We know (e.g. from the Carbon Mitigation Initiative at Princeton) that carbon dioxide levels rise by 0.22 ppm for each Gt carbon emitted.[11] Thus addition of around 140 Gt carbon dioxide up to the year 2040 from electric power generation would force carbon dioxide concentrations to rise by around 30 ppm.

So we have a clear outer limit to the 'carbon emissions' cost of China's energy revolution and associated industrialization, especially those in relation to burning coal and other fossil fuels in the electric power sector (the largest user of coal in the Chinese economy). This outer limit of 140 Gt CO_2 up to 2040 is likely to drive up carbon dioxide concentrations by 30 ppm. Since the CO_2 concentration stands at 391 ppm (in 2012), China's net increase in carbon concentration (what the IPCC calls 'forcing') from electric power generation can be expected to drive this up to 421 ppm – taking the world close to the 'prudent level' of 450 ppm established by the IPCC. Of course China's and other countries' carbon emissions have to be added to this to gain a global perspective. China's industrialization is the first where its carbon emissions implications can be anticipated in advance.

Nevertheless it has to be stated again that China's energy-intensive and carbon-intensive industrial revolution (its coal-based black transformation) is exacting a fearsome toll in terms of polluted skies, waterways and earth, and the health risks and costs associated with all this. The human consequences of China's energy transformations are felt first in the cities – and it is here that most pressure for a new green approach will be felt first. Our projections are not meant to gloss over the fearful consequences of all these changes.

However, as we stated clearly in Part 1 of this article, we do not see this as an argument that China should hold back its industrialization efforts. Rather we see China's strategies as designed to build the green energy sector as fast as is technically and humanly feasible, so that the logistic industrial dynamics that drive the green energy revolution may overtake the dynamics of continued fossil fuelled development. The prospects for our industrial civilization are being shaped not so much by what happens in Washington or Brussels or Tokyo, but increasingly by decisions being taken in China.

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Hao Tan, Newcastle Business School, University of Newcastle, Australia. Their article "The Transformation of the Electric Power Industry in China" appears in *Energy Policy*, Vol. 52, January 2013.

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Notes

[1] According to the data available at the China Electricity Council, China added 58.3 GW of conventional thermal electricity capacity in 2010, 58.9 GW in 2011, and 35.6 GW from January to November in 2012.

[2] Accounts of China's energy revolution that emphasize its dependence on fossil fuels, and particularly coal, include the regularly updated accounts from the US Energy Information Administration (at:

http://www.eia.gov/countries/cab.cfm?fips=CH) and the report from Goldman Sachs, 'Sustainable growth in China: Spotlight on energy' (August 2012), at: http://www.goldmansachs.com/our-thinking/topics/environment-and-energy/sustainable-growth-china.html

[3] The data from China Electricity Council (CEC) are: Total investment in new capacity for the first 11 months of 2012: RMB 302 billion (US$48.3 b) – of which, RMB 79.4 billion in thermal, while RMB 102.8 billion in hydro, 49.5 billion in wind and RMB 65.0 billion in nuclear, with the balance coming from solar and bioenergy.

[4] According to the China Electricity Council (CEC), for the first 11 months of 2012, China added 57.3 GW of electricity capacity in total, in which thermal, hydro and wind accounts for 35.6 GW, 13.1 GW and 8.2 GW respectively. See the latest brief (in Chinese) at http://tj.cec.org.cn/fenxiyuce/yunxingfenxi/yuedufenxi/2012-12-17/94911.html

[5] According to Lin Boqiang, Director of the China Centre for Energy Economics Research (CCEER) at Xiamen University, investment in coal-fired power stations in 2012 would amount to about 100 billion yuan ($15 billion) – half the level of 2005.

[6] See 'China cancels 1-yr control on thermal coal prices', *China Daily*, 32 Dec 2012, available at: http://www.chinadaily.com.cn/china/2012-12/23/content_16044457.htm

[7] See ERI. 2009. China's Low Carbon Development Pathways by 2050: Scenario Analysis of Energy Demand and Carbon Emissions. NDRC Energy Research Institute Research Team. Science Press. Beijing. (in Chinese)

[8] These energy intensity data include projections of China's future GDP, as follows:

Period	2005-10	2010-20	2020-30	2030-40	2040-50
Average GDP Growth per Year (%)	9.67	8.38	7.11	4.98	3.6

Source: Adapted from ERI. 2009. China's Low Carbon Development Pathways by 2050: Scenario Analysis of Energy Demand and Carbon Emissions. NDRC Energy Research Institute Research Team. Science Press. Beijing. (in Chinese)

[9] See 'China's latest energy consumption data reveals new opportunities and challenges', China FAQs, Nov 5 2012, at: http://www.chinafaqs.org/blog-posts/chinas-latest-energy-consumption-data-reveals-new-opportunities-and-challenges-0

[10] This is supported by Liu et al. (2011) 'Development forecast of renewable energy in China and its influence on the GHG control strategy of the country'. Renewable Energy, 26: 1284-1292, who estimates that the emission factors of hydro, wind, solar and biomass-based electricity are 17, 36, 57, and 46 g CO_2 / kWh compared with 1017 g CO_2 / kWh by coal-fired power plants,

[11] See the Carbon Mitigation Initiative website, and the presentation on Stabilization wedges: http://cmi.princeton.edu/wedges/slides.php