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Viewpoint

The transformation of the electric power sector in China

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HIGHLIGHTS

- Our interpretation of official projections to 2020.
- Our projections to 2050 using logistic industrial dynamics.
- A strong and smart national power grid.
- A national high-speed rail system.

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ABSTRACT

China's industrial transformation of the past thirty years, when its GDP has been increasing by an average of 10% per year, has been underpinned by an energy industrial revolution. Electrical energy is the driver of this transformation, with China utilizing latecomer advantages in building an electrical energy generation machine of prodigious size. In terms of electrical energy generated, China's system has expanded twelve-fold in 30 years, from 280 TWh in 1980 to over 3500 TWh in 2010. In this paper we describe the principal features of this remarkable transformation, examining the official projections to 2020, the semi-official projections to 2050, and offering our own projections based on observed logistic industrial dynamics for the uptake of renewable energies as well as the continuing role to be played by fossil fuels, particularly coal. We emphasize the role to be played by China's construction of a 'strong and smart' electric power grid, as envisaged in the 12th Five Year Plan released in March 2011, and the complementary proposals to build a national high speed rail system. We see China as on track to phase out fossil fuels altogether in its power production system by the end of the century. We develop an argument as to why it might be expected that fossil fuel utilization will decline while renewable energy utilization might increase in China, constituting a genuine energy industrial revolution.

1. Introduction

China's industrial transformation of the past thirty years, when its GDP has been increasing by an average of 10% per year, leading to a doubling then tripling of its economy, raising income levels and lifting millions of people out of poverty, has attracted the world's attention like no other phenomenon. But this impressive performance has been underpinned by an even more impressive industrial transformation involving China's energy system. In just the first decade of the 21st century, with China entering the WTO in 2001, its primary energy production/consumption more than doubled, from 1.4 billion tonnes coal-equivalent in 2000 to 3.25 billion tonnes coal-equivalent in 2010. It is expected by the Chinese leadership to grow further to 4 billion tonnes coal-equivalent or more by 2020, making it the largest national energy system on the planet.

Electrical energy is the driver of this transformation. In terms of electrical energy generated, China's system has expanded twelve-fold in 30 years, from just 280 TWh in 1980 to more than 3500 TWh in 2010. China's electric power 'machine' was rated at just on 1 trillion watts (1 TW) by the end of 2010. This is the 'machine' that generated close to 4 billion kWh (TWh) of electrical energy in 2010, over 75% of which is generated from coal, and over 75% of which is utilized by China's industry. During the period of the 11th Five-Year Plan (FYP), from 2006–2010, electricity usage grew by 12% per year; if this continues into the

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12th FYP, China would be using twice as much electricity in 2015 as it did in 2010 (and three times as much by 2020). Yet even so it is worth pointing out that with a population in 2010 of 1.34 billion, China's per capita consumption of electrical energy was still only around 3000 kWh per person per year—slightly above the world average in the year 2008 (2850 kWh/cap) and a long way behind the OECD average in the same year 2008 (8410 kWh/cap).[1]

The current estimates from China's national planning body, the National Development and Reform Commission (NDRC), is that the total electric power system will expand to 1.6 TW by 2020—adding a further 600 GW to the system in just a further ten years (or adding more than a 1-GW power station each week). If the words of Zhou et al. (2010) describing the rate of growth of electric power in the mid-2000s as 'the largest in history' then these further projections based firmly on the new 12th Five Year Plan have to be described as larger still. By 2050 the electric power 'machine' could be rated at 2.5 TW—again, the largest such national system in the world.

This huge scale of electricity generation is mostly based on the burning of coal—and that presents a problem for China (because of particulate emissions), and for the world because of the carbon emissions. Based on generating capacity, China is dependent on coal for 76% of its electrical power (686 GW out of 903 GW up to November 2010). It is dependent on hydro for 19% of its generating capacity—and for small amounts for both wind (around 3%) and nuclear (1%). But this is changing rapidly, as renewable sources are scaled up and dependence on coal is scaled down. The issue is—can this dependence on coal be scaled down fast enough, through the building of an electric power system based on non-carbon sources?

In this paper we outline the major developments in China's building of a 21st century electric power system, one that is capable of underpinning continued expansion of its manufacturing and logistics engine, and one that is capable of accommodating further revolutions in transport involving high-speed rail and electric vehicles. The world is starting to notice that China is actually utilizing these initiatives to lay the foundations for its next industrial revolution.

Based on the projections made by the Energy Research Institute and the explorations of the projections using a logistic model, we probe the timeframe of this major transformation in China's power sector, from the current point when the majority of the electricity in China is generated by fossil fuels, mainly from coal power stations, to the point when electricity provided from renewable sources is likely to become dominant. Our projections of renewable electricity capacity and generation are based on logistic industrial dynamics, which we regard as a potentially insightful form of investigation—but rarely been engaged explicitly. Logistic dynamics are not used, for example, by the IEA in its projections (see e.g. IEA, 2010).

The paper proceeds as follows. In Section 2 we outline the overall lineaments of China's electrical energy transformation, emphasizing both its 'black' (coal-fired) and 'green' (renewables) aspects. We discuss the current trends and those projected to 2020 by China's official agencies, particularly the NDRC. In Section 3 we then make projections to the year 2050, based on simulations provided by the Energy Research Institute (ERI), in Beijing, a research establishment affiliated with the NDRC. In this section we fit logistic and convex curves to the existing trends in order to make projections out to 2100, to demonstrate why we believe it realistic to see China phasing out fossil fuels altogether in its electrical power production system. In Section 4 we then discuss the infrastructure investments needed to make these projections materialize, particularly in the realm of the 'smart' and 'strong' national electric power grid, noting the massive investments already under way and those envisaged by the current 12th Five Year Plan. In Section 5 we discuss the complementary developments in infrastructure investment, involving the rapid extension of the high-speed rail network which potentially provides a low-carbon alternative to automotive and air transport systems. Then in Section 6 we turn our attention to the learning curves involved in the development of the coal-burning thermal power generation sector, to support an argument that China as latecomer is leapfrogging the advanced countries to become a leader in low-carbon thermal efficiency in coal-fired power production.[2] Finally in Section 7 we draw the argument to a conclusion, making the case that China is taking advantage of its relative latecomer status in building a new 21st century electrical power system to reach technological parity, if not leadership, in certain energy technologies.

2. Green and black electrical energy

China's 12th FYP sets ambitious goals for the scaling-up of renewable energy sources, to the point that they are anticipated to account for **15% of primary energy sources by 2020**. In terms of electric power, China's leadership, in the form of the NDRC, anticipates that electric power capacity will by 2020 be rated at 1.6 TW, and of this, 500 GW (0.5 TW) will be renewable sources – hydro, wind, solar etc. – i.e. **REs accounting for 30% of electric power capacity by 2020.** The interim goals under the 12th FYP are for REs to account for 11.4% of primary energy sources by 2015. If these goals are met, and from past experience where energy goals have actually been exceeded, they show every likelihood of being so, then China is on track to phase out conventional fossil fuels altogether by renewable sources in its electric power generation by the end of this century.

China's leadership as well as key industrial players such as State Grid Corporation (SGCC) understands that a drastic scaling-up of renewable energy calls for its integration into a national grid, and that such integration calls for a massive upgrading of the capacity of the grid to carry electrical energy across huge distances, but also an upgrading of the grid to cope with fluctuating levels of supply and demand. The former calls for technological upgrading to ultra-high-voltage power lines and distributors (what China is dubbing the 'strong grid') and the latter for IT-enabled grid operations that build intelligence into the network (what the world, including China, is calling the 'smart grid'). But while the world discusses and debates these concepts, China is getting on with the job of building and installing them, on a vast scale.

As the SGCC itself says in its path-breaking document outlining its roadmap for a 'strong and smart grid', the construction of such a grid 'will provide great support for utilizing renewable energy sources in large-scale, reducing dependence on fossil fuel'; this 'massive use of renewable energy sources and the development of smart grid are at the core of a forthcoming revolution of energy development pattern' (2010: 8).

In fact the electric power sector provides a vivid picture of the green and black aspects of China's energy revolution—more so than the energy system in general. The power sector is currently more dependent on coal than the larger energy system, with

[1] Calculated based on the data available from the US EIA International Energy Statistics Database.

[2] We use the phrase 'leapfrogging' in a way which is consistent with general treatments, such as that of the cultural historian Jack Goody, when he states "Modernization is a continuous [historical] process and in which regions have taken part in leap-frogging fashion (Goody, 1996: 7).