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Steel mills and other heavy industries amplify carbon emissions in Inner Mongolia, while the products are consumed in more affluent parts of China.

A low-carbon road map for China

Recycling, renewables and a reinvigorated domestic energy market will allow China to lead the world in low-carbon development, say **Zhu Liu** and colleagues.

China is a major force behind anthropogenic carbon emissions and their mitigation. The world's leading primary energy consumer in 2012, China devoured almost half of all coal produced. The nation accounted for one-quarter of global carbon dioxide emissions in 2011 and 80% of the world's rise in CO_2 emissions since 2008 (ref. 1).

Facing international pressures to curb its CO_2 releases, as well as a tight domestic fossil-energy supply and high levels of air pollution, China has implemented a bold national strategy for energy conservation and emissions mitigation. The country plans to reduce its carbon intensity (CO_2 per unit of gross domestic product, or GDP) to 55–60% of 2005 levels by 2020.

This can be achieved only if China becomes a low-carbon economy. With powerful regulatory control, we believe that the nation's energy appetite could drive the development and use of low-carbon technologies, in which China could become a world leader. We identify the major challenges in such a transition, and propose a five-pronged strategy to get China onto this low-carbon pathway.

First, China must move away from coal and boost recycling and renewable energies. Second, emissions-mitigation indicators, such as energy-efficiency targets, should be set relative to physical output (such as tonnes of steel production) rather than to economic growth. Third, regional energy supply and demand must be balanced. Fourth, energy prices should be linked to market mechanisms rather than set centrally by authorities. And fifth, China must reduce air pollutants alongside CO_2 emissions.

China has made great progress in cutting carbon emissions in the past decade. In its 11th five-year plan (2006–10), the government set goals to reduce energy intensity (energy consumption per unit of GDP) by 20% on average across all provinces by 2010. Thousands of inefficient power plants and factories were closed to meet the targets[2], saving the equivalent of 750 million tonnes of coal and 1.5 billion tonnes of CO_2 (5% of global CO_2 emissions in 2010).

The government's 12th five-year plan (2011–15) calls for a 16% reduction in energy intensity and for a 17% reduction in carbon intensity. Each region has been allocated mandatory targets. Such cuts would save about 1.4 billion tonnes of coal between 2006 and 2015, reducing CO_2 emissions by more than 3 billion tonnes (roughly 60% of US emissions in 2010). As a result, air-pollution levels would fall.

LOW-CARBON CHALLENGES

Challenges remain in curbing fossil-energy use and emissions while maintaining economic growth. Although two-thirds of China's provinces met their intensity targets for 2006–10, CO_2 emissions rose nationwide in that period by 50% as the economy grew[3]. Efficiency targets were met by expanding scale of production. When pressure to reach the targets became so great that several provinces instituted blackouts, many factories turned to inefficient diesel power generators, leading to a national diesel shortage in 2010.

Infrastructure construction has been the major driver of China's rapid economic and emissions growth since 2002. As a result, the economy relies on carbon-intensive industries (see 'Economic growth'). From 2005 to 2011, many of China's industries grew faster than its GDP, which rose by 87% (constant price at 2005 value). Thermal power generation grew by 90%, steel production by 135%, cement by 96% and vehicle production by 223% (ref. 4). In 2008, the growth was further exacerbated when China initiated a 4-trillion-renminbi (US$600-billion) economic stimulus plan, of which 85% was for building infrastructure. Today, China accounts for much of the world production of crude steel (45%), cement (60%), primary aluminium (44%), coke (64%) and coal (50%). Almost all of these products are consumed domestically.

China's energy- and emissions-intensity targets are expressed as ratios of energy use or total emissions to GDP. There are thus two ways to achieve the targets: by upgrading equipment and industrial processes to use less energy and to drive down emissions, or by expanding the scale of production, thereby boosting GDP. Both strategies, but especially scale expansion, have contributed to China's improved energy intensity. However, they have resulted in much higher emissions overall. For instance, from 2002 to 2009 China's coal-fired power plants improved their energy intensity by 10%, but because their production capacity more than doubled, total emissions from the sector also doubled[4].

Current emissions targets may exaggerate regional development inequalities by outsourcing the mitigation cost from rich to poor. Some of China's poorest regions rely on carbon-intensive industries, such as cement and steel, and such regions have per capita emissions approaching those of the United States (see 'China emissions'). To support economic development, these regions have been allocated small reduction targets. But most products from these poorer areas are consumed in more affluent regions[5].

For example, in 2010, about 20% of carbon emissions from Inner Mongolia, a poor region in the north of the country, were from the production of electricity that was exported to other provinces. Two-thirds of the region's processed metals, half of its chemical products and 43% of its cement were also sent to more developed areas on the coast.

Beijing and Shanghai import about 70% and 33% of their electricity, respectively[6]. In this way, the cities avoid emitting 50 million tonnes and 38 million tonnes of CO_2, respectively. If each region's emissions, and those embodied in traded products, were allocated to final consumers, Inner Mongolia would have exceeded its energy-intensity reduction commitments by around 40% in 2010, whereas Shanghai and Beijing would have failed to achieve theirs.

The immaturity of China's electricity grid results in power shortages and inefficiencies. Many new power plants remain unconnected to the national grid, owing to poor coordination between local governments and the State Grid Corporation of China, which builds and manages all grids in the country. One-third of Inner Mongolia's power capacity (100 billion kilowatt hours, or kWh) remains unused each year for this reason.

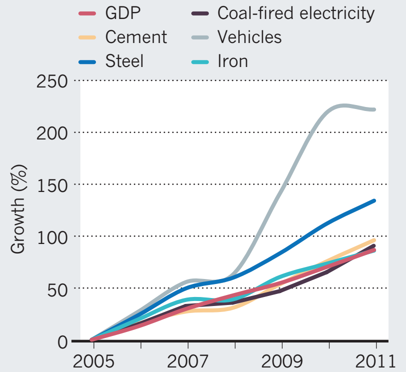
Because the prices of fuels such as coal are set by and fluctuate with the market, but the cost of electricity consumption is fixed by the central government, power plants slow their production rate when fuel prices are high. This is inefficient and causes blackouts. In 2010, China produced only about half of its capacity of 6,220 billion kWh.

LOW-CARBON LEAPFROGGING

China's economy can be decarbonized only by reducing fossil-energy demand and emissions together. Recycling construction materials could reduce total energy intensity by as much as 90%. China recycled about 70 million tonnes of steel scrap in 2008, and scrap has the potential to replace 80% of iron ore as a resource for primary steel production by 2050 (ref. 7). Schemes encouraging 'urban mining' of scrap and exchanging by-products among regional factories are needed.

ECONOMIC GROWTH

China's manufacturing output has risen rapidly since 2005 (relative levels shown).



GDP, gross domestic product in constant price at 2005 value

SOURCE: REF. 4

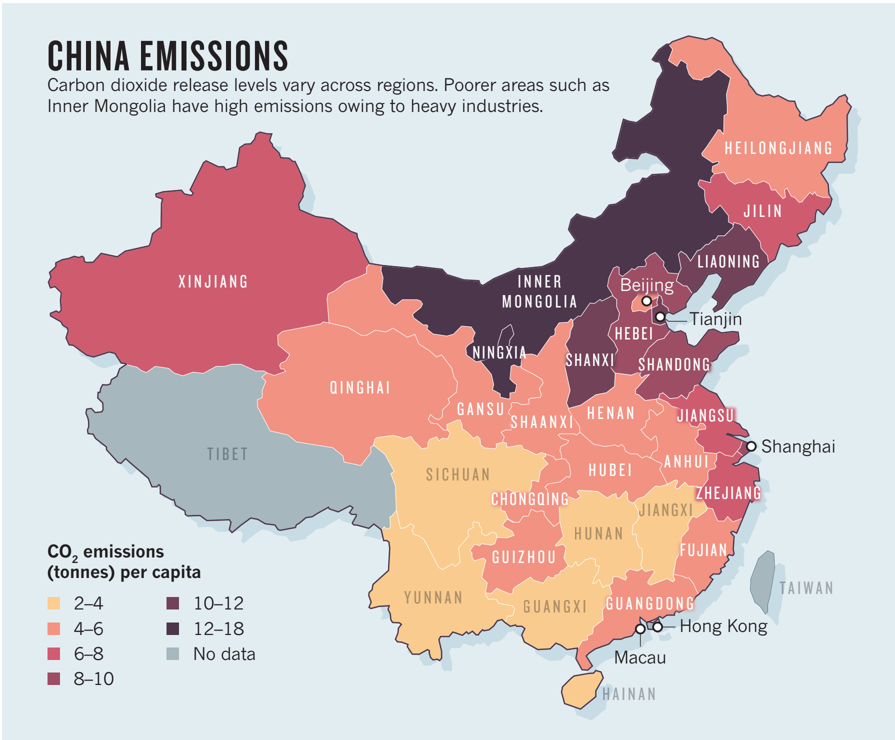
China leads the world in renewable energy, having invested $68 billion in 2012 — more than one-fifth of the global total for that year. The country's installed renewable capacity of 300 gigawatts (GW) in 2011 was already twice the US capacity for the same year (146 GW). China's wind turbines and hydropower stations were the world's most productive in 2011, generating 70 billion kWh and 720 billion kWh, respectively.

Yet China is producing more renewable technologies than it can use. In 2012, the country's manufacturing capacity for solar photovoltaic cells reached 40 GW. But it produced only 23 GW, which accounts for 60% of world's total annual production (37 GW). Less than 10% of these domestically produced photovoltaics were installed in the country — in part owing to the lack of grid connections. The rest were exported. Further investments are urgently needed to extend the electricity grid to remote rural regions, where solar power is a solution for electrification, and to explore other markets for the surplus supply of panels.

There is great potential for low-carbon energy technologies in China. Wind power alone could meet the entire projected increase in electricity demand up to 2030. Introducing 640 GW of wind capacity (costing about $900 billion) over the next 20 years will reduce carbon emissions by 30% in the period[8]. Using China's waste gutter oil (13.7 million tonnes in 2010), which is refined from discarded cooking oil, for biomass fuel could reduce CO_2 emissions by some 90 million tonnes per year[9]. Such a reduction would be equivalent to 15% of the total emissions reduction from 1990 to 2008 by the 39 industrialized countries under Annex B of the Kyoto Protocol — the international treaty that commits parties to cutting greenhouse-gas emissions.

In the meantime, cleaner, non-renewable options, such as natural gas and nuclear power, could provide a buffer during the low-carbon transition. Through further exploitation of coal-bed methane and by improving connectivity of domestic and international gas pipelines, natural-gas consumption in China could swell to 250 billion cubic metres by 2020, with double-digit growth from 2010 to 2020. Switching from coal to gas would simultaneously reduce air pollutants, such as sulphur dioxide and nitrogen oxides, as well as CO_2.

With 17 reactors in operation, nuclear power currently accounts for 1% (13 GW) of China's electricity production capacity. Another 28 nuclear plants are under construction and more technologically advanced reactors are planned. The total nuclear capacity is set to rise to 80 GW by 2020, 200 GW by 2030, and 400 GW by 2050.



SOURCE: GUAN, D. *ET AL. NATURE CLIM. CHANGE* **2,** 672–675 (2012)

To measure and promote progress, energy and emissions targets must be considered separately to economic performance. Physical intensity indicators, such as emissions per unit production of steel, should be used rather than relative economic intensity indicators, such as emissions per unit of GDP. China has set a coal-consumption cap of about 3.9 billion tonnes by 2015. Similarly, a national carbon-emissions cap should be introduced, leveraged by energy taxes and allowances.

A carbon budget that considers both emissions and offsets from carbon sinks should be introduced for CO_2 inventories. This would encourage forest planting and waste management through carbon-credit schemes. The carbon sink created by China's enhanced afforestation and territorial ecosystem might have taken up as much as 15% of China's fossil-fuel CO_2 from 2002 to 2007 (ref. 10).

Regional compensation mechanisms would accelerate technology transfer between Chinese provinces. Targets for industrial sectors, rather than regions, would lessen geographic disparities. Regions should count emissions according to electricity consumption rather than by production. Mitigation responsibilities should be required throughout the supply chain of energy-intensive enterprises, from company headquarters in rich areas to factories in poor ones. Rigorous environmental standards need to be strictly applied.

China's first domestic carbon market for permits to discharge CO_2 opened in June this year in Shenzhen, with permits for 20,000 tonnes of CO_2 traded in the first day. Full marketization with moderate administrative intervention in China's fuel consumption will be crucial for the success of its domestic cap-and-trade scheme, which is currently being tested in seven provinces and municipalities, affecting an annual 1.5 billion tonnes of CO_2 emissions. The system will be implemented nationwide in 2016.

Through the Kyoto Protocol, China is hosting more than 2,000 projects (half of the world total) under the Clean Development Mechanism, which can offset about 600 million tonnes of CO_2 from China. The domestic cap-and-trade system is expected to cover 1 billion tonnes of CO_2 per year by 2015 (about 10% of China's total CO_2 emissions) and generate billions of US dollars of government revenue.

A successful cap-and-trade scheme requires reliable carbon data, a transparent carbon market and fair credit allocations. China's central government should compile and verify the emissions inventories; coordinate, monitor and report on the market measures; define the reduction baselines and certify emissions-reduction credits.

The wealthiest 5% of China's population accounts for 25% of electricity use. The government should pioneer other economic mechanisms, such as a carbon tax, that target consumption. As a first step, China has implemented a household 'incline block tariff' since July 2012, whereby electricity purchased beyond a certain limit has a higher price. Similar taxes should be introduced for other consumables (such as vehicle fuels) and the revenue used to subsidize low-carbon products (such as electric cars), renewable-energy development and energy infrastructure construction.

Because CO_2 emissions and air pollution largely stem from fossil-fuel use, regional control strategies for both should be integrated. China implemented regulations in June this year and plans to invest 1.7 trillion renminbi between 2013 and 2017 to limit urban air pollution, including particulates and ozone. These regulations suggest phasing out inefficient industrial boilers, limiting the expansion of emissions-intensive industries and enhancing regulations and market stimuli for green-energy development, which would accelerate the development of energy saving and environmental protection industries.

China's energy-management system is being restructured under new government leadership. The streamlining associated with the annexing of the State Electricity Regulatory Commission by the National Energy Administration should help to harmonize energy prices and policies across central and local governments and enterprises. A high-level governmental organization (such as the State Council) is also required to coordinate energy policies across agencies, such as the Ministry of Environmental Protection, National Development and Reform Commission, and provincial governments.

By tackling these challenges, we believe that China can lead the global climate-change mitigation movement and create a pathway towards sustainable, low-carbon development. ■

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