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# The "Greening" of China: Progress, Limitations, and Contradictions

Chiara Piovani

Department of Economics, University of Denver, Denver, CO, USA

**ABSTRACT**
China's rapid economic growth in the last three decades has been fuelled by energy-intensive investment and manufacturing, which have become instrumental for China to become the world's largest economy based on purchasing power parity, and for the United States and the European Union to have access to cheap consumer goods. China's development strategy, however, has generated a serious domestic environmental crisis, which has also accelerated the global climate emergency. In addition, the 2008 economic crisis led to a collapse of China's external demand, inducing the leadership to support domestic investment – including investment in environmental projects – as an alternative source of effective demand. By setting ambitious green targets and by adopting strategic policy initiatives, China has become the world's largest investor in renewable energy. Yet China remains the world's largest coal consumer and the world's largest carbon dioxide emitter. The Chinese economy nears a crossroad: will it be able to maintain its commitment to green energies or will it fall back to its historical reliance on fossil fuels to sustain growth? This article evaluates the interplay between China's economy and environment over the course of the reform period, and investigates the set of forces that impinge upon China's ecological future.

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Since the adoption of its economic reforms in 1978, China has experienced what is referred to in the mainstream literature as an "economic miracle." Between 1980 and 2007, the economy grew at an average annual rate of 10%, leading China – based on purchasing power parity – to become the world's largest economy in 2014 (IMF 2014). China's economic ascendancy, however, has occurred at the expense of its environmental conditions. In recent years, air pollution in major cities has reached hazardous levels several times each year, causing an estimated 4,000 deaths every day because of $PM_{2.5}$ concentration in the air well beyond World Health Organisation recommendations (Rohde and Muller 2015).[1] China's water system is in a severe crisis; about 300 million rural citizens lack access to safe drinking water and over 60% of cities experience shortages (Liu and Yang 2012). China's Ministry of Agriculture estimates that 3.3 million hectares of land are now polluted due to overuse of fertilisers and pesticides and

**CONTACT**: Chiara Piovani, chiara.piovani@du.edu Department of Economics, University of Denver, 2000 E. Asbury, Denver, CO 80208, USA.

contamination with heavy metals, which in turn has made national food security one of the policy priorities of the government (Duggan 2014).

Statistics on environmental damage are aggravated by China's scarce endowment of natural resources in relation to its population. It is estimated that per-capita arable land and fresh water availability are about one-third of the world's average (Tisdall 2001). In addition, the government's plan to reach an urbanisation rate of 60% by 2020 makes environmental challenges even more compelling (Tiezzi 2013).

As China has become a major player in the world economy, its environmental problems have also acquired a global dimension. In 2007, China became the world's leading emitter of carbon dioxide, greatly accelerating the world's climate emergency and raising both equity and efficiency challenges in international climate negotiations.

In recent years, especially in response to the 2008 recession and the subsequent need to support effective demand through domestic investment, the government has pursued policies that aim to improve energy conservation and promote low-carbon energy sources. As a result of these efforts, China is now the world's leader in renewable energy capacity, while it also remains the world's largest consumer of fossil fuels.[2]

Is its current leadership in renewable energy the sign that China is on the road to embracing a more ecologically sustainable model of development? This article provides an exploration of the major issues that impinge upon China's aspiration of becoming "green."

Towards this goal, this article is organised as follows. The next section discusses the interplay between China's environment and economy over the course of the reform period, and evaluates the ecological, human and economic consequences of China's ecological crisis. This is followed by a section that presents the key policies that the government has used to protect the environment and promote renewable energy.[3] The subsequent section provides a critical assessment of the forces affecting China's prospects of "green development," followed by the conclusions.

## "Economic Miracle": Resource and Energy Requirements and the Environmental Consequences of China's Growth

China's process of economic development over the course of the reform period has been highly resource and energy intensive. Growth in resource and energy use has become especially rapid since the early 2000s, when investment became a primary engine for China's economic growth (Piovani and Li 2011).

China has become a large consumer of a broad range of primary commodities. Figure 1 shows China's escalating trend in the consumption of four key minerals, aluminium, iron ore, steel and cement, between 1995 and 2012. To satisfy this growing demand, in recent years China has dramatically increased domestic production of these resources. Figure 2 shows the production of each of these minerals between 2002 and 2012 against US and world production. These figures point to the same direction. China has contributed to a growing share of the world's production of these resources, while US production has remained substantially unchanged. In 2012, China produced around 45% of the world's steel, iron ore and aluminium, and 58% of the world's cement. In spite of rapidly growing production, China has a positive trade balance only for steel,

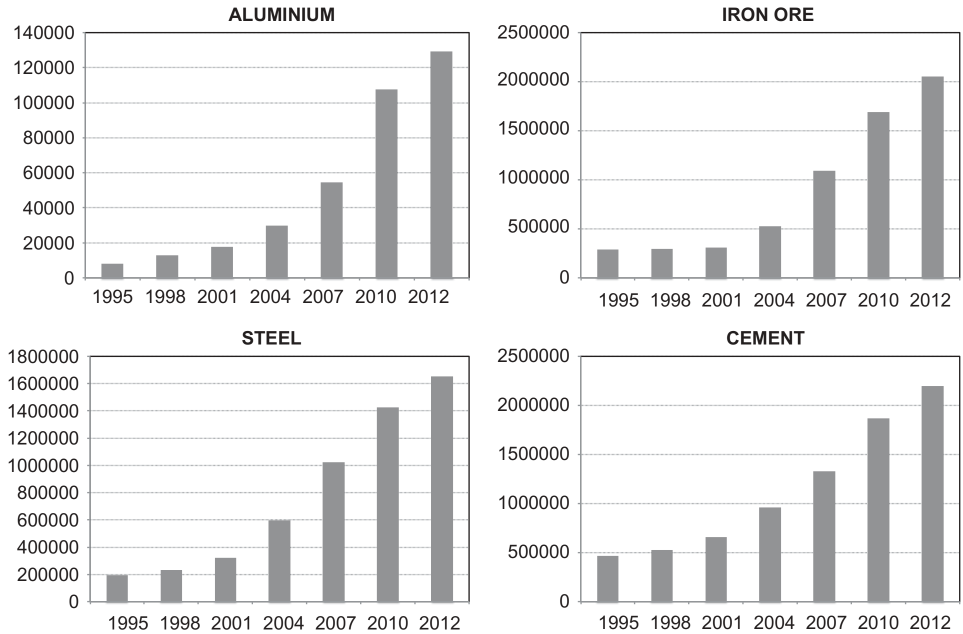


**Figure 1. China's consumption of minerals, 1995–2012 (thousand metric tons)**
Source: Author's processing of USGS data, 2014.

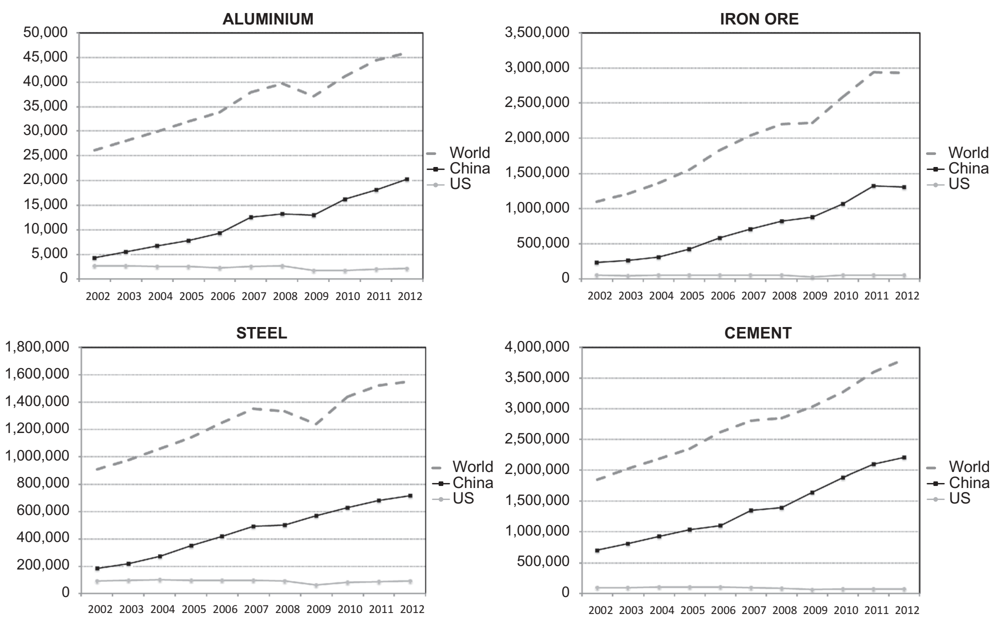


**Figure 2. Production of minerals: world, China and the US, 2002–12 (thousand metric tons)**
Source: USGS data, 2014.

whereas for aluminium, iron ore and cement China has become dependent on net imports to fulfil its growing demand (USGS 2014).

Over the course of the reforms, energy consumption has seen rapid growth. Based on EIA data ([2014] 2016), between 1980 and 2012 China's share of the world's primary energy use increased from 6% to 20%, and in 2010 China had become the world's largest energy consumer. These outcomes are primarily driven by massive coal consumption. Between 1980 and 2012, coal consumption as a share of total world coal consumption increased from 17% to 50%, indicating that China consumes as much coal as the rest of the world. Since the early 2000s, however, China's consumption of oil and natural gas has also increased substantially. Between 2002 and 2012, oil consumption increased by over 130%, and in 2009 China became the world's second largest oil consumer. Over the same period, the consumption of natural gas increased by over five times (EIA [2014] 2016).

This massive expansion in both resource and energy consumption over about 30 years is unprecedented in the development experience of any other country. Such massive demands on China's environmental base has led to the accumulation of serious ecological challenges that now threaten the long-term prospects of the economy (Vennemo 2009; World Bank 2007). Among the various indicators that can be used to assess a country's environmental state, the "Ecological Footprint" and the "Environmental Performance Index" (EPI) provide a poignant indication of the magnitude of the ecological crisis.

The Ecological Footprint is made up of six components: carbon, forest, cropland, grazing land, fishing grounds, and land covered by infrastructure. It refers to the amount of biologically productive land (including fishing grounds) required to provide the resources demanded by human activities and to sequester carbon emissions (see Borucke et al. 2013). By 2014, China was responsible for 19% of the world's total Ecological Footprint, the largest share owned by a single nation. Following China's rapid growth of energy use, the carbon footprint is the component of China's Ecological Footprint that has been growing at the fastest rate. Between 1961 and 2014, China's carbon footprint, as a share of the national Ecological Footprint, increased from 10% to 51% (WWF 2014).

The Ecological Footprint can be compared to the concept of "biocapacity," which consists of the amount of productive land and water that is available to generate the resources demanded by the economy, and to absorb the relative waste. Measured in per capita terms, since the early 1970s, China's Ecological Footprint has systematically exceeded the value of the national biocapacity, leading to the accumulation of an ecological deficit every single year. In 2010, China's Ecological Footprint in per capita terms (2.2 gha) was over 120% the value of China's per capita biocapacity (1.0 gha) (WWF 2015).[4] As a result, China is now confronted with an ecological debt, which – unless seriously addressed – may jeopardise the future development possibilities of the economy and threaten to rapidly aggravate the state of ecological overshoot of the world economy as a whole.[5]

The EPI can be interpreted as a complementary indicator to the Ecological Footprint; it targets the effectiveness of environmental policies implemented within a nation's borders. The latest EPI report ranked 180 countries according to their performance in the protection of human health from environmental degradation and protection of ecosystems (Hsu et al. 2016).[6] According to this assessment, China is a poor performer;

it ranked 109th. The nations positioned lowest in the ranking are countries facing political or economic disputes, suggesting that environmental policy is a secondary issue when a country faces more direct emergencies. In the case of China, however, its position in the ranking is the result of neglect for the quality of the environment for a great part of the reform era. Policy measures to protect the environment and reduce dependency on fossil fuels have only been introduced in the early 2000s, when the consequences of rapid economic growth and massive energy demand became compelling.

Four dimensions have contributed to shift the attention of the government towards environmental issues and their potential impact on development prospects: first, the escalation in the number of environmental protests; second, the growing research showing the adverse health effects of pollution on the population; third, the impact of climate change on the national territory; finally, the urgency to guarantee energy security.

As citizens are becoming increasingly aware of the heavy environmental costs associated with China's rapid economic growth, the number of "mass incidents" against pollution has rapidly accumulated, both in rural and urban areas (Tong 2009).[7] According to the 2013 annual report released by China's Ministry of Environmental Protection, 712 cases of "abrupt environmental incidents" – many of which are in fact citizens' protests – occurred in 2013 alone, an increase of 31% on 2012. There is consensus that discontent about environmental degradation has become a major cause of social unrest, and has intensified the tension between the government and civil society (Tong and Lei 2010; Göbel and Ong 2012).

The rise in environmental activism is closely tied to a growing number of studies showing a link between pollution and health risks. According to the World Bank (2007), in 2003 the health costs of outdoor air pollution in urban areas were between 157 and 520 billion yuan, corresponding to 1.2% to 3.3% of China's gross domestic product (GDP) in 2003. More recently, *Global Burden of Disease Study 2010* by Lim and colleagues (2012) estimates that exposure to outdoor air pollution is the fourth leading cause of reduced life expectancy in China, and is responsible for 1.2 million premature deaths, around 38% of the total number of premature deaths worldwide. In addition, due to a combination of both smoking habits and pollution, lung cancer has become the leading cause of death in China. According to a study by Stewart, Wild, and Wild (2014) at the International Agency for Research on Cancer, one-third of the global cases of lung cancer happen in China.

Other forms of pollution in China are also health hazards. Water and farmland contamination with toxic chemical pollutants and heavy metals have contributed to the emergence of over 450 "cancer villages," which is the term officially adopted by authorities to refer to local cancer epidemics (*The World Post*, February 23, 2013). In the last 30 years, cancer rates in China have increased by over 80% (Zhao et al. 2009). Environmental pollution is also identified as a major contributor to the observed increase in birth defects, infertility, respiratory infections and cardiovascular diseases (Balabanič, Rupnik, and Klemenčič 2011; Kana et al. 2009; Perera et al. 2008; Zhang et al. 2014; Zhou et al. 2011).

In addition to the impact on public health, China's massive fossil fuel consumption has accelerated the global climate emergency. On the one hand, as shown in Figure 3, the exponential rise in carbon emissions has paralleled GDP, suggesting that energy

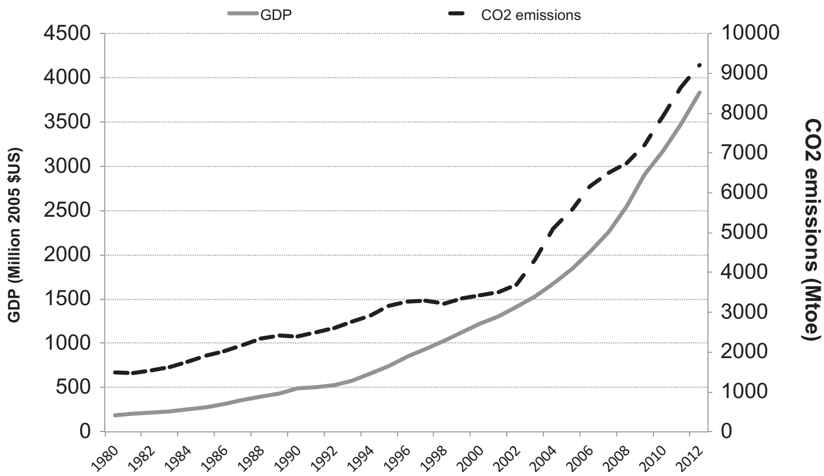


**Figure 3.** **China's $CO_2$ emissions and GDP, 1980–2012**
Source: EIA ([2014] 2016).

consumption has been closely related to China's stunning rise in income; on the other hand, however, the country has also become the world's leading emitter of carbon dioxide due to massive fossil fuel consumption, which is by now proven to be the major cause of the increase in global average temperatures (IPCC 2007).

China is estimated to be one of the countries that is more vulnerable to the effects of climate change. The country has already been experiencing severe droughts and floods, and more recurrent extreme weather patterns, which are expected to get worse in the coming years (Knight, Robins, and Chan 2011; National Development and Reform Commission 2012; Tiezzi 2014). As a result, China has experienced a rapid increase in the number of natural disasters; in 2011, 430 million people were victims of weather and climate calamities (Guha-Sapir, Hoyois, and Below 2013; National Development and Reform Commission 2012). According to the National Bureau of Statistics (2013, 2014), the economic losses from natural disasters in 2013 amounted to 421 billion yuan, an increase by 62% from 2012. The effects of climate change have made the need to reduce the dependency on fossil fuels a policy priority for the authorities (National Development and Reform Commission 2012, 2013).

Energy has become a prominent issue since 1993, when China for the first time became a net oil importer, ending energy self-sufficiency. Following the rapid growth of oil consumption, in 2013 China became the world's largest net oil importer. With respect to coal – the nation's primary energy source – China has been historically a net exporter; since 2009, China has become dependent on international trade to meet its coal demand. Since 2007, China has also been a net natural gas importer. Based on British Petroleum (BP) projections (2014), China's energy balance – measured by the difference between energy production and energy consumption – is expected to rapidly deteriorate, from -372 Mtoe (million tons of oil equivalent) in 2015 to -918 Mtoe in 2030. China will thus become increasingly dependent on foreign supplies to fulfil its energy demand, making energy security a fundamental concern for the authorities.

In response to these environmental challenges and to the fear that economic development may not be sustained if environmental problems are not addressed, the Chinese government has taken two types of action to guarantee both a steady supply of energy and primary resources and reduce the high level of domestic pollution. One strategy has involved securing primary resources in the developing world. China has increased its outward foreign direct investment (FDI) in extractive industries in Latin America and Africa. Since 2010, Chinese enterprises have invested an average of US$10 billion per year in Latin American countries. In Africa, China's FDI increased from around US$320 million in 2005 to US$5.2 billion in 2012. In both cases, around 30% of China's total FDI is invested in oil, minerals and other natural resources (ECLAC 2013; MOFCOM 2012). China has also proceeded to lock in relations with those developing countries that are major exporters of primary commodities or are recipients of China's FDI by committing to bilateral trade agreements, financial intermediation and foreign assistance. In 2014, China had free trade agreements with Chile and Peru, for both of which China is the primary export market of copper and other metals. In addition, China committed US$35 billion in loans to finance infrastructure and industrial development in Latin America and sought to increase loans to African countries to US$30 billion to support infrastructural projects (Ray, Gallagher, and Sarmiento, 2016; *The Wall Street Journal*, May 5, 2014). Between 2010 and 2012, China also allocated about US$14.4 billion to foreign aid, consisting of grants, interest-free loans and concessional loans, mostly destined to Latin America and Africa (Zhou 2014).

As a second strategy to address environmental problems, since the early 2000s China has begun to tackle its rapid growth of carbon emissions. To understand which measures a country can consider to confront its carbon emissions, it is useful to look at the "Kaya Identity" (Kaya and Yokobori 1997). The Kaya Identity provides a decomposition of carbon emissions, which identifies the drivers of greenhouse gas emissions and possible policy options.[8] These possible options are: first, diversifying the energy base away from fossil fuels towards renewable energy; second, reducing the amount of energy required by each unit of output; finally, accepting a reduction of income per capita or a decline in the population level.

In the case of China, the last two options have been outside the domain of consideration; for most of the reform period, officials have not demonstrated a willingness to give up improvements in standards of living and, in 2013, the "One Child Policy" has been revised to allow faster population growth. China has relied on carbon intensity of energy consumption and energy intensity to contribute to climate stabilisation and improve domestic environmental conditions. The product of these two variables is the CO2-to-GDP ratio, or the carbon intensity of GDP. At the Climate Conference in Copenhagen in 2009, China made a pledge to reduce its emission intensity (or CO2 emissions per unit of GDP) by 40% to 45% by 2020 compared to 2005 levels. Even though at this point scientists indicate only an absolute reduction in emissions can tackle the climate crisis, China has not committed to reduce the absolute level of its emissions, but to curb their growth rate. To fulfil this commitment, improvements in energy efficiency and investment in renewable energy have become the two key dimensions targeted by the policy measures that the government has established.

## China's World Leadership in Renewable Energy

Beginning in the early 2000s, the Communist Party began to demonstrate a commitment to the environment through a variety of directives, pledges and laws. In September 2003, the 16th Party Congress announced its intention to pursue a "scientific approach to development" to achieve "common prosperity" and a "harmonious society." Within this framework, the Chinese leadership promised to pay greater attention to social equity and environmental sustainability, shifting away from the commitment to economic growth only as an instrument for development. This new political agenda led to research on "green national economic accounting" – which ultimately only produced marginal results – and set the foundations of a series of policy initiatives targeting energy use and environmental protection (see Wang, Jiang, and Yu 2004; Rauch and Chi 2010; Worldwatch 2010).[9]

In November 2004, the National Development and Reform Commission (NDRC) issued the Medium and Long-Term Energy Conservation Plan, which constitutes the first critical recognition on the part of the government of the importance of energy saving for long-term development (New Climate Institute 2015). The plan targeted a reduction in energy intensity by an average annual rate of 2.2% from 2003 to 2010, and by 3% from 2003 to 2020. The plan specifies possible measures for energy conservation in individual energy intensive industries, different forms of transportation, in addition to construction, commercial and residential buildings. In addition, the plan introduced energy efficiency standards for major energy-consuming appliances, and identified the key sectors and projects that should be tackled to fulfil the energy intensity targets.

In 2005, the National People's Congress approved the Renewable Energy Law, which sanctioned China's commitment to renewable energy development and provided the following guiding mechanisms for the promotion of renewable energy: first, setting renewable energy development and utilisation targets; second, introducing a mandatory purchase policy for grid companies and gas and heat operators; third, adopting an on-grid electricity price for renewables to be set by the NDRC; lastly, using a cost-sharing mechanism to ensure grid companies are able to recover the additional cost of renewables with respect to fossil fuels (Schuman and Lin 2010). A 2009 amendment introduced three key new principles: first, in response to the observed systematic violation of the mandatory purchase policy, grid companies were required to provide a fixed share of their total power generation with renewables (where the share was left to be determined by specific government agencies); second, a Renewable Energy Development Fund was established to support both grid companies and new investments and research in renewable energy. It was determined that the fund would be financed through a surcharge imposed on electricity bills (Schuman 2010).

Energy was also at the core of the 11th Five-Year Plan (2006–10), which pledged an even more ambitious energy saving target than stated in the 2004 Medium- and Long-Term Energy Conservation Plan. The new goal consisted of a reduction in energy intensity by 20% from 2005 levels by 2010.[10] The plan also contained a series of commitments towards environmental protection, including more investment in water quality and conservation and a reduction of major pollutants by 10% from 2005 levels by 2010 (Fan 2006; Naughton 2005; Zhou, Levine, and Price 2010).

Based on these guidelines, the 2007 Medium- and Long-Term Energy Development Plan for Renewable Energy stated that the national share of primary energy consumption from renewables should rise to 10% by 2010 and to 15% by 2020 (National Development and Reform Commission 2007). It also specified that non-hydro renewables should provide 1% of total power generation by 2010 and 3% by 2020. In the same year, the government introduced a new Energy Conservation Law – amending the provisions of the same law enacted in 1997, which remained largely ignored – requiring that all new fixed investment considered by the government should undergo an energy efficiency evaluation before receiving approval. This new policy has intended to shift public investment towards low-carbon and energy saving projects.

China's commitment to energy conservation and emission reduction was confirmed in the context of the 2008 global economic crisis. When the recession hit, China responded with a stimulus package of 4 trillion yuan (US$586 billion) – 14% of GDP in 2008 – to be spent through 2010 to offset the collapse of exports with domestic demand, preventing a sharp decline of economic growth.[11] Around 38% of China's stimulus was directed towards environmental goals, including rail, grid and water infrastructure, as well as energy efficiency improvements, waste management and pollution control (Wong 2011).[12] The fiscal package was accommodated by a rapid growth of bank loans; about 75% of the plan was designed to become effective through bank credit rather than direct government outlays, and the People's Bank of China supported this process by lowering interest rates (Yueh 2010).

The *dirigiste* nature of the financial system has played an important role in supporting the Communist Party's environmental commitments. In 2007, the Ministry of Environmental Protection, the China Banking Regulatory Commission and the People's Bank of China jointly issued a Green Credit policy (with specific guidelines introduced in 2012), requiring banks to strictly control credit issuance to energy intensive or polluting industries and to support investments in energy saving, environmental protection and renewable energy. Based on these principles, banks have been critical in financing large-scale investment in clean energy and energy efficiency in the years following the global crisis. At the Industrial and Commercial Bank of China, one of China's four state-owned banks and the largest bank in the world for total assets, loans to finance energy efficiency and low-carbon projects (including nuclear power) have increased from 63 billion yuan in 2010 to 598 billion yuan in 2013.[13]

The 12th Five-Year Plan (2011–15) made further steps towards promoting low-carbon energy sources. The plan included a set of ambitious targets to be achieved by 2015: reducing energy intensity by 16%; raising the share of non-fossil fuel energy consumption to 11.4%; and reducing carbon intensity – defined by the ratio of carbon emissions to GDP – by 17% (Lewis 2011).[14] The plan also stated the goal of gradually establishing a carbon market. By 2016, seven carbon-trading pilots have been established in five cities (Beijing, Tianjin, Shanghai, Chongqing and Shenzhen) and in two provinces (Hubei and Guangdong), and a national emission-trading scheme has been announced for 2017 (Qiu 2013).

To support the targets indicated in the 12th Five-Year Plan, in 2013 the government introduced two important pieces of legislation to tackle pollution and climate change. First, the State Council issued an Action Plan for Air Pollution Prevention and Control, which committed to a specific set of measures to improve air quality over the following five years, including a pledge to reduce China's share of coal consumption in total energy consumption to 65% by 2017. Second, the council approved the first major blueprint for tackling climate change – the National Plan for Addressing Climate Change (2013–20) – which outlined a set of targets to mitigate and adapt to the effects of climate change, including raising the share of non-fossil fuel energy to 15% (confirming the commitment made in 2007), fulfilling the carbon intensity target declared at the 2009 Copenhagen Conference, and undertaking extensive reforestation programmes. To tackle climate change, in November 2014 China signed an agreement on emission reduction with the US. China committed to increase its share of renewable energy consumption to 20% by 2030, and pledged that domestic carbon emissions would peak in the same year (*New York Times*, November 11, 2014). In the Paris Agreement in 2015, China confirmed these commitments and added the pledge to reduce carbon dioxide intensity by 60% to 65% from 2005 levels by 2030 (Center for Climate and Energy Solutions 2015).

To support the declared commitment to reduce the dependency on fossil fuels, China has adopted specific measures to succeed in the manufacturing of renewable energy equipment. On the one hand, Chinese manufacturing firms have succeeded in lowering the costs of production of certain technologies originally developed in industrialised countries, which allowed them to obtain a competitive advantage in the global markets. On the other hand, Chinese firms have established joint ventures or have been involved in investment or acquisition of foreign firms in the wind and solar industries to gain access to new technologies and new markets; the US and Germany are the primary destination countries of China's investment in these industries (Knight 2012; Gallagher 2014; Tan et al. 2013).

Since 2012, China has become the world's leader for total installed capacity of renewable energy power, both inclusive and not inclusive of hydropower (REN21 2014). Figure 4 shows the level of renewable energy capacity from 1980 to 2012. Renewable energy capacity, driven by hydropower, has kept growing since the beginning of the reform period. In recent years, however, non-hydro renewable energy capacity has begun to increase very rapidly. Figure 5 shows the installed capacity level of solar photovoltaic (PV) and wind turbines, the two largest non-hydro energy sources, from 2003 to 2013. Solar PV has more than doubled on an annual basis since the global crisis. Starting in 2008, the installation of wind power has also shown a dramatic increase; by 2013, China's wind power capacity was 30% of the world's total wind energy capacity.

## "Green" Development: Limitations and Challenges

As demonstrated above, China has introduced many measures to improve the quality of its environment and shift away from the dependency on fossil fuels. Following the introduction of these initiatives, China has been praised for having become the global leader in clean energy and for potentially being on the road to embrace a "green" model of development (Hu 2011; Liu, Henry, and Huang 2013). In reality, however, China's recent development strategy is characterised by significant contradictions and imbalances, which threaten the sustainability of China's commitment to environmental concerns and put in question the long-term effectiveness of its environmental policies. The key relevant issues comprise domestic and international factors, both of which encompass economic and political dimensions.

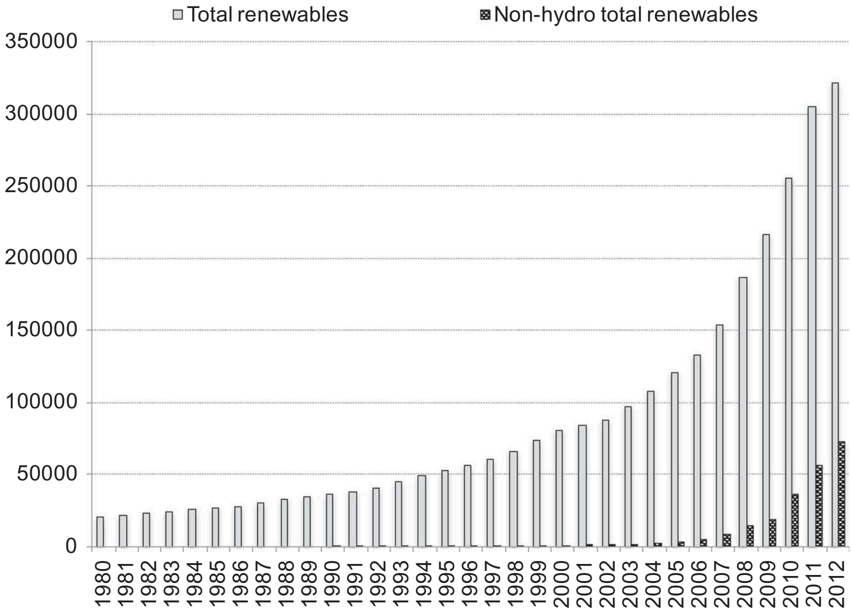


**Figure 4.** **China's renewable energy installed capacity, 1980–2012 (megawatts)**
Source: EIA ([2014] 2016).

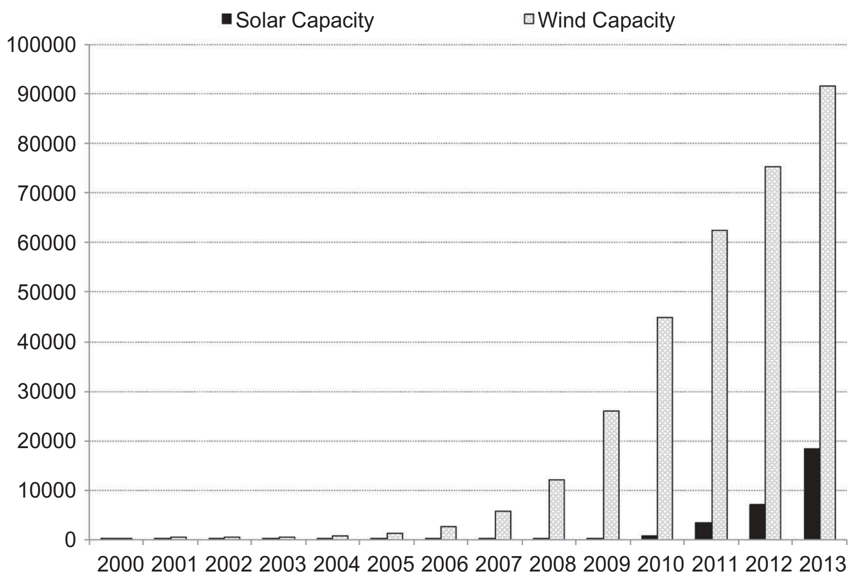


**Figure 5.** **China's solar and wind installed capacity, 2000–13 (megawatts)**
Source: BP (2014).

Domestically, there are powerful economic forces that challenge China's potential to move to a "green" development path. Since 2012, economic growth has slowed, and the expectations are for this trend to continue (Davis 2014). In 2014, for the first time in 15 years, economic growth fell short of the 7.5% target set by the government. A reduction in income growth implies that the government is going to face more constraints in the use of resources and in the setting of policy priorities. As a result, the government may come to act on the presumption that it has to pursue growth at all costs, even if at the cost of environmental degradation.

Poverty reduction, for example, which has already proceeded at a slower pace after China's transition to full-scale market liberalisation and privatisation in the early 1990s (Ravallion and Chen 2007), is likely to become even more challenging in a slowing economy. Granted that economic growth per se is not sufficient for poverty reduction, specific policy interventions are even more compelling in the context of lower GDP growth. In China, according to the official statistics, over 80 million rural citizens still live in poverty; addressing the problem may come to crowd out China's competing commitment to environmental protection, especially if the slowdown persists. Under these circumstances other pressing policy areas – such as education, technological innovation, health care and social security – could end up being in conflict with environmental targets as well.

Already in 2013, despite the discourse on pollution reduction and low-carbon promotion, central and local governments' expenditure for energy saving and environmental protection dropped by 9.7% from 2012 levels (Ministry of Finance 2014). China's spending for environmental purposes – US$30 billion in 2013 – remains inadequate in the face of the magnitude of the environmental challenges. It is estimated that at least 2% to 4% of annual GDP is required to achieve a discernible improvement in environmental conditions (Lin 2014). Despite this, the government has announced its intention to phase out state support for the production of solar and wind equipment by 2020. Based on the current technological capabilities of these industries, their economic viability without government support is precarious; in turn, this means that China's comparative advantage may not be maintained (Young 2014).

A critical variable for addressing environmental and climate challenges is energy efficiency. As shown in Figure 6, China's energy intensity – as measured by energy consumption per unit of GDP – has dramatically decreased between 1980 and the early 2000s. This reduction has been largely the result of a conscious effort on the part of the leadership; energy conservation state agencies have been established to support enterprises in setting up and implementing energy efficiency plans (Crossley 2013). Since the early 2000s, however, the reduction in energy intensity has proceeded at a much slower pace (with increases recorded in 2003 and 2004). In 2011, China's energy intensity was 40% higher than the world's average. Based on purchasing power parities, China's energy intensity is higher than energy intensity in Europe and in the US and also significantly higher than in other key emerging countries, like India and Brazil (EIA ([2014] 2016). The shift to more efficient infrastructures, equipment and engineering designs requires time and resources, and – at the current rate of transformation – the transition may not be completed within the time frame that the scientific community indicates to be available to ensure climate stabilisation.

In addition to the challenges associated with low energy efficiency, China's shift to a low-carbon economy is constrained by the current state of the country's electricity grids and by the typical enforcement problems associated with legislation. In spite of national targets on renewable energy, and financial subsidies, preferential loans and tax

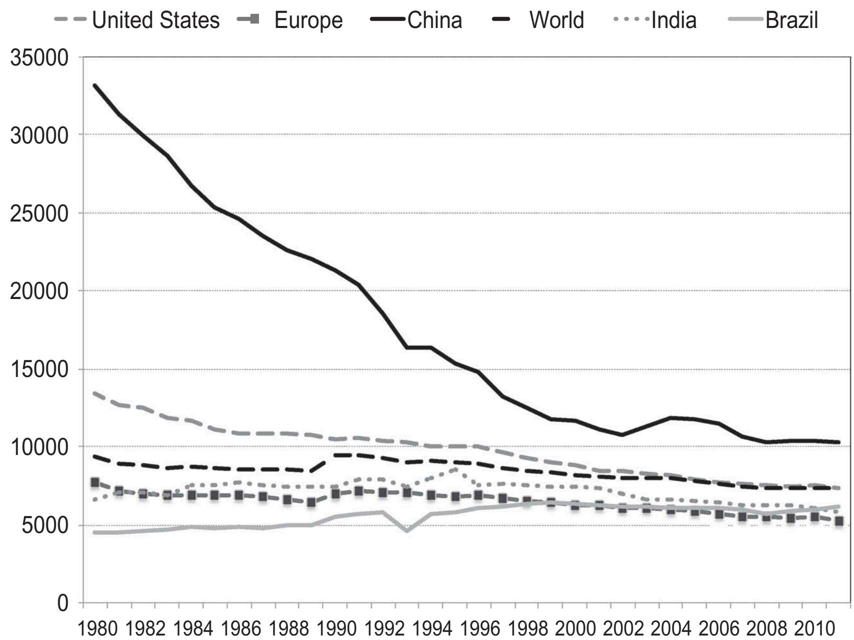


**Figure 6. Energy intensity: ratio of total primary energy consumption to GDP (Btu per 2005 US dollars - purchasing power parities), 1980–2011**

Source: EIA ([2014] 2016).

incentives to enterprises, China's state-controlled infrastructure system for electricity distribution represents a major obstacle for the development of renewable energy (REN21 2009). China's largest wind power plants are located in the north and the large-scale PV power plants have been built in western China, Tibet and Mongolia. The main demand, however, comes from the industrialised areas in the east and the south (IEA and Energy Research Institute 2011; Wang, Yin, and Li 2010). Grid connectivity between renewable power plants and the main power grids remains inadequate. Each regional grid unit is accountable for their own financial records, and therefore – based on the current institutional arrangement – there is insufficient incentive for co-operation across regions and for long-term planning. In addition, traditional energy dispatch rules provide each coal power plant an equal number of operating hours, independent of the level of efficiency and the environmental impact of each power plant. Although portfolio mandate schemes assign priority to renewables and "clean" coal power plants and the government has committed to the construction of new smart grids to specifically allow the transmission of wind and solar energy coming from power plants located in remote areas, thus far these efforts are not expected to contribute to a reduction in carbon emissions and may only lead to a significant increase in electricity prices for consumers (Madrigal and Porter 2013; Chandler et al. 2012; Wang, Yin, and Li 2010).

As mentioned above, a major challenge for China's environmental legislation is enforcement. The growing decentralisation of the central government observed during the reform period has brought greater relative autonomy to local governments. Such political restructuring, however, has generated enforcement problems at the local level, primarily due to widespread corruption and inadequate supervision, guidance and incentives from the central government. Several proposals have been advanced to repair this deficiency, but enforcement remains a critical institutional barrier for environmental protection (Lo et al. 2012; He et al. 2012).

Enforcement issues also magnify the challenges associated with the urbanisation targets set by the Chinese government for the coming years. As part of poverty reduction plans, the government has the intention to increase the urbanisation rate to 60% by 2020. This implies that by 2020, more than an additional 100 million people are expected to relocate from the countryside to urban areas. To fulfil this target, the government has committed to spending US$6.8 trillion for the construction of new cities and associated infrastructure (Roberts 2014). By 2009, 75% of China's total energy consumption was absorbed by the industrial sector, while the remaining 25% is distributed, in order of importance, among residential, transportation and commercial needs (Department of Energy Statistics 2010).

As urbanisation rates rise, China's energy composition will change. Looking at energy composition in the US in the same year as a reference – the urbanisation rate in the US is around 82% – the industrial sector absorbs around 30% of the total US energy consumption, whereas the shares of residential, commercial and transportation are about 22%, 19% and 29%, respectively ([2014] 2016). These last three sectors are thus clearly going to acquire a great weight in China in the coming years. Whether China will be able to satisfy these growing demands with a high proportion of renewable energy cannot be anticipated. Certainly, however, this is a major challenge that has never been attempted by any other country.

By 2012, the ratio of non-hydro renewables to China's total primary energy consumption was approximately 1.2% (BP 2014).[15] Despite a growing share of non-hydro renewable electricity capacity in total electricity capacity – which increased from 0.5% in 2004 to 6.1% in 2012 – the contribution of renewables (excluding hydropower) to China's energy consumption remains small and behind both the US and the European Union (BP 2014).[16]

On these foundations, China will have difficulties meeting its 2009 Copenhagen pledge. Figure 7 compares the historical rate of change of emission intensity – as measured by the ratio of carbon dioxide emissions to real GDP – with the average annual reduction rates of emission intensity required to meet its 2009 commitment. To ensure a reduction in emission intensity by 40–45% from 2005 by 2020, China's emission intensity should decline by 3.3–4% per year. After a reduction in emission intensity by over 5% in 2008, between 2009 and 2013 China did keep reducing its emission intensity; the observed reduction rate, however, only narrowly met the minimum average annual reduction rate required by China's pledge in Copenhagen in 2009. There is no doubt that very significant efforts will be required to fulfil China's urbanisation and other development plans while meeting climate stabilisation goals.

In addition to the factors discussed above creating impediments to an effective shift to ecological sustainability, there is also a set of international factors that need to be considered. Renewable energy technology and equipment have become for China not only instruments for "greener" development, but also a source of profit. Figures 8 and 9 provide an international perspective on the relative magnitude of annual manufacturing capacity of PV modules and wind turbines with respect to

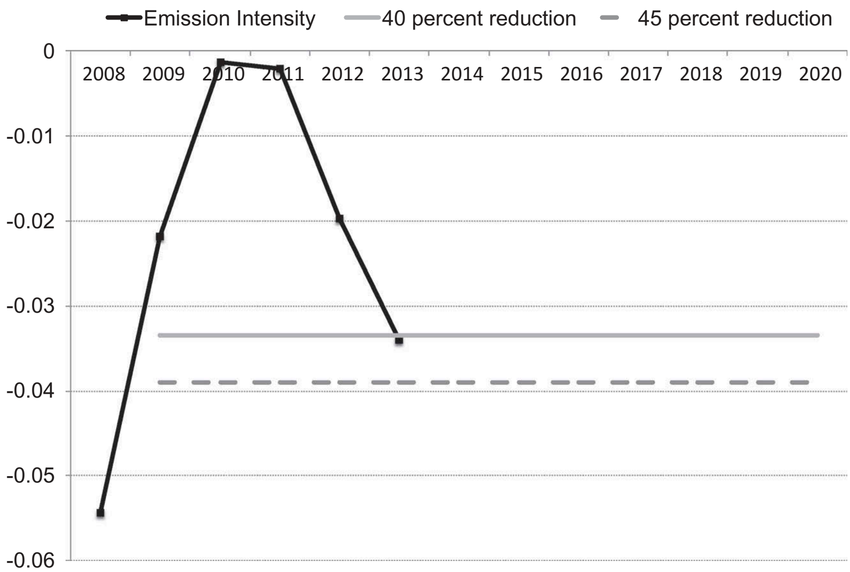


**Figure 7.** **China's annual rate of change in emission intensity vs. average annual rate of change in emission intensity required to fulfil the Copenhagen pledge**

Source: Processing of BP and WDI data (2014).

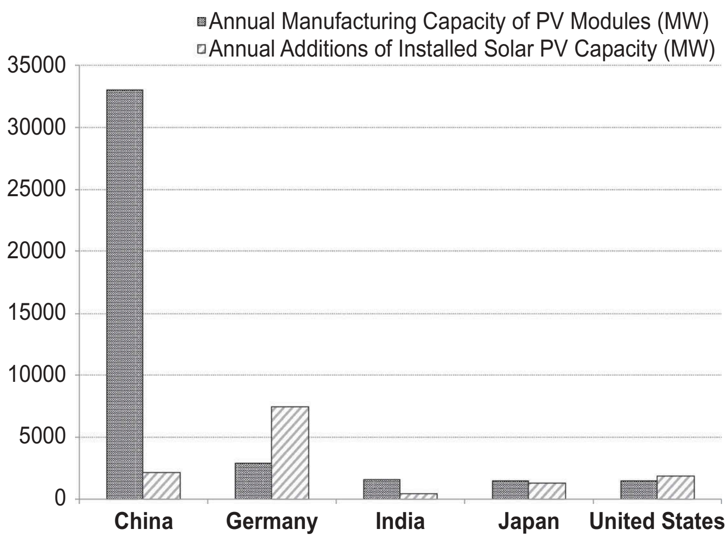


**Figure 8.** **International comparison annual manufacturing capacity of PV modules and annual additions of installed solar PV, 2011 (megawatts)**

Source: World Resource Institute (2014).

annual installations of the same items in 2011 for China, Germany, Japan, India and the US. In comparison to these countries, China produces per year a far higher number of solar PV and wind turbines than the number that is installed domestically. The remainder are available for export. It has been argued that China is

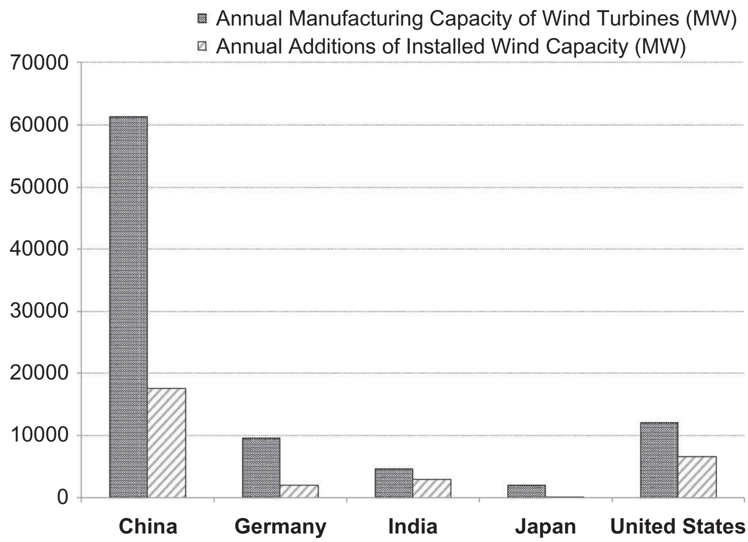


**Figure 9.** **International comparison of annual manufacturing capacity of wind turbines and annual additions of installed wind capacity, 2011 (megawatts)**
Source: World Resource Institute (2014).

pursuing "green mercantilism," hinting that a prominent component of China's interest in green technology lies in the desire to exploit the renewables market for profit rather than for building a sustainable economy (Stepp 2013). In particular, China has been singled out for using unfair trade and technology practices to build a competitive advantage in the solar and wind industry, which is seen as profitable in the short term but detrimental for incentives to invest in clean energy innovation in the industry as a whole.

At the same time, China's rising trade, financial and investment relations with both Latin America and Africa, while being instrumental for the provision of critical primary commodities to the Chinese economy, has also been an opportunity for China to externalise pollution and carbon emissions.[17] China's relationship with Latin America, primarily targeting natural resources, is already perceived as a threat for the adoption of climate change policy and for a shift to a low-carbon development model in the region (Edwards and Roberts 2014).

China's expansion in Africa is subject to similar concerns. China's trade and investment in extractive industries in African countries has been associated with growing environmental degradation and ecological footprint; lack of systematic data, however, is still a key constraint for reaching an accurate assessment of these environmental costs (Peh and Eyal 2010). The focus on domestic environmental issues on the part of the Chinese government has thus been accompanied with the shift of certain environmental costs to other countries rather than with their absolute reductions. Given that the environment is a global commons, however, it is only absolute decoupling – the absolute reduction in material and energy consumption – that matters for ecological sustainability and climate stabilisation (Jackson 2011).

## Conclusion

Rapid economic growth over the last three decades has made China a global economic powerhouse. This growth, however, has been associated with massive increases in the consumption of energy and primary commodities, and has generated a deterioration in the country's environmental conditions. Since the early 2000s, China's leadership has taken steps to address these environmental problems and the use of natural resources. The result is that China has become the world's largest investor in renewable energy sources. Nonetheless, the effectiveness and sustainability of these efforts remain questionable.

An analysis of both domestic and international forces suggests that China's prospects of moving towards a more ecologically sustainable model of development are challenged by sturdy limitations and contradictions. In this context, an effective solution to China's environmental crisis requires the acknowledgment of global responsibilities.

Following the neo-liberal transformation of global capitalism since the early 1980s (Robinson 2004), China's environmental crisis is not simply the product of a faulty developmental strategy undertaken by the Chinese government. Rather, it is also the result of the externalisation of pollution on the part of high-income economies. This process has allowed high-income countries to benefit from cheap manufacturing relocated to China – and other Asian nations – without experiencing the direct environmental costs associated with the industrial production of these commodities.[18]

To take into account the global responsibilities behind China's environmental crisis, a new approach to climate negotiations could prove to be both equitable and effective. If emission reduction negotiations were to be made on the basis of carbon consumption, as embedded in a country's net imports, higher-income countries could have a greater incentive to support emission reduction in developing countries through technology and income transfers. In addition to targeted domestic policies, this strategy could favour greater international co-operation in climate stabilisation and promotion of a low-carbon development path, and would represent one important step in responding to the enduring environmental challenge of our time (Ackerman 2011; Grasso and Roberts 2014).

## Notes

1. $PM_{2.5}$ refers to particles in the air that are less than 2.5 micrometers in diameter. Because of their small size, they are referred to as "fine" particles, and are considered to be the most dangerous type of air pollution for public health.
2. According to the classification used by the US Energy Information Administration (EIA) non-hydro energy sources include biomass, geothermal, solar, wind, ocean thermal, wave action and tidal action.
3. Conventionally, renewable energy refers to the following low-carbon energy sources: solar, wind, geothermal, biomass and hydropower.
4. Both the Ecological Footprint and biocapacity are reported in "global hectares" (gha), which measure areas of different types of land adjusted for productivity. China has the world's largest population, but its rate of growth has been declining over the last 40 years. Over the course of the reform period, however, China's per capita resource consumption has significantly increased. According to an analysis by WWF (2012), until the end of the 20th century, the average annual increase in the per capita Ecological Footprint was 0.02

gha per person. This rate increased to 0.07 gha between 2000 and 2008, leading to a rapidly growing gap between the national Ecological Footprint and national biocapacity.

5. Since the early 1970s, the world economy as a whole has been demanding more resources than what the planet can regenerate. The WWF (2014) calculates that 1.5 Earths would be required to provide all the resources that humanity currently demands.
6. Within these two policy domains, the EPI identifies nine issues (health impact, air quality, water and sanitation, water resources, agriculture, forests, fisheries, biodiversity and habitat, climate and energy), all measured by 20 indicators.
7. The first significant environmental demonstrations were in 2005 (Deng and O'Brian 2013). "Mass incidents" is an official term used to refer to protests involving at least 100 people.
8. The "Kaya Identity" is reported every year by the International Energy Agency (IEA) in the *World Energy Outlook*; it is used by the IEA to formulate future scenarios of emission growth. The Kaya Identity is expressed as follows: $CO2 = (CO2 / E) \times (E / GDP) \times (GDP / POP) \times POP$. Where: $(CO2 / E)$ = carbon intensity of energy consumption; $(E / GDP)$ = energy intensity; $(GDP / POP)$ = GDP-per-capita; $POP$ = population.
9. Green national accounting refers to a system of accounting that requires subtracting the costs of environmental degradation, depletion of national resources and environmental restoration plans from traditional GDP.
10. This target was introduced in response to an increase in energy intensity experienced between 2003 and 2005, which broke the trend of declining energy intensity that had been steadily observed since the beginning of the reform period.
11. The major areas targeted by China's stimulus plan are the following: (i) low-income housing; (ii) rural infrastructure; (iii) transportation (including railways, highways and airports); (iv) health, culture and education; (v) environmental protection; (vi) technology innovation and industrial reconstructing; (vii) post-Sichuan earthquake reconstruction. The plan was accompanied by income support for rural and urban citizens, a value-added reform tax to reduce the fiscal burden on enterprises by 210 billion yuan, and a financial reform (including removing ceilings on banks' credit) (Wong 2011).
12. Among the countries that implemented a fiscal stimulus plan during the global crisis, only the Republic of Korea introduced a greater share than China's for environmental projects (81%) (Strand and Toman 2010).
13. The China Development Bank – which since 2009 has lent more money to other developing countries than the World Bank – has financed over the past several years projects in natural resources (especially, metals and mining and oil and gas) and infrastructural construction abroad. This is in line with China's objective to secure natural resources in other countries to fulfil its internal demand. More recently, the bank has begun to finance renewable energy investment to support Chinese companies producing solar and wind power, and the purchase by foreign enterprises of renewable energy infrastructure made in China. Following the new guidelines introduced by the Chinese government in 2007, China Export and Import Bank – China's official state bank providing export credit to Chinese firms and loans for investment projects in foreign countries – is required to include a social and environmental assessment before approving loans for projects overseas. In addition, after the introduction of the Green Credit guidelines established in 2012, China Export and Import Bank is further constrained by the commitment to support a green and low-carbon economy.
14. As of March 2016, the government officially disclosed its 13th Five-Year Plan (2016–20). In the new plan, energy and environmental issues continue to be part of the government's agenda. The plan targets a reduction in carbon intensity by 18% from 2015 levels, and a reduction of energy intensity by 15% (Pashley 2016).
15. In 2012, the share of hydropower in China's total primary energy consumption was 7.2% (BP 2014).
16. As a comparison, in 2012 the share of renewables in total primary energy consumption was 2.3% for the US and 5.8% for the European Union (BP 2014).

17. This process of externalisation is exactly what currently rich nations have done as well over the course of the globalisation process by relocating manufacturing production to developing countries.
18. Such production of low-cost goods has also sustained living standards and consumption patterns in wealthy countries during a time of wage compression and rising inequality.

## Disclosure statement

No potential conflicts of interest was reported by the author.

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