CHINA'S CARBON EMISSIONS REPORT 2015

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HARVARD Kennedy School
BELFER CENTER for Science and International Affairs

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About the Author

Zhu Liu is a joint Giorgio Ruffolo Post-doctoral Research Fellow in the Sustainability Science Program and the Energy Technology Innovation Policy research group, a joint project of the Science Technology and Public Policy Program and the Environment and Natural Resources Program at the Belfer Center for Science and International Affairs.

His research focuses on global sustainability accounting and low carbon energy transition. Zhu is contributing to collaborative work with the Initiative on Sustainable Energy Development in China led by Professor Henry Lee and Professor Laura Diaz Anadon.

He conducted his Doctoral study in Ecology at the Chinese Academy of Sciences (CAS) and graduated with CAS highest honor (CAS Presidential Special Award). Zhu received his Ph.D. from CAS (2013) with joint training by the University of Cambridge (2012). He holds a Bachelor's degree in Geology from Northwest University (2007) and a Master's degree in Ecology from China Agricultural University (2009). His research on energy and climate has been published in *Nature*, *Nature Climate Change*, *PNAS*, and other professional journals.

Acknowledgements

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Summary

In 2012 China was the largest contributor to carbon emissions from fossil fuel burning and from cement production. With 8.50 Gt CO_2 in in carbon emissions from fossil burning and cement production in 2012, China was responsible for 25% of global carbon emissions. China's cumulative emissions from fossil fuel burning and cement production from 1950-2012 were 130 Gt CO_2.

The magnitude and growing annual rate of growth of China's carbon emissions make this country the major driver of global carbon emissions and thus a key focus for efforts in emissions mitigations. This report presents independent data on China's carbon emissions from 1950-2012, and provides a basis to support mitigation efforts and China's low-carbon development plan.

The research indicates that:

1. Total carbon emissions in China already equal the emissions from the U.S. and the E.U. combined, however, the per capita emissions are still significantly lower than that of the U.S., but are approaching the average level of the E.U. countries. Given the magnitude and growth rate of China's carbon emissions, the country has become a critical partner in developing policy approaches to reducing global CO_2 emissions.

2. Carbon emissions are mainly the result of fossil fuel combustion (90%) and cement production (10%). Manufacturing and power generation are the major sectors contributing to China's carbon emissions, together these sectors accounted for 85% of China's total carbon emissions in 2012.

3. Significant diversity exists in China's regional carbon emissions, for example, per capita carbon emissions, and carbon emissions intensity (carbon emissions per unit of GDP) often differ by an order of magnitude across regions (differences are most prominent between developed regions on the east coast and the underdeveloped regions in the west).

4. About twenty-five percent of China's carbon emissions are caused by manufacturing products that are consumed abroad. These, so-called virtual emissions, which are "embodied" in international trade, lead to China having the world's most unbalanced virtual emissions trade with its emissions associated to exports being 8 times higher than its emissions associated with imports.

5. Given the magnitude and uncertainty surrounding China's carbon emissions, the precise quantification of CO_2 emissions in China will be critical in the world effort to establish global carbon emissions mitigation.

Keywords: China, Carbon emissions, Carbon footprint, Low-carbon development.

1. Trends of China's Carbon Emissions in 1950–2012

China's carbon emissions from fossil fuel burning and cement production were 8.50 Gt CO_2 in 2012, making it the country with the largest emissions in the world. China's carbon emissions were only 5.46 Mt CO_2 in 1950, thus the total emissions increased more than 100-folds during those 60 years. Such a growth rate was the highest among the world's major economies. In 2007 China's carbon emissions surpassed that of the U.S., in 2012 China's carbon emissions were almost equivalent to the carbon emissions from both the U.S. and the E.U. combined. During the first decade of the twenty first century, China's total emissions tripled, thereby pushing China into first place as the world's largest carbon emitter in 2007.[1]

Particularly, the emissions from coal consumption increased at an average annual rate of 5% between 2000 and 2012. China's carbon emissions accounted for 73% of the cumulative global emissions growth between 2010 and 2012.

Carbon emissions are mainly the result of fossil fuel combustion (90%) and cement production (10%). In 2012, 90% of China's energy consumption was primarily derived from fossil fuel combustion (Figure 2): 68% from coal consumption; 13% from oil and 7% from gas. China
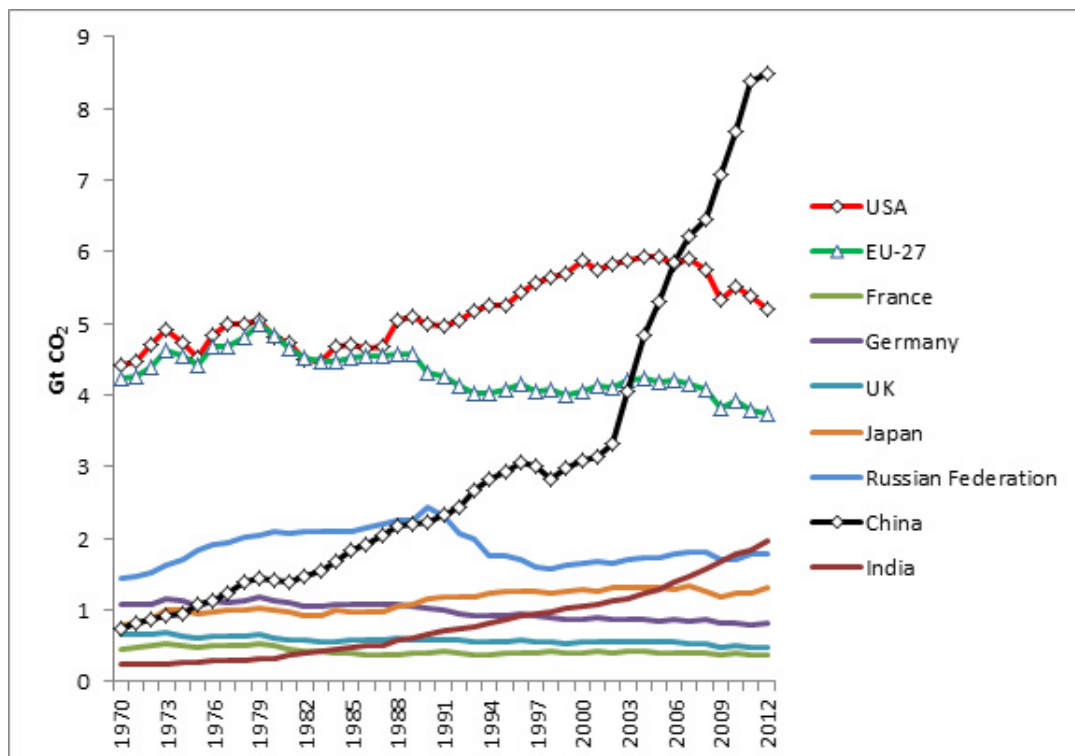
Figure 1: *Total CO_2 emissions of major emitters in 1970-2012. China's data on carbon emissions was calculated by the author, the emissions data of the other countries was sourced from the international datasets of CDIAC[2] and EDGAR.[3]*

produced 3.5 billion tons of coal, which was about half of the world's total;[4] cement produc-
tion in China was 2.3 billion tons, accounting for 60% of the total global cement production.
China's cement production from 2010-2012 was already higher than the total cement produc-
tion in the U.S. was for the entire 20th Century, the gigantic scale of fossil fuel combustion and
cement production makes China dominate the total global carbon emissions.

Among the industrial sectors, the emissions are mainly produced by the manufacturing and
power generation sectors (see Figure 3). In 2012 manufacturing accounted for 47% of China's
total carbon emissions, while thermal power generation contributed 32%, and the transpor-
tation sector accounted for only 6%. Such patterns differ with each sector's proportion of
emissions from other major emitters, especially from the developed countries where the emis-
sions are mainly from the transportation and household sectors. For example, in the U.S. the
transportation sector produces 32% of the total carbon emissions while the industrial sector
only accounts for 17%.
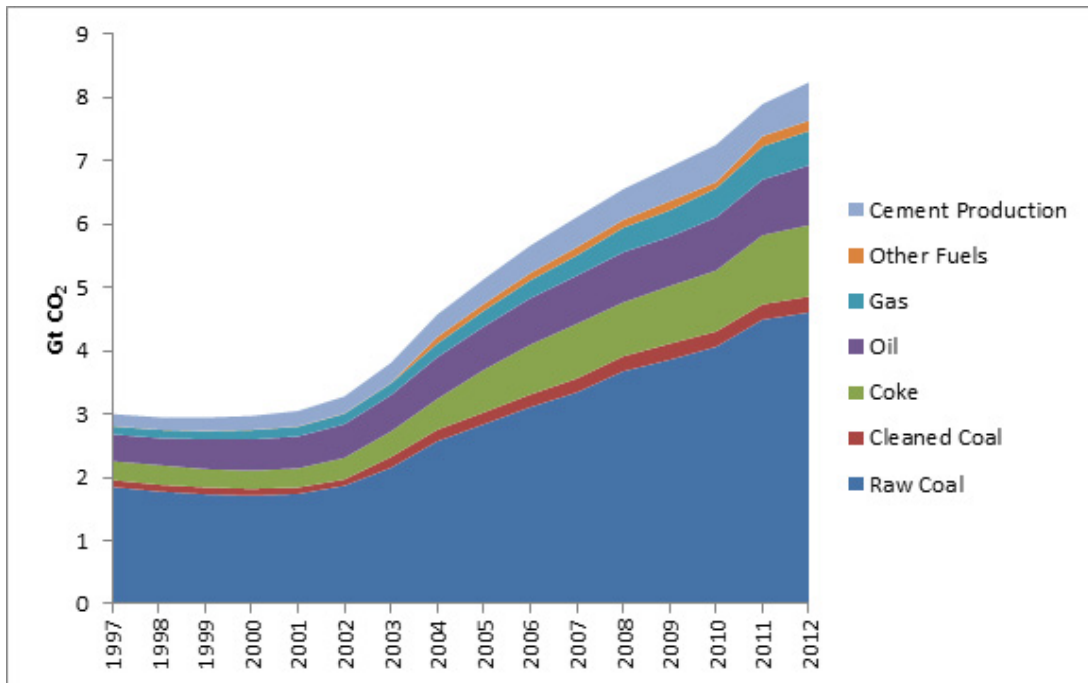
Figure 2: *China's emissions by fuels during 1997-2012.*
Data calculated by the author (See Section 5 for the detail methods)
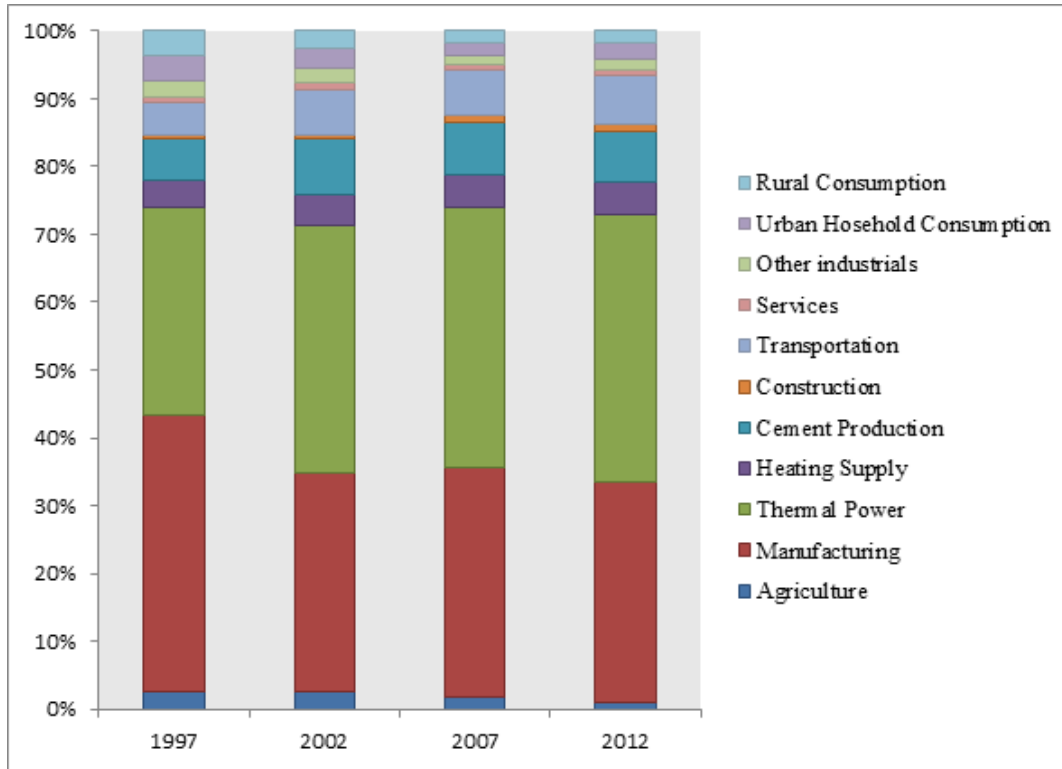
Figure 3: *Sector share of carbon emissions from China.*

2. Carbon Emissions per capita and Emissions Intensity

Carbon emissions per capita (Figure 4) and carbon emissions intensity (emissions per unit of GDP) are the indicators that have been widely used in the carbon emissions studies.[5, 6] Given that China is by now the largest country in terms of population and the second largest country in terms of GDP, analysis both in terms of emissions per capita and emissions intensity are essential to obtain a more holistic understanding of China's carbon emissions. Although China already leads the world in terms of total carbon emissions, its per capita emissions are still lower than those of the major developed countries. China's per capita carbon emissions are 6.26 t CO_2/per person, a level approaching that of the .E.U. average, but one that is lower than the level of the U.S. (17 t CO_2/per person, Figure 4).

It should be noted that the annual per capita emissions in major developed countries had already reached their peaking point and had decreased. China's per capita emissions are still on the rise. The theory of the Environmental Kuznets Curve suggests that the per capita emissions in China will also start decreasing with growing per capita GDP. China's current GDP per capita of $6807 (one-eighth of that for U.S.) suggests that per capita emissions still have the potential to increase for a long time before China will reach the tipping point -- assuming that the tipping point level is equal to either that of the U.S. (17 t CO_2/per person) or that of the E.U. (8 t CO_2/per person on average), which have different living styles and energy mixes.
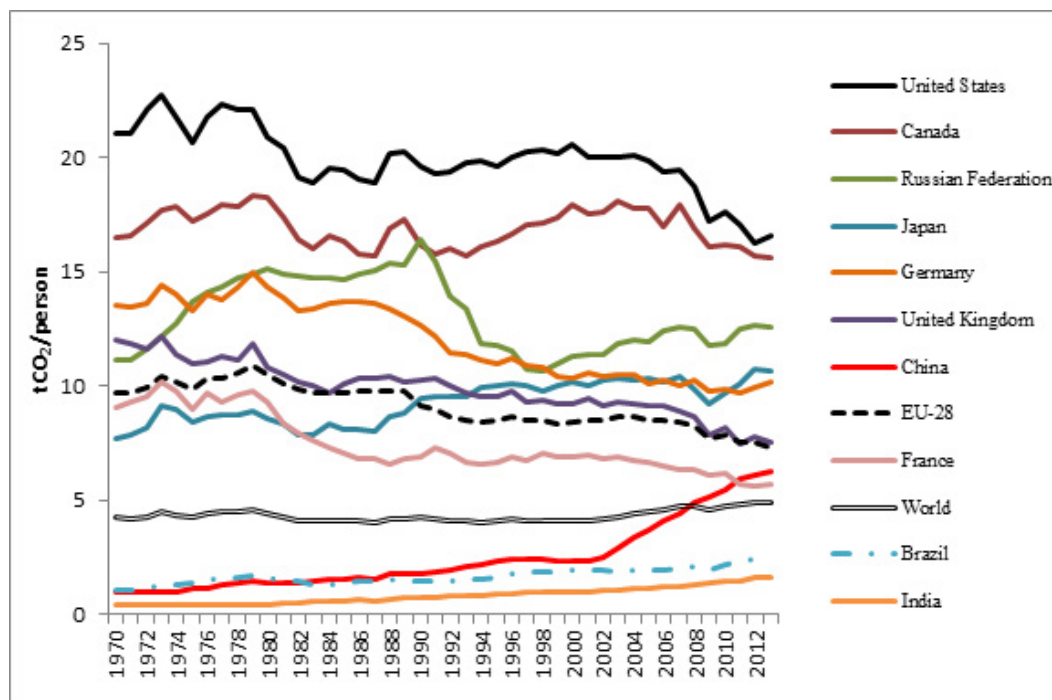

Figure 4: *CO_2 emissions per capita of major emitters in 1970-2012.*
China's emissions data is calculated by the author, the emissions data of
other countries are cited from the international dataset, EDGAR.[3]

Carbon intensity is widely used as an indicator of efficiency and technology development on a national scale.[7] In 2012, China's total emissions almost doubled those of the emissions in the U.S., however China's total GDP (with constant price) is only 55% of that of the U.S. This is explained by the high carbon emissions intensity of China's economy. China's carbon intensity is much greater than that of other major economies (such as G8 countries). The high level of carbon intensity suggests a significant potential for mitigating carbon emissions in China through controlling the emissions intensity up to a point, given that part of the difference in intensity comes from differences in the structure of China's industrial activity. Reducing carbon intensity is currently the most important mitigation initiative proposed by the Chinese national government. In 2009 China announced as their key policy to address climate change their target to reduce carbon intensity by 45% in 2020 when comparing with the carbon intensity in 2005.[8]

The energy intensity (energy consumption per unit of GDP), an indicator that is strongly related to carbon intensity, has already been adopted as the target for China's national development planning. During the last 30 years, the reduction targets of energy intensity proposed by the National Five-Year Plan have been China's major approach to improving energy efficiency at a national level. One can expect that carbon intensity will replace energy intensity as the major indicator after 2010. During the 12th Five-Year Plan (2010-2015) carbon intensity has already been adopted as the major environmental Indicator. The national target has been decomposed into provincial targets. Table 1 lists China's current energy intensity targets and a summary of the country's achievements in energy intensity and carbon intensity targets during the 11th and 12th Five-Year Plans.[9]

Controlling carbon emissions from China will be a critical factor in the quest for sustainability. China officially announced the national target would be to achieve a 45% reduction of carbon intensity by 2020 (against 2005 level), such a national target has been allocated into provinces and implemented through "top-down" administrative measures. "Top-down" command and control policies are the major approach that China is using to meet its energy saving and emissions reduction goals. In its 11th Five-Year Plan (2006–2010), the government set goals that would cut energy intensity (energy in heat per unit of GDP) by 20% and cut total SO2 emissions by 10%. The following 12th Five-Year Plan (2011-2015) called for a 16% reduction in energy intensity and a 17% reduction in carbon intensity with mandatory sub-targets allocated into regions (Figure 5). The 12th Five-Year Plan further allocated the targets into provinces, with the Eastern coastal regions being allocated more rigorous goals for intensity reduction. To meet the intensity reduction target in the 11th Five-Year Plan (2006-2010), both central and local governments closed thousands of inefficient power plants and factories, with a total production capacity of 100 million tons of iron, 55 million tons of steel, 250 million tons of cement, and 70 GW of coal-fired power generation. The cumulative impacts of such closures are equivalent to the reduction of 750 million tons of coal use and more than 1.5 billion tons of CO_2 emissions (5% of the global total in 2010)[8].

It should also be noted that the Chinese emissions reduction target is based on a relative intensity target, not an absolute target. With the rapid economic development and growth in China, a relative reduction (ratio-based indicators) may not necessarily mean a net reduction of GHG emissions. A relative improvement may result in a net emissions increase if one country's annual economic growth rate exceeds a certain level. The evaluation of such a relative indicator also depends on which types of GDP (or other units) are used for the calculation. For example, constant price GDP or purchasing power parity (PPP) may provide variations in results because constant price GDP is likely to appear lower than PPP for developing countries. The difference in improvement level becomes larger in both absolute and relative terms when such an indicator is calculated on the basis of GDP. Thus, peaking China's total emission will be the key step for China's carbon emission mitigation.

China has committed to peaking its total CO_2 emissions by 2030, under the November 2014 "U.S.- China Joint Announcement on Climate Change and Clean Energy Cooperation."[10] As a first step, China has addressed the cap of total coal consumption by 4 Gt per year, and plans to increase the share of renewable energy by 20% by 2030. Further integrated effort is needed to help China meet and perhaps surpass this goal—an effort that would likely require market-based instruments, technology innovation, energy structure optimization, recycling, as well as international cooperation.
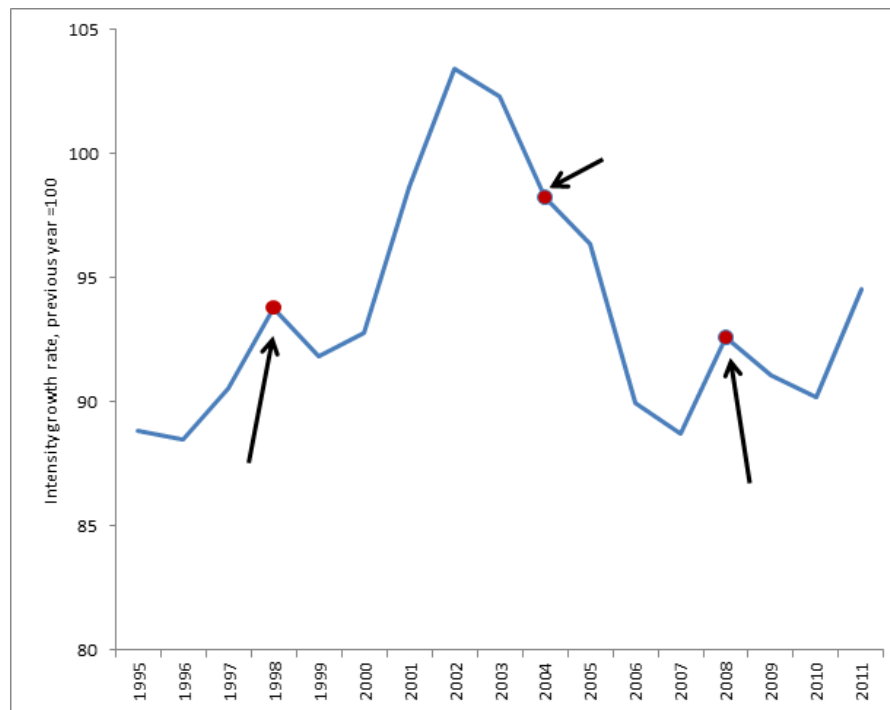

Figure 5: Growth rate of carbon emissions intensity during 1995-2011
(value of previous year has indexed into 100).

Table 1. Regional energy intensity targets and achievements in the 11th and 12th Five-Year Plans (2006-2015)

Region	Province	Energy intensity goal (2006–2010)	Energy intensity goal achievement (2006–2010)	Energy intensity in 2010 (ton/104RMB)	Energy intensity goal (2011–2015)
North China	Beijing	-20%	-26.59%	0.582	-17%
	Tianjin	-20%	-21.00%	0.826	-18%
	Hebei	-20%	-20.11%	1.583	-17%
	Shanxi	-22%	-20.66%	2.235	-16%
	Inner Mongolia	-22%	-22.62%	1.915	-15%
Northeastern China	Liaoning	-20%	-20.01%	1.38	-17%
	Jilin	-22%	-22.04%	1.145	-16%
	Heilongjiang	-20%	-20.79%	1.156	-16%
Eastern China	Shanghai	-20%	-20.00%	0.712	-18%
	Jiangsu	-20%	-20.45%	0.734	-18%
	Zhejiang	-20%	-20.01%	0.717	-18%
	Anhui	-20%	-20.36%	0.969	-16%
	Fujian	-16%	-16.45%	0.783	-16%
	Jiangxi	-20%	-20.04%	0.845	-16%
	Shandong	-22%	-22.09%	1.025	-17%
Central and South China	Henan	-20%	-20.12%	1.115	-16%
	Hubei	-20%	-21.67%	1.183	-16%
	Hunan	-20%	-20.43%	1.17	-16%
	Guangdong	-16%	-16.42%	0.664	-18%
	Guangxi	-15%	-15.22%	1.036	-15%
	Hainan	-12%	-12.14%	0.808	-10%
Southwestern China	Chongqing	-20%	-20.95%	1.127	-16%
	Sichuan	-20%	-20.31%	1.275	-16%
	Guizhou	-20%	-20.06%	2.248	-15%
	Yunnan	-17%	-17.41%	1.438	-15%
Northwestern China	Tibet	-12%	-12.00%	1.276	-10%
	Shannxi	-20%	-20.25%	1.129	-16%
	Gansu	-20%	-20.26%	1.801	-15%
	Qinghai	-17%	-17.04%	2.55	-10%
	Ningxia	-20%	-20.09%	3.308	-15%

Source: National Development and Reform Commission (NDRC), see also the paper from Liu et al. [9]

3. Regional Disparity of China's Carbon Emissions

China is a country with significant regional differences in terms of technology, energy mix, and economic development.[11] The distribution of carbon emissions varies among the 30 mainland provinces. In 2012, the total carbon emissions were mainly contributed by the Eastern coastal regions such as Shandong and Zhejiang and by the energy based provinces such as Inner Mongolia and Shanxi. The provinces like Inner Mongolia, rich in fossil resources, have experienced a 7-fold increase of CO_2 emissions since 2000. The emissions increment is also very significant for the other fossil-rich provinces.[9] The total emissions from several of the major provinces are already larger than the emissions from certain developed countries. For example, if Shandong were to be considered as a single country, it would be listed as one of the world's top 5 countries with a high level of total carbon emissions (more than 800 Mt CO_2 per year).

This high level of total emissions can be a result of the high population intensity and the living standard of the population. However, the CO_2 emissions per capita for the provinces show a different pattern when compared with the GDP per capita for the provinces. In general, the developed regions have a high level of GDP per capita, such as Beijing, Shanghai (Beijing and Shanghai are municipalities with administrative level equal to provinces) and Zhejiang province. In comparison, several of China's underdeveloped regions have a high level of per capita CO_2 emissions, for example, the per capita emissions in Ningxia and Inner Mongolia are much higher than in the other provinces, and are even higher than the level in the developed countries such as the U.S., the U.K., and Japan. For example, the per capita emissions in Ningxia alone are approaching 20t CO_2/person, which is higher than the U.S. average and almost three times higher than the E.U. average.

The high levels of per capita CO_2 emissions in these underdeveloped regions can be explained by two factors: first, these regions serve as energy and resource bases which provide the electricity and industrial materials that have been consumed in other regions. For example, more than one-third of the power generated by Inner Mongolia is exported to other provinces, and the economic value of Inner Mongolia's total export to other provinces is equivalent to about 50% of the GDP produced by Inner Mongolia[8],[12]. In comparison, the developed regions are mainly the consumers and the importers of the electricity and products that are supplied by underdeveloped regions, for example, one-third of Beijing's electricity supply is generated by neighboring regions around Beijing. Second, the carbon intensity of these under-developed regions is much higher than that of the developed regions, for example, the carbon intensity of Inner Mongolia, Shanxi, and Ningxia is more than 5 times that of Beijing.
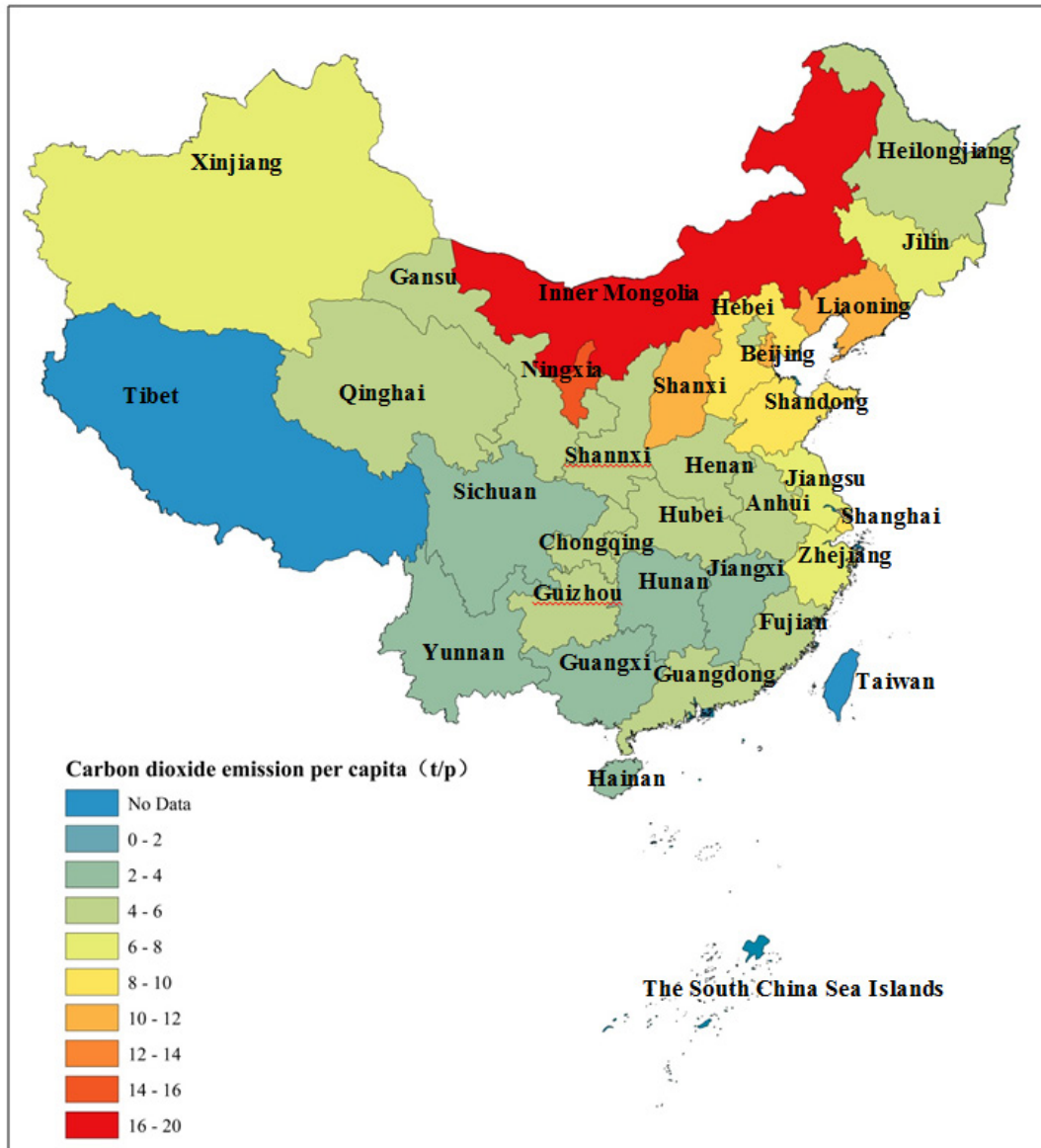
Figure 6: CO$_2$ emissions per capita in 2012.

The urbanization process has been considered as the major driver for China's development in the coming decades. Cities play an essential role in China's carbon emissions, for example, 85% of China's direct carbon emissions are from cities.[13] We found the total carbon emissions from 150 Chinese cities (this is the number of cities for which the emissions data is available) is about 6,006 Mt CO$_2$ in 2010, which is higher than total emissions from the U.S. (the second largest emitter) and which accounts for 70% of China's total carbon emissions. The per capita emissions show the significant variations of Chinese cities. The CO$_2$ emissions per capita in some Chinese cities are even higher than those of cities in developed countries. For example, the emissions in Tangshan city (in Hebei province), Suzhou city (in Jiangsu Province), Baotou
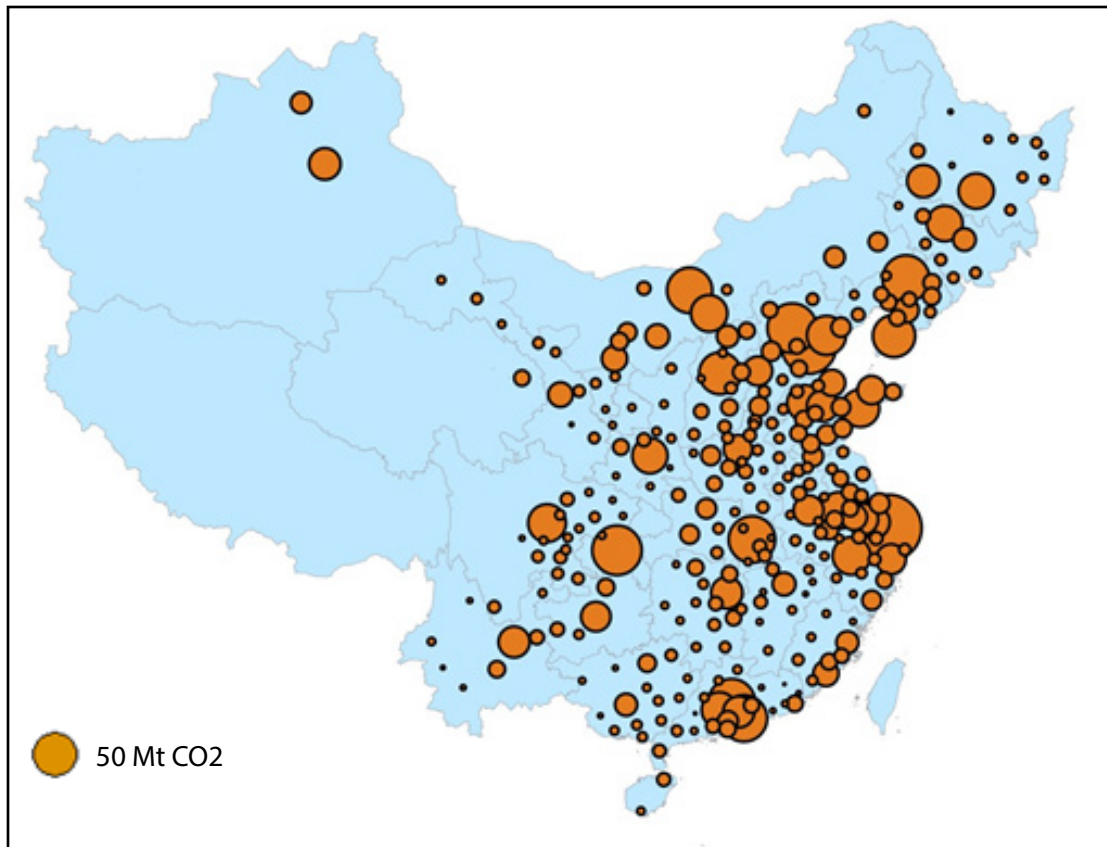
Figure 7: *CO$_2$ emissions in 150 largest Chinese cities in 2012.*

city (in Inner Mongolia), and Zibo City (in Shandong province) are more than 20 t CO$_2$ per capita—not surprisingly, these cities are important resource bases or manufacturing bases for China. However, in general, the per capita emissions in Chinese cities (about 7.5 t CO$_2$ emissions per capita) are much lower than the cities of developed countries, and are approaching the level of global average. The emissions per capita in rural China are much lower than the emissions per capita in urban areas, mainly due to the less-developed infrastructure and a lower standard of living conditions in rural China.

4. Emissions Embodied in International Trade

Carbon emissions are produced by either the manufacturing process or the power generation process, where the products and services that are to be exported are made. From the consumption perspective, the emissions are "embodied" in the products and services, through this perspective the emissions can be reallocated from the producers to the final consumers and is referred to as "consumption-based emissions"[14] or "carbon footprint."[15] The Life-cycle Analysis (LCA) methodology is frequently adopted for calculating the carbon footprint for a single production process. For calculating the carbon footprint for entire regions, the Multi-Regional Input-Output (MRIO) model is widely adopted. MRIO can trace the emissions embodied in international trade and can further calculate the nation's carbon footprint. This consumption-based accounting is also suggested by the IPCC as a supplementary measure for allocating mitigation responsibilities. Under the consumption-based accounting principle the countries are responsible for their consumption-related carbon emissions. Such a principle could help to avoid inequity issues that could arise when allocating climate mitigation responsibilities based on production, given that the developed countries are generally the net consumers of the international trade products, while the developing countries are the net producers.

Taking advantage of a sizeable labor force, China as "the world's workshop" is manufacturing products that are being consumed worldwide. China is thus a net exporter of embodied emissions, in other words, part of China's carbon emission is due to the consumption of Chinese made products in other countries. The total CO_2 emissions embodied in China's imports and exports combined reached 1.9 Gt CO_2 in 2007, this amount is higher than the total annual emissions from Japan (1.5 Gt CO_2 per year). The CO_2 embodied in international imports (0.2 Gt CO_2 per year) is much smaller than the emissions embodied in international exports (1.7 Gt CO_2). This suggests that about a quarter of China's domestic emissions are caused by the production of export goods that are consumed by other countries.

Developed countries, in general, but especially North America and Europe, are the major consumers of goods that embodied carbon emissions originating from China. The United States' consumption accounts for about 24% of China's emissions embodied in exports, followed by other major developed countries such as Japan (9%), Germany (5%), Korea (4%), the U.K. (4%), and Russia (3%). The European Union and other East Asian countries together account for 25% and 15% of China's export embodied emissions, respectively. On the contrast, China's exported embodied emissions accounted for the largest share of emissions imported to other countries. For example, the embodied emissions that originated from China and were exported to Japan, the U.S., and Russia accounted for 48%, 44%, and 42% of their total import embodied emissions, respectively.
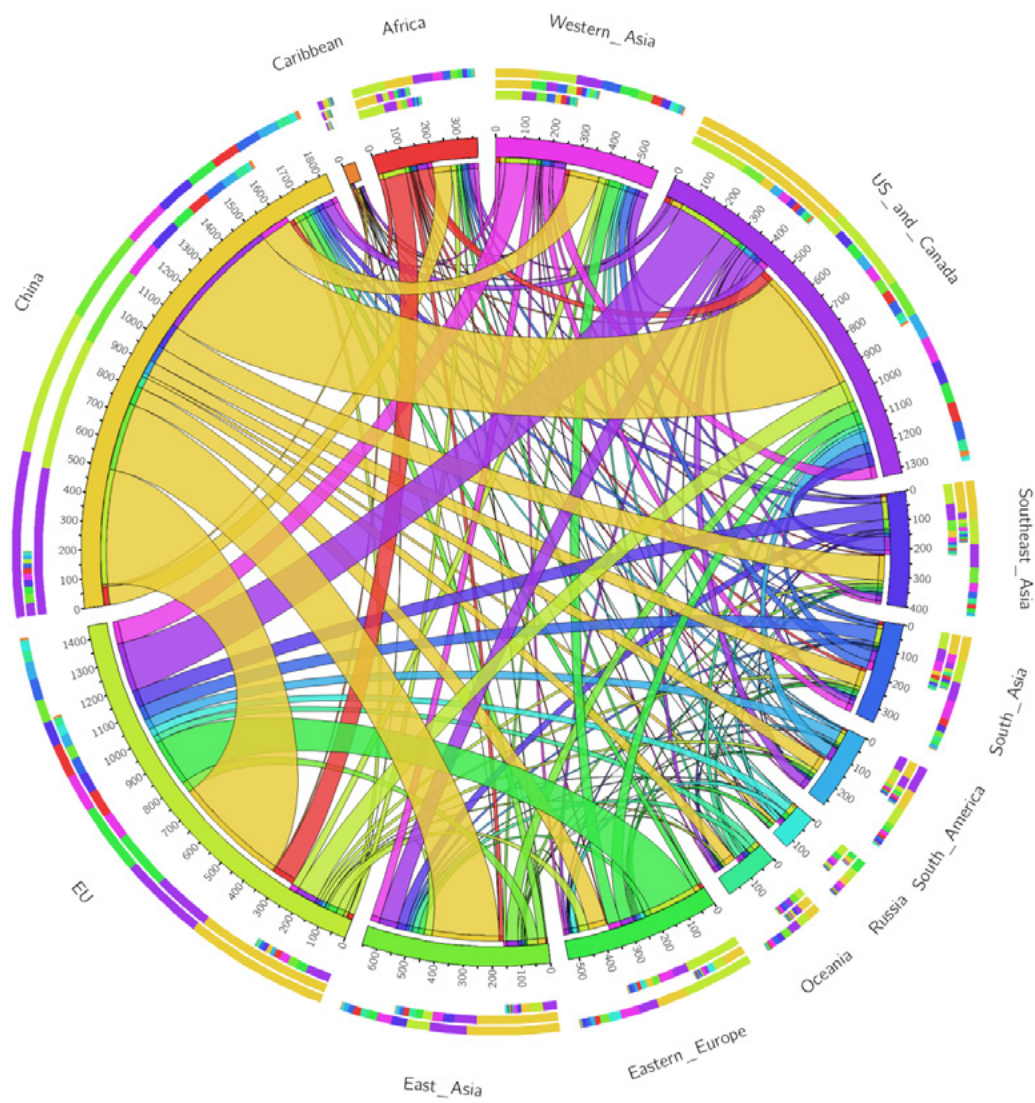
Figure 8: *Emissions embodied in international trade. The flow represents the emissions embodied in trade, the color represents the original production regions, for example, red flow represents the embodied emission that produced by Africa and exported and consumed by other regions.*

In 2013 the carbon emissions embodied in China's exports were greater than the total emissions in Japan, who listed as having the 5th largest CO_2 emissions in the world. The magnitude of emissions embodied in China's exports proposed a new direction of global emissions mitigation: controlling global carbon s not only relies on improved efficiency on the production side (mainly from developing countries such as China). Thus, it is important to allocate the international emissions mitigation responsibilities from consumption perspective.[16]

5. Methodology Used for the Calculation

Carbon emissions from fossil fuel combustion and cement production (EFF) are calculated by using the activity data (the amount of energy consumption or cement production) multiplied by the associated emissions factors (the ratio of carbon emission per unit of energy consumption or cement production). The uncertainty associated with carbon emissions in China comes from both uncertainties regarding activity data and emission factors. The Chinese National Bureau of Statistics (NBS) is the only official source for the data on energy consumption and cement production. NBS reports the national energy consumption data that been used by international organizations such as the United Nations or the World Bank. However, a conspicuous error in energy consumption data, reported by the NBS since 2000s, is that the provincial aggregated energy consumption data is 20% higher than the national energy consumption data[17]. Therefore, there is significant uncertainty regarding which of the two numbers is more accurate.

In this study we adopted an independent method to calculate China's energy consumption. We use the balance of production, trade, and physical stock change to estimate the "apparent consumption" of fossil fuels. Our estimates are higher than the national energy consumption reported by NBS, but lower than the provincial energy consumption.

In search of more precise estimates, we also adopted China's specific emissions factors instead of using the IPCC's default value that has been widely used in the Carbon Dioxide Information Analysis Center (CDIAC), the International Energy Agency (IEA), the United Nations (UN), the United States Department of Energy (DoE), the Energy Information Administration (EIA), and the Emissions Database for Global Atmospheric Research (EDGAR). China's specific emissions factors are based on measurements of the mine-level and factory-level investigations, with details of each listed in our previous literatures[18].

In principle, China's specific emissions factors are significantly lower than the IPCC's default values, with China's total emissions estimate being about 15% lower than that of the international agencies. However, we do acknowledge that there still exists huge uncertainty on the emissions estimates in China, including the possible under-reporting of coal production and consumption by small and privately owned coal mines or boilers; the manipulating of data by the governments to achieve a political or economic purpose; and the possibility of the double accounting of energy production and consumptions. The uncertainty range for China's carbon emissions as proposed by this report is considered to be about 10% (2-sigma uncertainty). Methodologies and verifications in full transparency towards better energy and emission data for China are urgent needed.

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