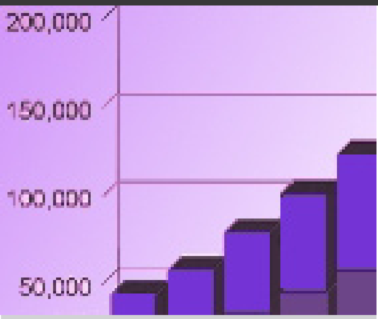

Atmospheric Changes Reveal China's Energy Trends

Key Points

- At a measuring station near Beijing, US and Chinese scientists are collecting unique measurements of carbon dioxide (CO_2) levels in air that has passed over one of China's most industrialized, urbanized regions. This record provides an independent view of China's efforts to improve energy efficiency.
- Comparing CO_2 levels with carbon monoxide (CO) levels serves as an independent indicator of overall trends in efficiency of fuel combustion in this critical region.
- The record shows a pattern of improved combustion efficiency from 2005 to 2008, consistent with energy efficiency policies pursued under the 11th Five Year Plan, in particular the goal to reduce energy intensity by 20%.

Contact An Expert
Chris Nielsen
Executive Director

Harvard China Project
nielsen2@fas.harvard.edu
(617) 496-2378

Chinese government statistics are not the only source of information on China's energy use and greenhouse gas emissions. Using instruments that measure carbon dioxide (CO_2) concentrations and monitor other air pollution trends, atmospheric scientists are able to get a second, independent view of China's efforts to improve energy efficiency, particularly in heavily industrialized parts of the country. And, so far, the data suggest that those moves are making a difference.

BACKGROUND

Traditionally, China has taken a "bottom up" approach to collecting energy use statistics. The government's National Bureau of Statistics collects numbers on everything from coal production to electricity use from a wide array of sources, including state-owned companies, trade associations, provincial leaders and local officials. The Bureau then cross-checks the numbers, in part by sending out teams to do local spot-checks and audits (see ChinaFAQs Fact Sheet "China's New Emissions Inventory").[i]

The tools of atmospheric science, however, can provide independent evidence of China's energy use and emissions trends by tracking the changing composition of the country's air. Since late 2004, researchers have been compiling a unique, continuous record of CO_2 concentrations and a number of other pollutants at an atmospheric research station 100 kilometers northeast of Beijing. The station is a joint effort of Tsinghua University's Department of Environmental Science and Engineering, and the China Project of Harvard University's School of Engineering and Applied Sciences.[ii] The instruments are operated according to the highest scientific standards and are "intercalibrated," meaning scientists used standard reference gases to make sure the instruments produce measurements that can be compared to those from other atmospheric stations around the world.[iii]

The station, located in the rural foothills north of Beijing, is sited to take advantage of changing winds. It captures clean, "background" air flowing into the region from Mongolia and Siberia, but also dirtier plumes from Beijing and the urbanized, industrialized region to the south. Station scientists can determine where the sampled air originated by reviewing meteorological data collected at the station, and data collected by scientific agencies around the region and the world.

It is important that the station samples a well-mixed plume when the winds deliver air from the urbanized, industrialized cities and provinces from the Southwest to the East. That air is affected by all combustion sources—power plants, industrial boilers, vehicles, and everything else—and the instruments effectively pick up the integrated emissions across this economically vital region.

Before researchers can use data from the station to draw inferences about China's energy use and emissions, however, they must account for a number of complex factors.[iv] The CO_2 concentrations measured at the station, for example, do not result from fuel combustion alone. In the summer, for instance, atmospheric CO_2 concentrations dip from July to September because plants "take up," or absorb, CO_2 through photosynthesis (see the red line in Figure 1).

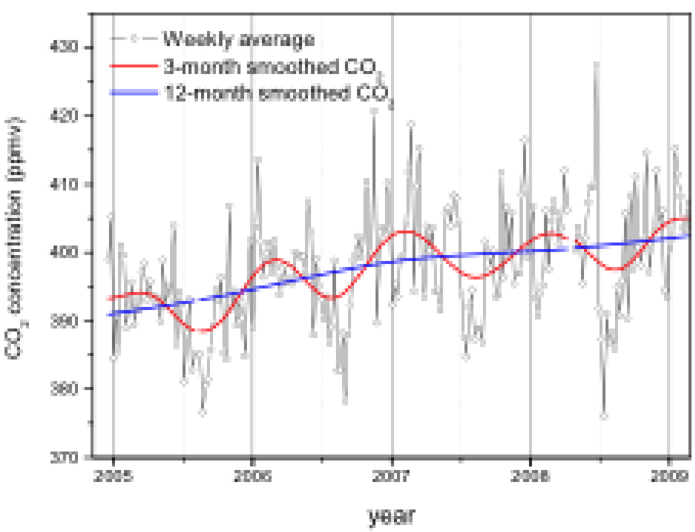

Figure 1. Weekly mean CO_2 at Miyun from December 2004 to February 2009 (black line). The red and blue lines are curves for the seasonal and annual variations, respectively. The vertical solid gray lines denote January of each year, and the dotted gray ones indicate June.

The researchers also have to check their numbers against other available scientific evidence, including measurements of CO_2 in air entering or leaving China. In this case, the concentrations observed at the site (see blue line, Figure 1) are appropriately higher than those measured at background sites on the Tibetan Plateau and in Mongolia, and are also consistent with measurements downwind in Korea and Japan.[v]

Overall, the data show that CO_2 concentrations measured at the station in recent years have increased, on average, faster than global background levels (from 2005 to 2008, station CO_2 concentrations annually increased by 2.7 parts per million by volume (ppmv); the global background rose by an average of 1.7 ppmv). This rise is expected, given that the fuel combustion powering China's booming economy has recently risen faster than the global average, and this increase should be reflected in a regional enhancement of CO_2.

TRENDS IN ENERGY USE

To detect trends in energy use, the research team capitalizes on another data record from the station, that of carbon monoxide (CO). CO is a product of inefficient combustion, while CO_2 is produced by efficient combustion. In modern power plants, for instance, conversion of coal carbon to CO_2 is nearly 100%; in contrast, in open burning of biomass, 10% or more of the fuel carbon is released as CO, with the rest as CO_2. This means that the ratio of CO_2 to CO in a sample of air will increase with the efficiency of the combustion that has affected that air.

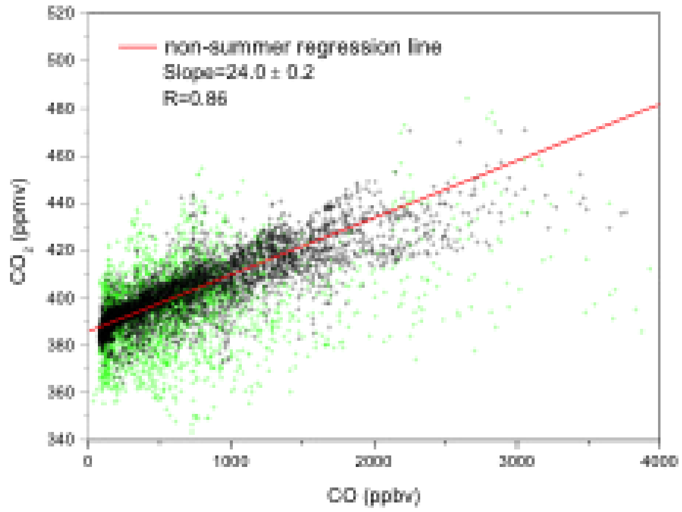

Figure 2. CO_2-CO relationship observed at Miyun (March 2007 – February 2008). Each data point represents hourly mean CO (x-axis) and CO_2 (y-axis). The green crosses represent summertime observations. The red line is the regression line for non-summer observations.

To best represent the CO_2/CO ratio, researchers plot paired measurements of the two gases for a given time period and then calculate a quantity called the "correlation slope."[vi] The correlation slope can be regarded as a proxy for relative combustion efficiency. Figure 2 illustrates a sample correlation slope for March 2007 to February 2008.[vii] If this slope increases year-to-year in air arriving from the same source area, it indicates that overall combustion efficiency is improving in that area.

In order to analyze energy trends specifically in the industrialized region of greatest interest, the researchers use chemical and meteorological criteria to "filter" the data. For instance, they filter out air samples that have come across the sparsely settled mountains from Mongolia, or samples that have passed over a nearby village, which can cause concentrations to spike in an unrepresentative way. The correlation slopes of the remaining air samples can then be compared across successive time periods, revealing trends in combustion efficiency.

Overall, the data reveal an improvement in combustion efficiency in the recent past. In particular, Figure 3 shows that the average winter correlation slopes (the proxy for combustion efficiency) increased by more than 11% in 2007-2008, when compared to 2005-2006.[viii] These results are strongly consistent with—while not strictly verifying —China's aggressive policies to improve energy efficiency from 2005 to 2010, including a 20% energy intensity reduction target pursued during the 11th Five Year Plan.[ix]

This approach to atmospheric monitoring provides scientifically independent, physical evidence of improving combustion efficiency in the overall fossil and biomass energy use of this economically critical region of China.

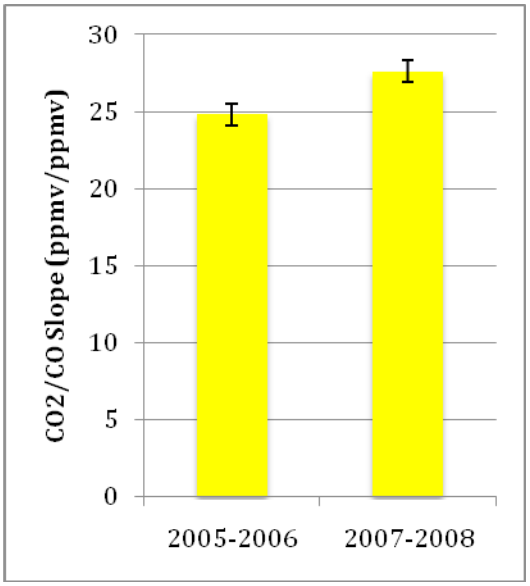

Figure 3. The average CO_2-CO correlation slopes for winter observations at Miyun in 2005-2006 and 2007-2008, for filtered northern China air masses. The 11% change suggests that China's efforts to improve energy efficiency are improving combustion efficiency in one of the nation's most industrialized regions.

This fact sheet is based on: Wang, Y.X., J.W. Munger, S.C. Xu, M.B. McElroy, J.M. Hao, C.P. Nielsen, H. Ma. 2010. CO_2 and its correlation with CO at a rural site near Beijing: Implications for combustion efficiency in China. Atmospheric Chemistry and Physics 10: 8881-8897, doi:10.5194/acp-10-1-2010.

This fact sheet is a product of ChinaFAQs, a joint project of the World Resources Institute and experts from leading American universities, think tanks and government laboratories. Find out more about the ChinaFAQs Project at: http://www.ChinaFAQs.org/.

Notes

[i] For more on China's energy-use tracking methods, see: Mintzer, I., J. Amber Leonard & Ivan Dario Valencia. Counting the Gigatonnes: Building trust in greenhouse gas inventories from the United States and China. World Wildlife Fund, Washington D.C., June 2010.

[ii] Wang, Y.X., J.W. Munger, S.C. Xu, M.B. McElroy, J.M. Hao, C.P. Nielsen, H. Ma. 2010. CO_2 and its correlation with CO at a rural site near Beijing: Implications for combustion efficiency in China. Atmospheric Chemistry and Physics 10: 8881-8897, doi:10.5194/acp-10-1-2010.

[iii] This means the instruments are constantly calibrated to canisters of gases of precisely known composition, which in turn have been compared to reference gases used by other measurement stations. This protocol insures the comparability of data collected by different instruments across the world.

[iv] Much of the Wang et al. (2010) paper on which this summary is based focuses on controlling for the effects of such factors.

[v] Another multi-year record of CO_2 observations in China is made by the Chinese Academy of Meteorological Sciences at a background station in Qinghai on the Tibetan Plateau, Waliguan Baseline Observatory.

[vi] The correlation slope results from a regression of these data for a given period. Calculating this slope instead of a simple ratio of concentrations of the two gases removes the effect of sizable global background levels of CO_2 in the atmosphere. It facilitates comparison of only the regional contributions of the two gases.

[vii] The regression omits three summer months. This is to control for the especially strong influence of biological processes on CO_2 levels at that time of year, which masks the chemical signals of combustion.

[viii] Winter is defined as December-February, identified by the year it began. Restricting this comparison to the averages of 2005-2006 and 2007-2008 is a cautious interpretation, avoiding possible sampling bias in 2004 data that otherwise strongly supports the trend. The correlation slope increased from 17.3 (±0.6) in winter 2004 to 28.6 (±1.1) in 2007, before retreating slightly to 26.6 (±0.9) in 2008 (following the Olympic Games).

[ix] Combustion efficiency here describes the completeness of conversion of the chemical energy of carbonaceous fossil and biomass fuels. While it is not equivalent to either energy efficiency (which also considers how well the realized chemical energy is then harnessed for given tasks) or energy intensity (which measures energy use against an economic indicator, GDP), its improvement will contribute to improvements in both of the latter energy use metrics.

ChinaFAQs
World Resources Institute
10 G St NE
Washington, DC 20002
202-729-7600
www.ChinaFAQs.org

v1.8 Published December 1, 2010