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The Rise of China — Progress at What Price?

As China undergoes an industrial revolution, its once pristine lands are being choked by pollution from coal-fired plants. Spurred by the upcoming 2008 Olympics in Beijing, China is quickly clearing the air. And, it has long-term plans to invest heavily in clean energy technologies.

Cindy Liu and her family used to live in Beijing, but they have since moved further out to escape the thick, gray haze looming in the air. Even though it takes her mom three hours to get into the city, it's worth it for the cleaner air, Liu says. Liu herself no longer lives in China. She has moved to Australia to complete her masters in engineering, hoping her project on coal will land her a job as a project manager for a coal company. When Liu goes back to Beijing, she listens to weather advisories to check to see if it's safe to go outside. When the dust storms whip through Beijing, she's chained inside. But when she's brave, she'll put on a mask to keep the sand out of her mouth.

A Chinese government report says the increasing violent dust storms that batter Beijing are linked to global warming. Other research papers indicate that emissions, particularly from China's numerous coal-fired power plants, are changing the weather around the world (box, p. 10).

Despite these environmental issues, China continues to industrialize at a rapid pace. The American Chemistry Council (www.americanchemistry.com) predicts that China's chemical industry will grow annually at 10.4% in the next 10 years, compared to a worldwide growth rate of 3.6%.

Over the next eight years, 562 new coal-fired plants are expected to be built, each with a life span of 50 years. In the recently released report, "The Future of Coal – Options for a Carbon Constrained World," conducted by an interdisciplinary faculty group from the Massachusetts Institute of Technology (MIT; web.mit.edu/coal), China is currently constructing the equivalent of two, 500-MW, coal-fired plants per week and a capacity comparable to the entire U.K. power grid each year. By 2011, China will have more coal-fired capacity than the U.S. and Europe combined, notes a study from the market research firm McIlvaine Co. (www.mcilvainecompany.com).

Within the next three years, most of the plants under development will be in operation. But by 2025, scientists predict China will emit more carbon dioxide (CO_2) and sulfur dioxide than the U.S., Japan and Canada combined. On April 24, 2007, the International Energy Agency (IEA; www.iea.org) warned that China could surpass the U.S. in greenhouse gases emissions within a matter of months — not years as was previously predicted. 2006 data from the U.S. Dept. of Energy's (DOE; www.doe.gov) Energy Information Administration (EIA; www.eia.doe.gov) predicts that coal use in China will increase annually by an average of 4%. If current policies remain unchecked, the efforts to reduce emissions in other countries may be futile.

China is currently a non-Annex I country under the United Nations Framework Convention on Climate Change — in other words, it is exempt from having to reduce CO_2 emissions. When it comes time to discuss the post-Kyoto Protocol in 2012, China might take responsibility for its emissions or take another pass.

With over half of China's primary energy needs dependent on coal, the coal-burning plants that are built in the next decade will need to be retrofitted to capture carbon or be shut down to keep emissions from escalating. Some experts warn that total emissions need to be reduced by 60–80% by 2050. If post-Kyoto allows developing countries like China to be exempt, developed nations will have to convert to carbon-free technologies to reach this goal.

Regardless of which countries decide to take action to mitigate CO_2 emissions, China will have to adapt to climate change in the future. Recently, the World Wildlife Fund (www.worldwildlife.org) reported on the impacts of climate change on

China. It predicted a 37% decrease in wheat, rice and corn yields by 2050 and declining rainfall (up to 30%) in three of China's seven major river basins.

Olympic clean up with lasting effects

China, in particular the city of Beijing, is already on the path to a cleaner future. With Beijing being the host city of the 2008 Olympic games, a spotlight is shining on the local government to address pollution problems. During the games, the government has promised to reduce air pollution by shutting down some of the chemical plants on the outskirts of the city.

For example, production at the Beijing Coking-Chemical plant came to an end last July. This will eliminate the the burning of 2.96 million tons of coal and the release of 4.3 billion m^3 of exhaust emissions. The government also plans to invest up to $40 billion for the Olympic games, hoping the effort will have long-lasting effects on improving its infrastructure and image.

In 2005, when Beijing pledged to the International Olympic Committee (IOC) to achieve World Health Organization standards for urban air quality for the games, the U.S. Dept. of Energy agreed to work with the Chinese government to make sure the "Green Olympic Protocol" (the official agreement between the DOE and Beijing) is met. The U.S. will also help China adopt cleaner technologies through the DOE's Office of International Science and Technology Cooperation. One project will use the hydrogen technology Hytane to fuel five buses in the Olympic Village. General Motors has donated a zero-emissions electricity-driven bus. And, the street lamps in the Olympic Village and the heat in the swimming pools will be powered by solar photovoltaics.

The IOC sees the Olympic games as a platform for environmental reform, hoping other municipalities will adopt the environmental solutions demonstrated during the games. Already, the environmental movement has started in Beijing, where hundreds of environmental-protection awareness programs have been established. The Beijing Municipal Commission for Development and

Reform plans to encourage 120,000 families to use natural gas. By demonstrating how natural gas, electricity and liquid petroleum can be used in the house for cooking and heating instead of the more commonly used coal, the municipal government hopes more people will adopt the cleaner technologies.

Applying cleaner technologies

In April, at the 5th World Congress of Science Journalists in Melbourne, Australia, a panel discussion focused on the future of coal. According to Wang Yu, one of the panelists and an energy journalist for *China Daily*, last year, China mined 1.86 billion tons of coal to generate about two-thirds of the country's electricity needs of 622 GW. By 2010, China targets reducing the amount of coal used in the entire energy scheme from 69.1% in 2005 to 66.1%. The Chinese also target increasing natural gas use from 2.8% to 5.3%. Other renewable energy sources are expected to climb from 7.1% to 8.1%.

Coal, however, will continue to be a crucial resource in China's energy portfolio due to its low cost and abundance. Peter Cook, CEO of the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC; www.co2crc.com.au), points out that studies show that a 50% increase in coal-burning efficiency delivers up to a 3% reduction of carbon emissions per unit of coal consumption. China has some of the most advanced technology for coal gasification in the world. "So if any country can decrease coal consumption and make it cleaner, China can," Cook reasoned.

Guodong Sun, an assistant professor of technology assessment in the Dept. of Technology and Society at State University of New York-Stony Brook (www.sunysb.edu), is an expert on advanced coal technologies (ACTs) and has studied their roles in addressing energy insecurity and global climate change. "Coal-gasification technologies have been widely used in China for decades to produce ammonia for fertilizers and to make towngas for cooking fuel," Sun says.

"But now, we are interested in gasification-based power generation technologies, such as the integrated gasification combined-cycle (IGCC) technologies." An IGCC plant combines the two old processes. The first process is coal gasification, which turns coal into synthesis gas (or syngas) composed of carbon monoxide and hydrogen. The second process, called combined cycle, uses the electricity generation technology that many natural-gas power plants already use. In an IGCC power plant, CO_2 can be captured before being sent to smokestacks, as is typical of conventional coal plants. "IGCC is

Research Links China's Pollution to Intensified Global Weather Patterns

According to a report by the World Health Organization (WHO), China already has seven of the ten most polluted cities in the world. This is largely due to the use of unwashed coal that emits sulfur dioxide and particulate matter. China's emissions are now the world's problem. New research indicates that the air pollution in China is now affecting global weather patterns. Renyi Zhang, professor of atmospheric sciences at Texas A&M and lead author of the paper "Intensification of Pacific Storm Track Linked to Asian Pollution," says the study provides evidence that China's industrial pollutants affect the storm track over the Pacific Ocean, a major weather event in the northern hemisphere during winter.

When the industrial plants emit pollutants such as soot and sulfate aerosols into the air, the prevailing winds over the Pacific Ocean carry the pollution to the rest of the world. Zhang says the study is the first of its kind that provides indisputable evidence that anthropogenic pollution is adversely affecting the weather.

Zhang's paper, which was published in *Proceedings of the National Academy of Sciences* (Mar. 2007; www.pnas.org/cgi/content/abstract/0700618104), compared data from 1984 to 1994 with data from 1994 to 2005. His analysis found an increase of 20–50% of deep convective clouds — the clouds that can create strong storms. "Using a novel and state-of-the-art weather research and forecast model, we have provided a link between the intensified storms of the storm track and Asian pollution, showing that the enhanced deep convective clouds are reproduced when accounting for the aerosol effect from the Asian pollution outflow," Zhang explains.

"The intensified Pacific storm track likely has profound implications on climate," Zhang says. It can significantly alter the cloud albedo (the ratio of reflected to incident electromagnetic radiation) and impact the radiative budget over such a large region. "The intensified Pacific storm track likely impacts the global general circulation because of its fundamental role in meridional and vertical heat transport and forcing of stationary waves," explains Zhang. The result — the intensified storm track moves the anthropogenic aerosols vertically and then northward.

"There is now ample observational evidence supporting an Arctic warming. We suggest that the intensified Pacific storm track can considerably contribute to and exacerbate the observed Arctic warming because of more efficient transfer of heat and anthropogenic aerosols to the polar region," he says. When soot collects in the Arctic ice caps, it attracts heat rays from the sun, which in turn accelerates the melting of the ice cap.

Zhang says further studies will investigate the effects of air pollution on cloud formation, weather systems and global climate system. "We currently have little knowledge on those. After that, the information should be considered by the decision-makers to develop control strategies."

cleaner than even the most advanced coal-combustion-based power generation technologies," Sun notes.

Capturing carbon dioxide

No matter how advanced clean-coal technology gets, carbon capture and storage (CCS) is the key to reducing CO_2 emissions in China. Barry Hooper, CO_2 capture program manager at the Univ. of Melbourne, Australia (www.chemeng.unimelb.edu.au/co2crc), explains, "CO_2 does occur naturally and as such is used as a source for soft drink carbonation and the like. This is a good analogy that shows how CO_2 can be stored for very long periods of time. In that sense, CCS is putting the CO_2 back where it came from."

"Removing CO_2 from the atmosphere is the quickest method of reducing greenhouse gases," says Hooper. If CCS is included in the suite of reduction technologies, the overall cost of mitigation is likely to be 35% lower than if it were not, he explains.

"If you want to capture and sequester most of the carbon from coal, hydrogen will be a very attractive energy carrier. Right now, the Chinese government supports basic research in CCS, and a larger number of research-and-development efforts in hydrogen production, storage and use. But there are currently no commercial projects underway in the energy industries," Sun says. Transitioning to a hydrogen economy will take decades. The Chinese government announced "hydrogen and fuel cell technologies" is one of the eight priority areas in its energy-technology-innovation strategy through 2020.

Can policy issues and carbon-neutral technology be taken lightly with large investments at stake — both financially and environmentally? With air pollution being a major cause of death in China, the technologies fueling the country's economic growth will need to be re-evaluated. Fortunately, the Chinese have been increasing their open-door policy. By closing unsustainable projects, China has attracted foreign investors interested in building cleaner plants using more sustainable technologies. Some estimates report that regulators have shut down 5,931 coal mines in 2006 with another 4,861 shutdowns planned this year. It still might be possible to see past the haze, as the green revolution catches on in China. CEP

Setting Environmental Priorities

The 11th Five-Year Program for National Economic and Social Development (2006–2010) outlines China's plans to reduce energy consumption per unit GDP by 20%, reduce the total amount of major pollutants by 10% and plant more trees to increase forest coverage by up to 20%. The nation expects to maintain an annual GDP growth of 7.5%, while doubling the 2000 per-capita GDP. The government recognizes the difficulty in enforcing national environmental standards because municipal and provincial officials rule and are not accountable for enforcing the national standards. Recently, though, China's State Environmental Protection Administration (SEPA) announced it would start to hold provincial officials accountable for environmental harm, starting in 2008. SEPA has already started to take action by expanding its Regional Permit Restriction — the strictest administrative measure the agency has taken in its 20-year history — which restricts all construction projects that don't comply with SEPA's environmental standards, including conducting environmental impact assessments. The environmental agency is taking strides and testing the policy before the National Development and Reform Commission, the Ministry of Land and Resources, and the State Administration of Work Safety. All ministries have agreed that stricter measures need to be imposed on the polluting and energy-intensive industries' growth.

The U.S. Environmental Protection Agency (EPA; www.epa.gov) is also working to help the Chinese government resolve its environmental issues — particularly in air and water pollution. Last month, EPA administrator Stephen L. Johnson and other members of the president's cabinet, along with their Chinese government counterparts, participated in the U.S.-China Strategic Economic Dialogue (SED) to discuss priority initiatives for energy and environmental cooperation. One of the outcomes of the discussion is a planned collaboration in which the U.S. and China will develop up to 15 large-scale coal-mine methane capture and utilization projects in China over the next 5 years. These projects are deemed critical, as methane is roughly 20 times more potent than CO_2 as a greenhouse gas. Furthermore, capturing methane creates a commodity that provides clean energy and increases mine safety.

Before the next session of the SED, the U.S. and China will complete a joint economic study to evaluate different policy approaches for saving energy and controlling emissions from the Chinese and U.S. power sectors. Once completed, the study can be used by both nations to enhance the effectiveness of energy and environmental policies by providing information about the costs and benefits of different control strategies.

On the water front, the EPA signed an agreement in late March with China's Ministry of Water Resources to help China protect water quality and help improve access to safe and sustainable water resources. According to Dale Kemery, an EPA press officer, "in the long run, China will be held responsible for their environmental record. However, the Chinese government, its provinces and their government leaders at all levels have recently shown a greater understanding that economic growth has a direct relation to environmental protection."

"EPA's actions in improving China's regulatory process can help impact China's environmental priorities," Kemery adds. The U.S. plans to cooperate with China through monitoring water resources, man-made wetlands, and water resources protection, to name a few of the mutual interests.