
# China's burning ambition

**The economic miracle that is transforming the world's most populous nation is threatened by energy shortages and rising pollution. It also risks plunging the planet's climate into chaos. Peter Aldhous reports.**

China is booming, and its hunger for energy is insatiable. For its people, the dismal air quality across much of the country is a constant reminder of its reliance on coal and other dirty fuels. When *Nature* visited Beijing to meet the technocrats responsible for China's energy policy, the city was blanketed in acrid smog. After just a few days of stagnant weather, visibility in some districts had dropped to tens of metres. Flights were delayed and the Beijing Environmental Protection Agency advised people to stay indoors. You could almost taste the sulphur in the air.

Energy and its consequences for health and the environment are high on the Chinese political agenda. But the hard-headed approach of the country's leaders should give us all pause for thought. China's energy policy will continue to be based around coal, they say, so the question of whether this notoriously filthy fuel can ever be made 'clean' is central to the country's development — and to the long-term stability of the global climate.

The most immediate problem for China is that its economic growth is already outstripping its energy supplies. In boomtowns from Shenzhen to Chengdu, electricity is now an unstable commodity. Last year, 24 of China's 31 provinces, municipalities and autonomous regions admitted that they lacked sufficient power. In the summer, when drought curtails hydropower and air conditioners surge into life, blackouts have become commonplace.

The nation's coal mines are straining to meet the demand, at a terrible human cost. According to conservative official estimates, more than 6,000 workers were killed in China's mines last year — making them the world's most dangerous — and the death rate was undiminished in the first half of 2005.

Most coal-related fatalities never make the headlines, however. Many Chinese cities fail to meet international — or even their own — standards for air quality, causing hundreds of thousands of premature deaths each year. China's increasing use of coal is also sending $CO_2$ emissions skyrocketing, threatening a global climate disaster. "We understand that coal means not only energy, but also social and environmental impacts in the long term," says Zhou Dadi, director-general of the Energy Research Institute in Beijing and a leading adviser on energy strategy to China's leaders.

While Dadi and other senior energy planners recognize these problems, their enthusiasm for coal remains strong. The country's leaders are determined that its economy will quadruple in size by 2020, which will require at least a doubling of the energy supply. Coal will bear most of the burden. "We have to increase coal consumption," says Guo Yuan, an energy systems analyst at Dadi's institute. "It's not a good picture, but we have to do it."

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Electricity generation is by far the biggest consumer of energy, although the demands of the transport sector are growing fast. Between 75% and 80% of China's electricity is generated by burning coal. Another 20% comes from large-scale hydropower projects, with most of the rest coming from nuclear stations. As yet, oil, natural gas and renewables such as wind barely feature in the electricity mix. But by 2020, according to official projections, gas-fired stations could be meeting 15% of China's electricity needs, while nuclear power may have expanded to around 5%. And thanks to a law passed in February this year designed to promote renewable energy, wind and other renewables could account for 10%. However, with power demands poised to double over the same period, it's clear that a massive increase in coal consumption is unavoidable.

Sustaining economic growth is the leadership's priority, say seasoned China watchers, but it wants to achieve this without compromising energy security. China lacks substantial reserves of oil and natural gas, and is determined not to become heavily dependent on imports. But the country has coal in abundance. So it will use the fuel in ever-larger quantities, mainly to avoid a reliance on Russian oil and gas that could eventually bring the two powers to the brink of war.

But can China meet its energy needs without poisoning its environment and filling the lungs of millions of people with particulates and oxides of sulphur and nitrogen? The effects of acid rain are spreading, and there are suggestions that soot is already disrupting the regional climate (see 'Brown clouds cast a dark shadow', overleaf).

Global climate change doesn't yet loom large in the thinking of China's leaders, but international experts note with alarm that coal is the worst offender in terms of $CO_2$ emissions. "The global problem is climate. But for China, conventional pollution is the main problem," says Li Zheng, who directs the Tsinghua-BP Clean Energy Research and Education Centre, a collaboration between Beijing's leading scientific university and the British energy firm.

## Efficiency drive

China's energy planners have realized that improving energy efficiency is the easiest way to promote economic growth while controlling pollution. "China should work first on this," says Dadi. Predictions that assume 'business-as-usual' suggest that total energy demands will rise to the equivalent of 3.5 billion tonnes of coal per year by 2020. But introducing a suite of measures to improve efficiency could keep that below 3 billion tonnes, says Dadi. "Technically, it's do-able."

This new drive for efficiency stems in part from a quietly influential initiative run by the San Francisco-based Energy Foundation. Bankrolled for a total of US$40 million since 1999 by the Hewlett and Packard foundations, the China Sustainable Energy Program is working with Chinese energy researchers to improve efficiency and cut pollution. Priorities include new efficiency standards for buildings, appliances and vehicles, and promoting renewable energy sources. Fuqiang Yang, who heads the Energy Foundation's Beijing office, points to recent successes such as the renewable energy law, plus fuel-efficiency standards and energy-efficient building codes adopted by central and local governments.

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Smog city: China's energy crisis is boosting interest in new technologies like coal liquefaction (below).

SHANXI COAL CHEMISTRY INSTITUTE

Energy efficiency is an admirable goal, but China's appetite for growth and the leadership's desire to limit imports of foreign oil mean it won't be enough. So China is embracing technologies that, in the West, remain on the fringes. Du Minghua, director of the Beijing Research Institute of Coal Chemistry, sees coal as an energy panacea, able to meet China's demands for electricity, liquid fuels and gas. "Coal is the solution for all three," he exclaims, before launching into a presentation on his institute's work on coal gasification and liquefaction.

Finding ways to reduce dependence on oil, critical for the transport sector, is the top priority for Minghua's institute. Young coals such as lignite can be converted straight to liquid fuels by heating them to 450 °C with hydrogen and a suitable catalyst, Minghua explains. Older coals such as anthracite must first be heated in oxygen to produce a mix of hydrogen and carbon monoxide known as syngas, which can then be converted into liquid fuels. Some of these can be blended with diesel and pumped straight into a conventional engine.

Despite Western experts' scepticism about the direct coal-to-liquid technology[1], the state-owned Shenhua Group is now building the world's first commercial direct coal-liquefaction plant in Inner Mongolia, scheduled for completion by 2008. And China is also in discussions with the South African company Sasol about the possibility of building two large indirect liquefaction plants.

## Crude substitute

Neither process is a model of efficiency, however. Direct liquefaction is about 60% energy-efficient, indirect techniques around 45%. But China's desire to seek alternative liquid fuels is so great that Minghua estimates that liquefaction technologies could be providing it with more than 50 million tonnes of fuel per year by 2020. "This is a personal estimate," he stresses — but one that will be music to the ears of China's leaders. If Minghua is correct, coal liquefaction could reduce China's demand for crude by 100 million tonnes per year, or about one-third of its anticipated imports by 2020.

Coal is also central to the thinking of researchers at the Tsinghua-BP centre. Zheng is focusing on a strategy called polygeneration in which a single plant would convert coal into syngas, then use it in gas turbines to generate electricity and also convert it into liquid fuels[2]. Sulphur is removed as an integral part of gasification, cutting pollution. To demonstrate the technology's potential, Zheng and his colleagues have conducted a 'syngas city' simulation for Zaozhuang in the eastern Shandong Province. Like many industrial centres in

## Brown clouds cast a dark shadow

China's flood season officially started this month with destructive floods in many parts of the country. In the past 20 years it has seen increasing summer floods in the south and drought in the north. The likely culprit is air pollution and, as this escalates with China's rapid industrial growth, it could alter weather across the region.

The key player in China's climate woes is the blanket of aerosol particles that hover over Asia. China isn't alone in creating this pollution hazard. India is a major contributor to the brown clouds of smog — mostly black carbon, organic carbon and other aerosols such as sulphates and nitrates — formed by wildfires and by burning fossil fuels and biofuels.

Black carbon, a sooty by-product of coal-burning, absorbs sunlight, resulting in a hotter atmosphere and cooler ground. Sooty particles also affect rainfall by seeding smaller droplets and preventing the formation of larger droplets. This aids cloud formation, but reduces the amount of rain produced.

To simulate the observed changes in China's rainfall patterns in recent decades, a team led by Surabi Menon of the NASA Goddard Institute for Space Studies in New York used a global climate model that factored in black-carbon emissions[4]. But although climatologists generally agree that aerosol pollution has altered China's rainfall, they remain cautious about its potential regional impact.

"We are dealing with imperfect measurements and imperfect models," says George Carmichael of the University of Iowa. Reliable measurements of aerosol emissions are lacking, particularly for black carbon. And climate models are riddled with uncertainties, for example how aerosols modify clouds.

Even so, studies reveal a similar picture elsewhere.

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Simulations by Veerabhadran Ramanathan from the Scripps Institution of Oceanography in La Jolla, California, and colleagues show that aerosol pollution caused changes over the north Indian Ocean that resulted in decreased monsoon rainfall and increased drought in India[5]. Similarly, China's pollution could affect surrounding oceans, altering monsoon rainfall across the region, says Ramanathan.

The next step is to reduce some of the uncertainties. Project Atmospheric Brown Clouds, run by the United Nations Environment Programme, began monitoring Asia's smog earlier this year. And improvements in satellite measurements of aerosols, together with China's plans to increase emission monitoring, will help determine the extent and impact of the country's air pollution. **Carina Dennis**

China, Zaozhuang faces a major problem: how to continue growing when the only readily available fuel is high-sulphur coal.

In the 'syngas city' model, the Zaozhuang authorities would provide incentives to promote polygeneration, which not only generates electricity but also produces methanol for vehicle fuel and dimethyl ether for domestic cooking and heating. The simulation suggests that polygeneration could meet more than a quarter of Zaozhuang's electricity needs by 2020. It would also achieve drastic cuts in sulphur dioxide emissions while reducing the need to invest in expensive flue-gas desulphurization technology at conventional power plants[3]. Further reductions in air pollutants, such as ozone-forming compounds, would come from the wider use of methanol and dimethyl ether.

Such simulations are the stock-in-trade of energy researchers worldwide. But in China there may be a greater chance of their being implemented, given the authorities' power to enforce their will. Preparations for the 2008 Beijing Olympics are a case in point. Realizing that the city's appalling air quality could damage athletes' health — and present a poor image of China to the world — the city is now engaged in a frantic clean-up, closing some 200 heavily polluting factories, piping in natural gas, and introducing a clean 'bus rapid transit' system. "The Olympics are a very big opportunity," says Li Hao, who heads Earth-View, a Beijing-based environmental group.

Zheng and his colleagues hope that growing official concerns about environmental health will also boost their proposal to build a polygeneration demonstration plant, costing some 5 billion yuan (US$600 million), which would generate up to 400 megawatts of electricity and produce as much as 400,000 tonnes of liquid fuel per year. "We got a very good response from the government," says Zheng.

### Greenhouse city

But while polygeneration and other clean-coal technologies may help to scrub China's filthy air, they won't do much in the short term to limit the nation's growing greenhouse-gas emissions. According to Zheng's simulation, total $CO_2$ emissions from power plants would be higher for the syngas city than if Zaozhuang continues using conventional technologies[3].

In the long run, however, polygeneration could provide a route to a more sustainable future, in which hydrogen is extracted from syngas and used to power fuel cells, while $CO_2$ is captured and sequestered. "But to get there, the investment will be huge," warns Zheng.

Given the costs involved, experts say that China's interest in carbon sequestration will depend largely on the willingness of Europe, North America and Japan to pay for it. Those who work in the energy industry are blunt about China's determination to strike a hard bargain. If the necessary cash isn't forthcoming, they say, all deals are off.

China's potential to single-handedly emit enough $CO_2$ to negate all other nations' efforts to control their greenhouse-gas emissions could place its leaders in a strong negotiating position. "If it's business as usual, then the planet is dead," says David Moskowitz, director of the Regulatory Assistance Project, based in Gardiner, Maine, who is advising Chinese officials on reforming the electricity-generation sector.

That should provide food for thought for the leaders of the G8 wealthy nations, who meet in Scotland in July with global warming on their agenda. China is a signatory to the Kyoto Protocol on climate change, but as a developing country it doesn't yet have an emissions reduction target. Whatever strategy world leaders contrive to save the planet, China will sooner or later have to be brought on board. And that won't come cheap. ■

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**For more on China's environmental problems see page 1179.**