demand is so high and the domestic transport systems are overwhelmed, and secondly, in order to minimise the emissions — carbon dioxide ($CO_2$), sulphur oxides ($SO_x$), nitrogen oxides ($NO_x$) and particulates — they must use coal that is of higher quality than what is available within their borders.

The top exporters of coal in 2008 were Australia (25.6% of global total), Indonesia (21.0%) and Russia (10.6%).[10] All three are already shipping millions of tons to Asian markets and plan to substantially expand their loading capacities.

## Alarm over Asia's Emissions

Coal is the undisputed leader in dirty fuel sources. Asia's governments are jostling to buy the best quality coals available in order to minimise emissions. Japan, for some time has been willing to pay a higher than average price for top coals and it closely monitors its emissions. It uses the most advanced means possible to mitigate the emissions. Other consuming countries in Asia, however, are much less able to do so.

Over the last few decades, the main targets of environmentalists and green businesses who are concerned about climate change have been the oil and gas companies. However, coal production and transport companies are increasingly seen as villains in the fight against climate change. American coal mines, coal-fed power plants and coal transport infrastructure have all been targeted over the past five years, and recently the world's largest coal port, Newcastle in Australia, was again shut down for a few hours by environmentalists attempting to draw attention to the role of coal in climate change. Some 45 people were arrested. This port currently exports about 90 million tons, and by 2013 will be able to export over 180 million tons.[11] Further huge expansion plans are in the offing. Australia has seven coal ports and all are bracing for more blockades by citizens concerned that the country's coal industry is fast becoming one of the world's largest contributors to global warming.

## Conclusion: Uncertainty

The spectre of global warming and climate change looms over Asia. As more countries increase their dependence on coal, their emissions will concomitantly rise. But in the foreseeable future, little of the $CO_2$ emissions will be captured. Experimentation continues with carbon capture and storage (CCS) technologies. There are many technical issues to resolve. Moreover, high costs and poor regulatory frameworks hamper their deployment. Individual regulatory mandates are difficult to implement in countries with numerous pressing socio-political issues. International co-operation faltered somewhat following the inconclusive results of the United Nations Climate Change Conference held in Copenhagen in December 2009. Much work needs to be done before CCS can achieve widespread deployment anywhere, including Asia. Like climate change itself, there are greatly varying opinions about it.

1 *British Petroleum Statistical Review of World Energy 2010* at http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2008/STAGING/local_assets/2010_downloads/coal_section_2010.pdf [all websites cited here accessed in Oct. 2010].

2 International Energy Agency (IEA), *World Energy Outlook 2009* (WEO) (Paris: OECD/IEA, 2009), p. 647.

3 IEA, *WEO 2009*, p. 649.

4 US Energy Information Administration (EIA) website http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=2

5 IEA, *WEO 2009*, pp. 646, 628 and 648.

6 IEA, *WEO 2009*, pp. 647, 629 and 649.

7 EIA at http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=3

8 EIA at http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=3

9 IEA, *WEO 2009*, calculated from pp. 90-91.

10 EIA at http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=4

11 Newcastle Coal Infrastructure Group Website at http://www.ncig.com.au/.

# The Real Drivers of Carbon Capture and Storage in China

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Carbon capture and storage (CCS) is now widely viewed as imperative for global climate stabilisation. Coal is the world's fastest growing fossil fuel, and coal combustion is now the largest single source of anthropogenic $CO_2$ emissions. China's coal sector is the world's largest and the rapid industrialisation of China is inexorably tied to the same process that fuelled the West's development - burning coal. International Energy Agency (IEA) projections suggest that

China will have 1,332 gigawatts (GW) of coal power generation capacity by 2030, compared to 583 GW in the US and EU combined.

This trend presents a forceful case for the development and wide dissemination of technologies that can decouple coal consumption from $CO_2$ emissions. The leading candidate technology to do this is carbon capture and storage (CCS). Indeed, IEA climate mitigation scenarios call for CCS in China to supply 20-25% of its total emissions reductions, and over 60% of those reductions will need to be applied to coal-fired power plants.

The stark reality is that China's incentives for being at the forefront of CCS technology learning do not translate into incentives to massively deploy CCS in power plant applications as climate mitigation goals would have it.

A few CCS projects are now being developed for the Chinese market. The first major CCS projects in China - Shenhua's coal-to-liquids (CTL) project in Ordos, Inner Mongolia, and the GreenGen integrated gasification combined cycle (IGCC) plant in Tianjin - have progressed rapidly because they explore technology with implications for China's long-term energy security. However, in the case of crucial post-combustion technologies which do not have potential benefits for fuel security, China has been slower to undertake major projects and is eager to spread risks across international partnerships.

The strategic logic of Shenhua's CTL project is all about using coal to hedge against oil import dependence. Integrating CCS into CTL processes would further boost security of oil supply by providing high purity $CO_2$ streams with little additional capture cost, as these streams would be pumped into declining oil reservoirs for enhanced oil recovery (EOR). However, CCS for CTL has limited relevance to global $CO_2$ mitigation goals. CTL is not a major source of emissions in China compared to current and future coal-fired power. In addition, the CCS-CTL process essentially results in a transport fuel that is roughly net equivalent in carbon emissions to oil. In any case, project owners are only likely to pursue these capital-intensive CTL-CCS projects where EOR opportunities exist to provide stable revenue streams over long-time horizons.

*Lao Ye Temple Mine, Datong, Shanxi, China.*

*Source: Flickr User Lhoon (Creative Commons Licence – changing of caption is allowed)*

*http://www.flickr.com/photos/lhoon/191844801/*

*Coal miner in Xingtai, Hebei China*

*Source: Wikimedia Commons User Zhart (Creative Commons Licence)*

*http://commons.wikimedia.org/wiki/File:Coal_Miner.JPG*

CCS technology integrated with IGCC, as envisioned by GreenGen, is now the major focus of state-supported CCS for power plants in China. The main advantages of CCS with IGCC are the high combustion efficiencies of IGCC and the relative ease of its $CO_2$ capture compared to post-combustion $CO_2$ capture processes (where the $CO_2$ partial pressure is much lower and hence capture is more complicated and expensive). The drivers for making IGCC power plants a state priority are again rooted in energy security concerns, as well as co-benefits from reduced local pollution and synergies with chemicals production. The potential direct benefits to Chinese energy security through higher energy efficiency and the development of potentially lucrative domestic intellectual property (IP) explain why the Chinese government is funding GreenGen. The information that GreenGen provides the Chinese government about IGCC costs and associated $CO_2$ capture will be crucial as China prepares the roadmap of its power generation build-out beyond 2020. CCS currently remains an afterthought relative to the more strategically important goal of developing IGCC.

China is leveraging international support for developing CCS, especially in cases where domestic benefits are less clear. These projects have tended to progress at a slower rate than those inherently motivated by China's security interests. While all of these projects certainly represent useful research efforts, they do not represent a level of investment comparable to the Shenhua and GreenGen projects (see Table 1).

China's interests are not well aligned with installing post-combustion capture on its biggest source of emissions - the existing 600 GW fleet of conventional coal plants. The implementation of CCS in the present-day Chinese power sector presents two special impediments: the structure of the power market and the supply chain for coal. While China now has mature coal markets increasingly exposed to international prices, China's central planning apparatus, the National Development and Reform Commission, keeps tight control over electricity prices in China in order to meet overarching political priorities. This means that the Chinese power market cannot internalise increased costs, making it nearly impossible for it to deploy a commercially viable CCS model on its own. In 2008, much of the Chinese power market could not even bear the cost fluctuations of its primary input - coal.

*A coal mine near Hailar, Inner Mongolia*

*Source: Flickr User Wolfiewolf (Creative Commons Licence)*

*http://www.flickr.com/photos/herry/35146366/in/photostream/*

Moreover, CCS costs extend beyond the power sector to the entire coal value chain. Adding $CO_2$ capture reduces generation efficiency by 20-30%. We estimate that CCS at scale in China, as prescribed by the IEA Blue scenario, would demand approximately 200-300 million tons of additional coal production per year. Beyond obvious additional cost increases for generators, ramping up coal production to these levels would require new mining capacity, rail infrastructure, port expansions and shipping capacity - investments on a massive scale - to maintain the paramount objective of cheap and reliable electricity. Costs would be well in excess of 100 million RMB (15 billion USD). CCS would also likely come at the expense of some investments in local wind, solar and nuclear power. These other alternatives enhance China's diversity of energy supply, whereas CCS does not.

Global investments in CCS have been deterred by a number of key factors, including technological and regulatory uncertainty, high costs and the lack of clear carbon policies that could provide a steady revenue stream for capital-intensive $CO_2$ capture. In the Chinese context, additional


*Hunger for coal. Datong, China.*

*Source: Flickr User Madiko 83 (Creative Commons Licence)*

*http://www.flickr.com/photos/desdegus/2833848056/*

barriers exist. The country's increasing involvement in CCS projects should be understood in the context of its overarching energy security agenda, rather than climate change considerations. The highest priorities are security and diversity of fuel supplies, cheap and reliable electricity, and development of domestic intellectual property for key energy technologies. While these drivers are likely to foster the development of China's CCS demonstration efforts, they do not translate into incentives to deploy CCS at scale in power plant applications where they are most needed. Fundamental and interrelated Chinese interests - in energy security, economic growth and macroeconomic stability - directly argue against large-scale implementation of CCS in China, unless such an implementation can be almost entirely supported by outside funding.

*This article was adapted by ESI Research Associate Geoffrey Pakiam from the report, "The Real Drivers of Carbon Capture and Storage in China and Implications for Climate Policy", published by PESD (http://pesd.stanford.edu/).*

*A good luck charm hangs from the belt of a rescue worker at the Wangjialing coal mine in Hejin, Shanxi. Rescue teams pulled 115 miners out alive more than a week after the mine flooded with water.*

*Source: Josh Chin (Creative Commons Licence)*

*http://www.flickr.com/photos/21953266@N00/4537141178/in/photostream/*

**Table 1: Major CCS Projects in China**

| CCS Projects | Technology | Partnership model | Financial arrangement | Status |
|---|---|---|---|---|
| GreenGen Corporation | IGCC<br><br>Pre-combustion de-carbonisation<br><br>Gasification or partial oxidation shift plus $CO_2$ separation. | Huaneng with seven other state-owned companies<br><br>Peabody Energy | Registered capital: RMB 300 million (USD 44 million)<br><br>Huaneng 51%, and another 7 in the group 7% each<br><br>Total investment will reach RMB 7 billion. | Under construction |
| Shenhua CTL | Coal to synfuels (direct coal liquefaction) | Shenhua Group<br><br>Sasol<br><br>West Virginia University | USD 1.4 billion | CTL operational |
| Huaneng Beijing Thermal Power | Post-combustion | Huaneng<br><br>Australia CSIRO | USD 4 million research project by CSIRO | Operational since 2008 |
| Near Zero Emission Coal | Research, Development and Demonstration (R&DD) | UK<br><br>China Ministry of Science and Technology | USD 5.6 million equivalent from the UK Government's Dept. of Energy and Climate Change | In planning stages |
| COACH Project (Cooperation Action within CCS China-EU) | R&DD | COACH project groups 20 partners (R&D, manufacturers, oil & gas companies, etc)<br><br>12 for Europe and 8 for China | Partially funded by European Union | In planning stages |
| Shanghai Huaneng Shidongkou | Post-combustion | Huaneng | Corporation investment | Under construction |

# The Role of Coal in India's Energy Sector

**Geoffrey Pakiam, Research Associate, ESI**

The story of the Indian coal sector has roots reaching back into the early 1800s. During the British colonial period, coal extraction went hand-in-hand with the extension of steam-powered railways and the production of pig-iron in select industrial centres. The advent of electricity brought with it further impetus for mechanised industrialisation, with most of the early demand located in the West Bengal and Bombay states. Industries, tramways, commercial enterprises and domestic users all needed coal, resulting in an annual demand growth rate of 20% until 1940.

With one of the largest hard coal reserves in the world (currently third highest), coal-fired power has been the foundation of India's growing electricity sector for the past three decades. In 2007, over two-thirds of India's electricity (549 TWh out of 803 TWh, see Figure 1) was generated from coal. However, to put this into perspective, India's coal-fired power generation that year was still only about a fifth of China's and a quarter of the USA's.

The power sector alone consumes nearly three quarters of all coal used in India, with most of the remainder used by heavy industries such as iron, steelmaking, cement and fertiliser production.

With several hundred million people still lacking access to