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China and Cleaner Coal

A marriage of necessity destined for failure?

John Seaman

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Executive Summary

For China, coal is a crucial source of abundant, indigenous and affordable energy and is a pillar of economic and social stability. From a logic of energy security, and because the industry itself maintains a formidable political presence through the sheer fact of its history and size, this resource will continue to play a central role in the country's energy mix. But in order to respond to the growing need to reduce the burden of coal use on the environment and the Chinese population, and to prevent catastrophic climate change, both Chinese leaders and the industry itself have faced a certain reality – coal must become cleaner.

This has led to a tenuous compromise between those in China advocating for the use of coal as a matter of economic necessity and social stability (security of supply, reliable and cheap electricity, and indigenous energy technologies) and those who strive for more environmentally sustainable growth (and thus emphasize "clean" coal). The convergence of these two concepts has spurred a major shift towards newer, more efficient, though still highly polluting technologies – notably larger scale, hotter burning supercritical and ultra-supercritical coal-fired plants. But it has also spawned a number of demonstration-scale projects in various cutting-edge technologies to include coal gasification and carbon capture and storage (CCS), which promise vast improvements in CO_2 and other, toxic emissions if widely adopted. Indeed, mitigating climate change while continuing to rely heavily on coal will only be possible if carbon can successfully be captured and stored on a broad scale.

The push to develop new coal technologies opens doors for both foreign and Chinese businesses to work together, potentially creating new market opportunities at home and abroad. Chinese companies can receive much-needed capital and expertise, while foreign companies and researchers are given the chance to test and develop technologies at a level of speed and scale that is not possible on their own domestic markets. This cooperation has also had clear benefits on a political level, particularly between China and the United States. Indeed, it has proven a useful diplomatic tool and a meaningful cushion in an otherwise rocky bilateral relationship. But if and when the time comes to access third markets, the culture of cooperation around advanced coal may quickly turn into a cutthroat race for market access.

But before this stage can be reached, a number of very high hurdles remain. Implementing and maintaining these technologies is

expensive and requires vast amounts of additional energy in order to make them truly cleaner in respect to emissions. Responding to the price challenge is particularly tricky. It means successfully reducing the cost of advanced technology and reforming China's power pricing structure to internalize the real cost of coal on society. This must somehow happen without tipping the balance of affordable energy needed to power the country's economic development. Moreover, in regards to CCS in particular, progress must also be made in reducing the energy demand. Current technologies require an input of 20-30% more energy to capture and store carbon. In China, this could translate into an untenable increase in coal demand, likely pushing an already overburdened industry well beyond the breaking point. And yet another formidable hurdle risks negating any progress made in developing cleaner coal technologies: water scarcity. The coal industry is China's largest industrial water user – demanding 34 billion m^3 in current times – and is also concentrated in the nation's driest regions. But a lack of adequate consideration of the relationship between coal and water in policy planning holds grave risks for the future.

Ultimately, while coal will continue to play an important role in China's economy, the challenges to making it truly cleaner are formidable. A certain reality must be granted to the need for cleaner coal in China today, but substantial pressure should be put on a phasing down, if not a phasing out of coal in China's future energy mix.

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Introduction

Overcoming the threat of climate change is perhaps the greatest challenge that the current generation faces. It is no secret that coal is the leading source of human-generated carbon dioxide emissions, and that China, as the world's top consumer of coal, is also the largest emitter of CO_2. For this reason, China's efforts to develop cleaner methods of using coal have attracted global attention in recent years. So-called "clean coal" technologies are by no means a magic bullet, but many argue that their successful application could prove to be the difference between a 2°C increase in average global temperatures, and something much worse. Yet, viewing these technologies through a lens of climate change obscures many of the driving factors behind their development in China, including the reason why, in the first place, China will continue to choose coal as its primary energy resource for decades to come – thus rendering cleaner forms of producing and using coal a necessity – and why many of these new technologies may never be deployed on a commercial scale.

The purpose of this paper is to underscore some major, guiding principles underlying the debate on cleaner coal in China, though it does not provide an *exhaustive* analysis of technology options. It begins by highlighting the tenuous compromise between those in China advocating for the use of coal as a matter of economic necessity and social stability (security of supply, reliable and cheap electricity, and indigenous energy technologies) and those who strive for more environmentally sustainable growth (and thus emphasize "clean" coal). The convergence of these two concepts has spurred a major shift towards newer, more efficient, though still highly polluting technologies – notably larger scale, hotter burning supercritical and ultra-supercritical coal-fired plants. But it has also spawned a number of demonstration-scale projects in various cutting-edge technologies to include coal gasification and carbon capture and storage (CCS), which promise vast improvements in CO_2 and other, toxic emissions if widely adopted.

These latest technologies have also opened the door for the creation of future market leaders, as well as meaningful cooperation

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between China and a number of foreign partners, particularly the United States. Indeed, the push to develop cleaner methods of using coal has provided a win-win opportunity for Sino-American cooperation and a meaningful cushion in an otherwise rocky bilateral relationship. Chinese interests can receive much-needed capital and expertise, while foreign companies and researchers are given the chance to test and develop technologies at a level of speed and scale that is not possible on their own domestic markets. While the U.S. and China in particular have recently agreed on a framework for resolving outstanding intellectual property issues on this joint research, these relationships could become more strained if and when the time comes to access third markets – for instance, India.

But before that step is ever reached, much skepticism remains about the viability of many advanced coal technologies, particularly CCS. Outstanding issues include increased energy demand of these new technologies themselves, higher electricity prices and environmental risks such as amplified water demand in arid regions as a consequence of growing coal use. Ultimately, those advocating the merits of coal from a standpoint of economic and social stability could find their marriage with a cleaner energy future much more difficult than previously imagined.

'Clean' and 'Coal' in China: A marriage of convenience, necessity and opportunity

Coal has played a central role in China's economic miracle. It is a major input for power generation and an important player for industry (steel, construction and chemicals) and heating. Coupled with China's dramatic economic growth, the country's coal consumption has grown by more than 180% since the year 2000. Accounting for nearly 70% of total energy demand, and 80% of electricity production in current times, coal has allowed for hundreds of millions of Chinese citizens to improve their living standards. As such, it is a key, strategic resource for the Chinese authorities, permitting the maintenance of economic, social and thus political stability amid an era of rapid transition.

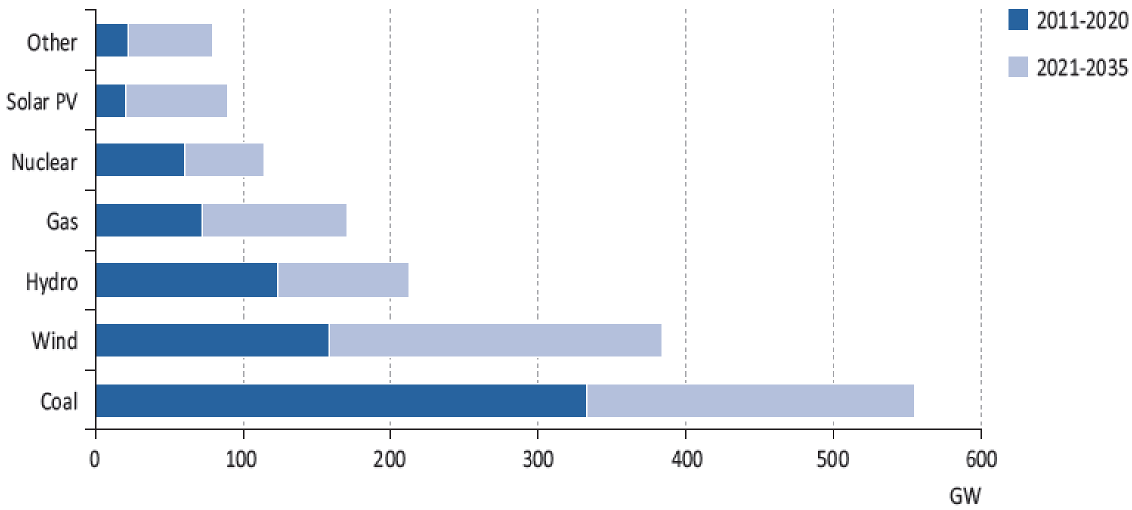
Coal as central to Chinese energy strategy and politics

Three characteristics of coal have given it such importance: it is an indigenous resource for China, abundant, and affordable. As a consequence of China's past relationships with foreign powers, particularly the "hundred years of humiliation" that began with the first Opium War in the 1840s, China's strategists have long held to the principle of autonomy and self sufficiency. The country's opening in the 1970s and subsequent economic development has given new impetus to this principle. Growing dependence on foreign energy sources – notably oil – have reinforced fears that foreign powers could use this dependency as a geopolitical lever to contain China's rise, or to bring about regime change. Coal has been a saving grace. China today accounts for 19% of global coal reserves (defined as economically accessible deposits, given current mining and market conditions), with a current, annual production of 3.2 billion tons. While some have argued that an era of "peak coal" is rapidly approaching,[1] Chinese strategists remain broadly confident in the abundance of this resource.

[1] Meng Li, "Peak Coal and China", The Oil Drum, 4 July 2011, http://www.theoildrum.com/node/8064.

Still, energy security is only a pillar of a larger, more important objective, on which rests the legitimacy of China's ruling party in the eyes of the local population: economic development and social stability. In this respect, the price of energy is just as important as its availability. With per capita incomes of only a fraction of post-industrial economies, access to cheap resources to support low energy prices has been crucial to economic development. Coal has traditionally been a cheap source of energy – precisely because the negative externalities of its use have not been accounted for in the price. In this respect, much of China's economic development would not have been possible had it not been for this resource. As a result of this strategic calculus, coal will continue to play a central role in China's future.

Figure 1. China's projected new additions of power-generating capacity by type (2011-2035)



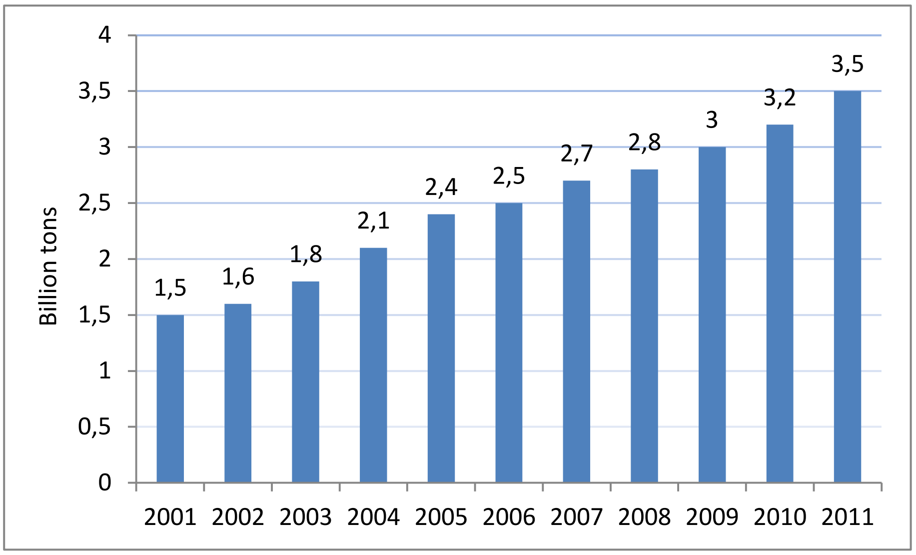
Source: IEA (2011), p.385 [2]

But another factor also contributes largely to this prognosis. China's heavy reliance on coal has given rise to a colossal and formidable coal industry, ripe with interest groups of its own that are eager to carve a place for themselves in the future of China's energy landscape. The 11th Five-Year Plan (2006-2010) led to a dramatic consolidation of the coal industry, establishing 13 large-scale production bases, eliminating smaller operations and nurturing the emergence of large-scale coal mining groups. Today, the industry counts as many as 5 million employees and as such has become an economic and social pillar of the country's coal producing regions.

[2] Projection *based on New Policy Scenarios to include: A 40% reduction in carbon intensity compared with 2005 by 2020; CO_2 pricing from 2020; a 15% share of non-fossil energy in total energy supply by 2020; 70 to 80 GW of nuclear power by 2020; 12th Five-Year Plan renewables targets exceeded. PLDV fuel economy targets by 2015.*

Transitioning away from coal would therefore engender an enormous amount of political risk.

Figure 2. The Evolution of Coal Production in China (2001-2011)



Source: China National Bureau of Statistics

The cost of coal and 'dirty growth'

Yet pressure to respond to the nefarious effects of coal use on the environment and human health has been increasing on local, national, and international levels. Initial discussions of China's coal industry often focus on its contribution to global climate change. Indeed, coal in China is responsible for 60% of the country's emissions of carbon-dioxide, as well as large quantities – 15 billion m^3 – of methane gas. Rising sea levels, melting glaciers, severe droughts and extreme weather events are all recognized threats and Chinese authorities view these risks with a high degree of seriousness. Despite criticism that China has been unwilling to commit to binding reductions of CO_2 emissions during UNFCCC negotiations,[3] the government has established its own targets for energy efficiency and carbon intensity – 20% improvement in energy intensity per unit of GDP by 2020, and a 40-45% reduction in carbon intensity per unit of GDP by 2035. Whether and how these targets will be met, and whether they will be sufficient in preventing dramatic climate change is the topic of another discussion, but they

[3] Chinese negotiators at the latest UNFCCC conference in Durban, South Africa in December 2011 did convey their willingness to submit to a binding agreement taking effect in 2020.

nevertheless demonstrate the level of consciousness in China – which has now reached the highest levels of power.

Still, carbon emissions are but one aspect of the problem created by 'dirty' coal, and not the most urgent. At the local level this resource has been at the root of widespread pollution and environmental destruction. Air quality is the most obvious side effect, with serious consequences for human health. Coal combustion is responsible for emitting 75% of China's sulfur dioxide, 80% of nitrogen oxides and 70% of total suspended particulates, including heavy metals such as mercury. But even before coal is burned, localized pollutants are also released in the form of gas, dust or waste-water during extraction, transportation and storage. The direct consequences of coal use on human health in particular have been difficult to quantify. In 2007, for instance, the World Bank and China's State Environmental Protection Administration published a study[4] – which was famously censored before its final release – estimating that 750,000 people die premature deaths each year in China as a result of pollution, though the role of coal was not specifically cited.[5] As the most immediately visible side effect of coal use, pollutants such as SO_2, NO_X and suspended particulates are often considered a more pressing concern for China's authorities than the longer term threats of climate change from CO_2 emissions.

Water supply is another significant problem. Coal is a major contributor to water shortages in some of China's driest regions – particularly Shanxi, Shaanxi and Western Inner Mongolia, which make up the heart of the country's "coal triangle", but whose runoff also feeds water-strapped Hebei, Beijing and Shandong. For coal preparation alone, every ton of coal produced requires 4-5 m^3 of water to wash the coal. Additional water resources are needed for transformation and cooling processes. Among China's state-owned coal mines, 71% report water shortages, while 40% qualify the shortage as severe.[6] Individual studies in China have shown that water demand from the coal industry is likely to increase dramatically and will surpass supply capacity if dramatic improvements are not made in the coming decade.[7]

Additional consequences of China's reliance on coal that deserve pause are the human effects of mining safety – while safety

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[4] *The Cost of Pollution in China: Economic Estimates of Physical Damages*, the World Bank & the State Environmental Protection Administration, P.R. China, 2007, http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/China_Cost_of_Pollution.pdf.

[5] Geoff Dyer, "China: Difficulties of a difficulties of a different energy model", The Financial Times, 12 October 2009.

[6] Yushi Mao, Hong Sheng, Fuqiang Yang, *et al.*, "The True Cost of Coal", Greenpeace, The Energy Foundation and WWF, September 2008, http://act.greenpeace.org.cn/coal/report/TCOC-Final-EN.pdf.

[7] Pan Lingying, Pei Liu, Zheng Li, Shiyao Chang, and Yun Li, "Water Issues in the Coal Supply Chain in China", 2011 Conference on Materials for Renewable Energy & Environment, Shanghai, 20-22 May 2011.

has improved over the decades, mining deaths in 2009 totaled 2,631, down from a high of almost 7,000 in 2002. China's coal mines remain among the most dangerous in the world. Burgeoning coal demand has also stretched the industry to its limits and serious transportation bottlenecks have pushed coal transport to evolve from its traditional reliance on rail, creating increasing headaches for the country's roadway and waterway transport networks. This problem has also resulted in a "coal-by-wire" policy to concentrate production in coal producing regions, which will result in a further concentration of pollution to affect local populations.

The true human and economic cost of coal production is difficult to quantify, as many of the externalities on health and the environment have not been internalized. Chinese economists have estimated that social and environmental damages from coal pollution could be as high as 1.7 trillion RMB ($250 billion) per year.[8] Regardless of the statistics, environmental awareness is growing at both the local and national levels. Environmental movements in China are increasingly widespread, and so long as the political regime is not directly challenged by such movements, they are largely left to their own devices. But the immediate impact of coal on local populations and the longer-term threat of climate change to China's future are rapidly gaining in importance as the economic costs come into clearer focus and social movements gain in magnitude. In this sense, this has become a political issue.

A marriage of convenience, and of necessity

Given the strategic value of coal in China's energy mix, the established nature of the coal industry, and the increasing threat that the resource's use poses to maintaining economic development and social stability, it is only natural for China to search for ways to reduce the impact of coal use. This has lead to a tenuous marriage of convenience between dirty resources and clean energy. But given the speed of China's expansion – China adds on average two new 500 MW coal-fired power plants per week, in addition to historic, record growth in the nuclear, wind and solar industries – and the growing urgency of the environmental problem, it is also a marriage of necessity. China cannot meet its future energy demand on the back of nuclear and renewables alone, and it is only a matter of time before a critical amount of carbon emissions and pollution is "locked-in" to the lifecycle of a new generation of power plants and industrial production. Cleaner coal technologies are seen as a way to extend this deadline or in some cases even to eliminate the risk altogether.

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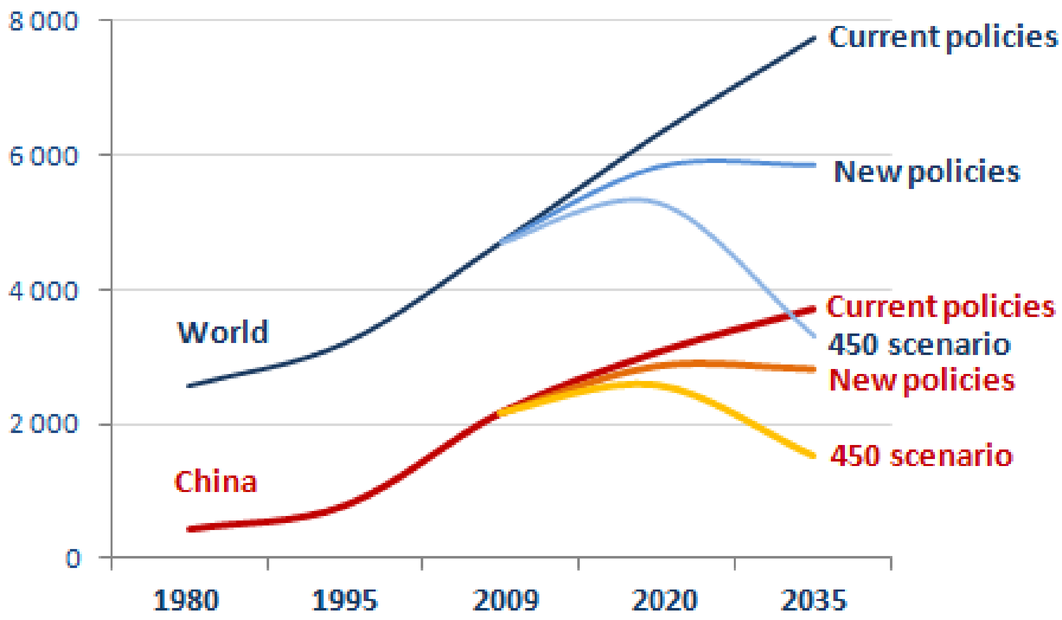
[8] Yushi Mao, *et al.*, *op cit.*

Chinese authorities have been facilitating the clean-coal union through regulation and goal-setting. Penalties for elevated levels of SO_2, NO_X and heavy metal pollutants have been established, goals have been set for CO_2 intensity, and a far-reaching initiative to close down many of the country's smaller, most inefficient coal mines and power plants was an important component of the 11th Five-Year Plan and are now guiding progress under the 12th. These and other policy measures are, among other things, facilitating the adoption of new, more efficient methods of using coal and the development of more advanced, seemingly cleaner coal technologies. This drive for technological advancement is representative of Hu Jintao's lauded "scientific development", wherein the challenges of the future can be met through human ingenuity and innovation. The future of China's coal demand ultimately depends on the speed and scope of this development.

Figure 3. Projected Coal Demand for China and the World (million tons/year)



Source: IEA (2011),[9]

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[9] **Current policies scenario** based on implementation of measures in 12th Five-Year Plan, including 17% cut in CO_2 intensity by 2015; solar additions of 5 GW by 2015; wind additions of 70 GW by 2015 and start construction of 120 GW of hydropower by 2015. **New policies scenario** based on: A 40% reduction in carbon intensity compared with 2005 by 2020; CO_2 pricing from 2020; a 15% share of non-fossil energy in total energy supply by 2020; 70 to 80 GW of nuclear power by 2020; 12th Five-Year Plan renewables targets exceeded. PLDV fuel economy targets by 2015. **450 scenario** based on: A 45% reduction in carbon intensity compared with 2005 by 2020; higher CO_2 pricing; enhanced support for renewables.

Technologies of now, and of tomorrow

Two generations of technology exist for China in transforming its coal industry. The first is technology that has already been developed, tested and marketed, while the second is technology that remains theoretical or at the demonstration stage. In each category, various possibilities exist for improving the impact of coal at all stages, to include mining, processing, conversion, combustion and emission.

Much of China's coal industry has for decades used outdated, inefficient technologies. Improvements can therefore be made simply by upgrading technology or applying proven methods. One example that applies to the preparation process is coal washing. China's coal deposits naturally contain large amounts of sulfur and ash. Toxic emissions can therefore be reduced by treating the coal prior to combustion. Less than 30% of coal in China today is washed, though investments are being made to improve the ratio and China has now become the world's largest market for coal preparation plants.[10] Coal mixing – combining Chinese coal with foreign supplies that naturally contain lower amounts of pollutants – can also reduce pollution and is an increasingly sought-after solution.[11] During the combustion process, efficiency gains can also be made by increasing the heat at which coal is burned. The majority of power plants operate at what is referred to as a "subcritical" level, burning coal at temperatures below 374°C and an efficiency rate of 30-36%. Transitioning to new, commercially available technology such as supercritical plants can improve efficiency, thus reducing the amount of emissions per ton of coal consumed and unit of energy produced (see Table 1 below). Transitioning to supercritical technology has been given short-medium term priority for Chinese energy policy, as supercritical coal-fired capacity is expected to jump from 50 GW in 2007 to 200-220 GW in 2020 and 300-330 GW in 2030.[12] Once coal has been burned, harmful emissions can also be removed from the flue gas through existing technologies known as "scrubbers", which can remove sulfur dioxide from flue gas (flue gas desulfurization – FGD), for instance.

The advantage of using existing technology is that it can enable proven gains with minimal risk to investment. In fact, many of these technologies have been in place in other parts of the world for decades. Yet, despite these efficiency gains and emissions reductions, coal remains highly polluting. Sulfur may be removed from flue gas to prevent acid rain, and more energy may be produced per

[10] Lilian Luca, "Clean Coal: China's Coming Revolution", *The China Analyst*, March 2011, http://www.thebeijingaxis.com/tca/editions/the-china-analyst-mar-2011/32.
[11] Keith Bradsher, "A Green Solution, or the Dark Side to Cleaner Coal?", *New York Times*, 14 June 2011, http://www.nytimes.com/2011/06/15/business/energy-environment/15iht-sreCHINA15.html?pagewanted=all.
[12] IEA, "Cleaner Coal in China", International Energy Agency, 2009, pp. 101.

unit of coal burned, but with China's projected increases in coal demand, toxic emissions, particularly of CO_2, will continue to grow even with a large-scale upgrade to commercially available technologies.

Table 1. Comparison of Select Coal-Based Power Generation Technologies

Combustion type	Estimated cost ($/kW)	Efficiency	CO_2 emissions (kg/h)	Estimated CO_2 emissions with CCS (90% capture rate)
Subcritical	500-600	30-36%	466,000	63,600
Supercritical	600-900	41%	415,000	54,500
Ultra-supercritical	600-900	43%	369,000	46,800
IGCC	1100-1400	45-55%	416,000	51,200

Note: Efficiency of supercritical and ultra-supercritical units is expected to increase. Calculation of CO_2 emissions based on 500MW net output – see MIT (2007), p.19.

Sources: IEA (2007), MIT (2007), Fernando, et al. (2008), interviews March 2011

A host of potential technologies currently at the research, testing and demonstration stages promise to propel the coal industry into a cleaner future. Transformation and combustion technologies such as Integrated Gasification Combined Cycle (IGCC) technology, which transforms hard coal into gas before combustion, and ultra-supercritical plants that could raise combustion temperatures from 560°C up to even 700°C also propose further efficiency gains and reduced emissions. The NDRC has been pushing forward on the development of ultra-supercritical plants and it is projected that 80 GW or more of power could be generated using this technology in 2020, and as much as 280 GW by 2030.[13] Going a step further, underground coal gasification (UCG) proposes to gasify coal before extraction, leaving many of the harmful pollutants underground and opening up new, previously unreachable reserves. Combining power generation with heating and or chemical processing also promises to combine previously independent processes and therefore make large efficiency gains as well. But the technology that is billed as perhaps the most promising, and the most crucial in terms of avoiding climate change (as indicated in the table above), is carbon capture and storage (CCS) – which has even been referred to optimistically as 'zero-emissions coal'. After combustion, carbon dioxide can be trapped and stored either for use in industrial processes such as chemicals, for enhanced oil recovery, or even for 'permanent' sequestration in porous rock deep underground, in essence burying

[13] *Ibid.*

carbon emissions as opposed to emitting them into the atmosphere. To date, work on carbon capture in China has largely been coupled with IGCC technology.

A field of opportunity: From market share to win-win partnerships

Mature technologies, which can be purchased from foreign suppliers, are a relatively quick-and-easy step for China to improve the efficiency of the coal industry and its impact on the local environment and population. But by developing and commercializing advanced coal technologies currently in the research and development stages, China can hope to position itself as a world leader in this field and thus benefit from opportunities to market new innovation worldwide. This is particularly relevant in a post-Fukushima era, when many major economies (including Germany, an important coal user in itself) are questioning the future of nuclear energy.

Indeed, China is home to range of demonstration projects that all hope to be precursors to a global boom in cleaner coal technologies. The GreenGen project, outside the city of Tianjin, is perhaps the best-known example. It is the first commercial-scale demonstration project under development that hopes to combine IGCC and CCS technologies. The project is a $1 billion endeavor involving a consortium of seven Chinese enterprises lead by Huaneng and including Datang, Huadian and Shenhua. The only foreign investor, Peabody Energy, an American coal giant, joined the project in 2007. The project also benefits from the support of the Chinese government via the NDRC and the Ministry of Science and Technology. Construction of the plant began in earnest in 2009 and is set, by the end of 2011, to produce 250 MW of power with simultaneous capacity to generate heat and synthetic gas. By full maturation in 2016, the project is expected to attain 650 MW with the capacity to inject 1 million tons of CO_2 for enhanced oil recovery.

There is a vast array of development projects with a diversity of technologies, but one important feature of many of them is the role played by foreign investors, both private and public. For instance, in September 2011, Alstom signed a Memorandum of Understanding with the China Datang Corporation to pursue a long-term partnership in developing CCS technologies. By 2015 the partners hope to build two coal-fired plants (350 MW and 1000 MW) in Daqing using Alstom's oxy-firing technology and capture 1 million tons of CO_2 to be used for enhanced oil recovery.[14] China is certainly not the only country in the world with demonstration projects in CCS, or other

[14] "Alstom and Datang agree to jointly develop carbon capture demonstration projects in China", Alstom Press Release, 21 September 2011, http://www.alstom.com/.

advanced technologies, but it is nevertheless considered as the Eldorado for any company looking to successfully develop such technology for commercialization. For foreign industries, China presents opportunities that can be found neither at home, nor abroad. The country is increasing its capacity with such speed that it can afford to experiment, adapt and refine new technologies in ways other, more developed markets such as Europe or the U.S. cannot. By partnering with Chinese developers, foreign firms can learn and develop technology in real-world situations. As one U.S. official explained in *The Atlantic*, "You can think of China as a huge laboratory for deploying technology. […] They can go from concept to deployment in half the time we can, sometimes a third. We have some advanced ideas. They have the capability to deploy it very quickly. That's where the partnership works."[15] Following recent failures of CCS demonstration projects in West Virginia, Scotland and Germany due to high costs and lack of political will, China is also seen as a last chance.[16]

But beyond win-win business opportunities, cooperation on advanced coal technologies has a useful geopolitical function as well, particularly in regards to the China-U.S. bilateral relationship. Relations between the two powers were relatively calm in the period following the terrorist attacks of September 2001, as U.S. attention was focused on combating terrorism and fighting wars in Iraq and Afghanistan. But since the arrival of Barack Obama in the White House, U.S. attention has turned increasingly to Asia and strategists on both sides of the Pacific have begun to warn once again of strategic competition and inevitable conflict. Cooperation on clean energy projects has proven a useful diplomatic tool in attempts to maintain a culture of cooperation amid growing friction, and clean coal has been a prominent feature of this initiative. When Hu Jintao and Barack Obama met for the first time in the fall of 2009, one of their lauded achievements was the founding of the U.S.-China Clean Energy Research Center (CERC) to conduct fundamental research into problems of common interest. When they met again on the occasion of Hu Jintao's visit to the U.S. in January 2011 they reinforced the initiative, making front-page news by putting on display a number of research and business deals that have resulted from cooperation in clean energy. This included a key project to collaborate on the development of IGCC power generation with CCS, bringing on board a number of universities, public laboratories and companies, including Huaneng, Shenhua, ENN, Duke Energy, General Electric, American Electric Power and Alstom.[17] While

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[15] James Fallows, "Dirty Coal, Clean Future", *The Atlantic*, December 2010, http://www.theatlantic.com/magazine/archive/2010/12/dirty-coal-clean-future/8307/

[16] Timothy Gardner, "Coal's bridge to future might lie in the past", *Reuters*, 11 December 2011.

[17] "Joint Work Plan for Research on Clean Coal Including Carbon Capture and Storage", U.S.-China Clean Energy Research Center (CERC), 18 January 2011, http://www.us-china-cerc.org/pdfs/CERC_Coal_JWP.pdf.

politics obliges that tough stances are taken on contentious issues, identifying common ground and advancing cooperation on questions of mutual interest, such as the joint development of advanced coal technologies, is useful in calming tempers and avoiding conflict.

A doomed marriage?

Despite the opportunities for business and international cooperation and the stated promises of these technologies in reducing environmental impact and slowing, or halting human-driven climate change, serious problems remain to be resolved. In China in particular, the points of friction between energy security and environmental protection are becoming better defined with regards to the future of coal. Pricing and a continued or even increased use of natural resources are of particular concern. An extensive debate is being waged on the feasibility of capture and storage technology, considered by many to be the only way to avoid severe climate change while continuing to rely on coal-fired power.

The price burden and the cost of affordable energy

Even before integrating more costly methods of advanced coal production, the price of coal in China has already risen to unsustainable levels in relation to the managed price of electricity. The coal industry has struggled to keep up with rising demand due in large part to infrastructure problems such as transportation bottlenecks. Moreover, the government's policy of maintaining low electricity prices in order to keep inflation in check and ensure affordable power for both households and industry have resulted in significant losses for the power sector. In 2008, for example, China's power companies lost an estimated 70 billion RMB, as they were forced to operate at a loss.[18] Naturally, this recurrent problem has led to backlash from the power sector that has even included power plant stoppage resulting in temporary blackouts – not for lack of capacity to meet demand, but rather due to market distortions. The China Electricity Council has already warned that a shortage of 30-40 million kilowatts of electricity could lead to blackouts in early 2012, and the

[18] Richard Morse, Varun Rai, and Gang He, "The Real Drivers of Carbon Capture and Storage in China and Implications for Climate Policy", Working Paper #88, Program on Energy and Sustainable Development, Stanford University, August 2009.

NDRC has announced that it will introduce incremental price hikes on electricity, coupled with caps on coal prices.[19]

Adding new spending requirements on an already overburdened power sector could spell disaster. But this is precisely what must happen in order to bring about any significant change in the environmental impact of coal. As discussed above, a large portion of the real costs of coal use are currently externalized. Without creating a pricing mechanism to internalize these costs then dirty coal will remain an economically attractive option while the most advanced coal technologies, as well as various non carbon options, will remain prohibitively expensive. Efforts to penalize producers for SO_2, NO_X and suspended particulates are certainly a step in this direction, and have favored a number of matured technologies, including flue gas desulfurization, supercritical and ultra-supercritical combustion technology. But this only takes China part way on emissions. Making real progress on carbon requires serious investment in capture and storage technologies, which will considerably increase capital and operating costs (see table below).

[19] "China hikes power tariffs, adjusts coal prices to ease power shortages", *Xinhua*, 30 November 2011,
http://news.xinhuanet.com/english2010/china/2011-11/30/c_131280061.htm.

Table 2. Estimated Cost Increases for Integrating Carbon Capture Technologies

	Subcritical PC		Supercritical PC		Ultra-Supercritical PC		IGCC	
	W/O Capture	W/ Capture	W/O Capture	W/ Capture	W/O Capture	W/ Capture	W/O Capture	W/ Capture
Performance								
Generating Efficiency (HHV)	34.3%	25.1%	38.5%	29.3%	43.3%	43.1%	38.4%	31.2%
CO_2 emitted, kg/h	466,000	63,600	415,000	54,500	369,000	46,800	415,983	51,198
CO_2 captured at 90%, kg/h (2)	0	573,000	0	491,000	0	422,000	0	460,782
	74%		61%		54%		32%	
Costs								
Total Plant Cost $/kW (3)	1,280	2,230	1,330	2,140	1,360	2,090	1,430	1,890
Investment Charge cents/kWh	2.60	4.52	2.70	4.34	2.76	4.24	2.90	3.83
Fuel cost, cents/kWh @ $1.50/MMBtu	1.49	2.04	1.33	1.75	1.18	1.50	1.33	1.64
O&M cost, cents/kWh	0.75	1.60	0.75	1.60	0.75	1.60	0.90	1.05
COE cents/kWh	4.84	8.16	4.78	7.69	4.69	7.34	5.13	6.52

Basis: 500MW plant net output, 85% capacity factor; for IGCC, GE radiant cooled gasifier for no-capture case and GE full-quench gasifier for capture case.

(1) Efficiency = (3414 Btu/kWe -h)/(heat rate)

(2) 90% removal used for all capture cases

(3) Based on design studies done in a period of price stability between 2000 and 2004. Updated to 2005 dollars using CPI inflation rate. Current costs would be higher because of recent increses in engineering and construction costs.

(4) Does not include costs associated with transportation and injection/storage.

Source: MIT

Image source: Fernando (2008), p.27

The solution to preventing climate change ultimately lies in creating a cost for pollution – particularly carbon – and reforming pricing mechanisms in the power sector. Politically, however, raising power prices to such an extent is practically unthinkable. Tackling rising inflation, although tempered to the 5% range in recent months, has been a key challenge for Beijing in recent times. As such, Chinese authorities face enormous pressure from industrial and consumer groups who oppose creating prices for carbon, among other pollutants. The concern for China's leadership is that rising prices could cause social tension and possibly even threaten the fragile social contract between China's Communist Party and the Chinese people, wherein the former guarantees progress, opportunity and improved standards of living for the latter in exchange for power and legitimacy. Affordable energy built on cheap coal has been crucial in helping China's regime make good on its end of the bargain. If the cost of advanced coal, particularly capture and storage, cannot be reduced then these technologies face a highly uncertain future.

Increased energy demand

But the price burden of advanced coal technologies are not the only problem. Additional questions arise from many of the new technologies themselves, particularly increased energy demand. Cleaning coal, in a sense, requires a considerable amount of additional energy and CCS, once again, is a prime example culprit. Current CCS technologies require an additional energy input of 20% to 30%, thus reducing the efficiency of coal-fired power. But more significantly, the increased demand for energy to capture carbon will have a significant impact on the entire coal industry. Prices for coal will rise as demand rise. Mining and transportation infrastructure, already overburdened by current levels of coal demand, will likely be stretched well beyond limit. The IEA Blue scenario recommends that China use CCS to capture 2 Gt of carbon emissions by 2050, with 1.2 Gt (60%) coming from the power sector, and thus coal. Researchers at Stanford University have estimated that such an endeavor would require an additional 200-300 million tons of coal per year.[20] Given that China's coal infrastructure is currently stretched to the breaking point, adding additional demand on top of projected increases is highly problematic and damages further the prospects of advanced coal development.

Water – the forgotten element

But the debate over cleaner coal is also heavily focused on air quality and climate change. As a consequence, the problem of water usage by the coal industry has gone largely ignored, or at least understudied. This could pose a strategic risk not only to the development of the coal industry and national energy production, but to the nation as a whole.

Coal washing is one aspect of the problem. As the coal industry increases the rate of coal preparation to reduce levels of toxic dust and pollutants, water demand and toxic runoff increase as a consequence. But policies to concentrate coal power production in mining regions to reduce the burden on the nation's transportation system will also have a considerable effect on water demand. As China's coal producing regions are also among its driest, concentrating the industry's most water-intensive processes is a risky bet. The cooling process for generating 600 MW of electricity from a supercritical coal-fired plant, for example, is more than 2,300 m^3 of water.[21] Water consumption of the coal industry as a whole is

[20] Morse *et al*. (2009), *op cit*, p.17.
[21] Author's calculations based on statistics from the U.S. Department of Energy's National Energy Technology Laboratory.

estimated at 34 billion m^3 per year – or roughly 6 percent of the nation's water consumption in 2009.[22] If these figures were broken down on a regional basis – concentrating on China's coal triangle, for instance – the burden of the coal industry on local water supply would certainly be shown as much higher.

Coal consumption therefore poses a significant problem for the nation's water scarcity issue, and vice-versa. But rather than increase conservation by finding technological solutions to the problem – which could include a transition away from coal – Chinese authorities have taken to supply-side solutions. Chief among them is the pharaonic South-to-North Water Diversion Project, which plans to divert 44 billion m^3 of water per year from southern waterways to the north of China by 2050. Compared to the 34 billion m^3 consumed by China's coal industry annually – and the increase that is likely as a consequence of rising demand for coal – both the problem and the solution could seemingly be found in the same place.

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[22] Rene Cho, "How is China dealing with its water crisis?", *State of the Planet*, The Earth Insitute of Columbia University, 5 May 2011, http://blogs.ei.columbia.edu/2011/05/05/how-china-is-dealing-with-its-water-crisis/.

Conclusion
Facing the hard reality of compromise

Technology choices will ultimately need to be made for China's energy future. Choosing to invest resources into developing cleaner methods for burning coal inevitably shift valuable resources away from the search for other solutions – be they the pre-destined wind, solar and nuclear options, or more theoretical energy sources such as thorium-based nuclear power, or hydrogen-based technologies. Each alternative, or group of alternatives, contains its own risks, of course.

Nevertheless, a line seems to have been drawn. Coal will continue to play a central role in China's energy mix. It has become a crucial source of abundant, indigenous and affordable energy and is a pillar of economic and social stability. From a logic of energy security, and because the industry itself maintains a formidable political presence through the sheer fact of its size, the environmentalist's dream of overthrowing King Coal is not a foreseeable option for China in coming decades. But in order to respond to the growing need to reduce the burden of coal use on the environment and the Chinese population, and to prevent catastrophic climate change, both Chinese leaders and the industry itself have faced a certain reality – coal must become cleaner.

This conclusion opens doors for both foreign and Chinese businesses looking to develop technologies that could, if successful in their stated goals, create potential domestic and export markets. This also has clear benefits for relations between China and its partners in the West, particularly the United States. If and when the time comes to access third markets, however, the culture of cooperation around advanced coal may quickly turn into a cutthroat race for market access.

But before this stage can be reached, a number of very high hurdles remain. The two obvious challenges to linking coal and clean energy are the effects of advanced technologies on resource and energy demand and on prices, particularly with regards to carbon capture and storage. Implementing and maintaining these technologies are expensive, and they require vast amounts of additional energy in order to make them truly cleaner in respect to emissions. Responding to the price challenge means successfully reducing the cost of advanced technology and reforming China's power pricing structure to internalize the real cost of coal on society. But this must happen without tipping the balance of affordable energy needed to power the country's economic development. If considerable effort is made during the development stage, it may even be possible to improve the efficiency of carbon capture.

And yet, the problem of water usage looms in the background, threatening to negate any progress if not properly accounted for. Indeed, the relationship between coal production and water use is one that urgently needs further study and a more refined focus of policy discussion.

Ultimately, if China's economy, and by extension the global economy is to achieve a more sustainable future, a certain reality must be granted to the future of coal in China today. Nevertheless, substantial pressure should be put on a phasing down, if not a phasing out of coal in China's energy mix.

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