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CLEAN COAL

U.S. - China Cooperation In Energy Security

David Wendt

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U.S.-CHINA COOPERATION IN ENERGY SECURITY

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ABOUT THE AUTHOR*

David Wendt co-founded the Jackson Hole Center for Global Affairs in 2002 and has been its president since that time. For over three decades he has been a leader in promoting efforts to build awareness and consensus on global policy issues. These efforts include a U.S. bicentennial program on global interdependence at the World Affairs Council of Philadelphia (1975-77); a program on global health, population, and environmental issues at the Center for Strategic and International Studies, in Washington, D.C. (1977-98); and the international program of Idaho State University, in Pocatello, Idaho (1998-2006). Dr. Wendt is a Phi Beta Kappa graduate of Harvard College, receiving his A.B. in Social Studies in 1967. He earned his doctorate in Political Science at Columbia University in 1975.

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EXECUTIVE SUMMARY

As major consumers of the world's energy resources, the United States and China are in dire need of secure energy solutions that can keep pace with their large appetites for energy. Enter coal. Both countries possess abundant coal reserves measured in the hundreds of billions of tons. But the approach to coal policy has been one of favoring cheap extraction rather than taking into serious consideration the societal costs of coal. For the United States, coal represents a major source of electrical power—and a major source of pollution. In China, the accessibility of coal has overtaken the environmental and health arguments against its widespread use. China uses more coal than the United States and European Union combined. The damaging side effects of coal mining and consumption have been overlooked in the face of easy availability and undeveloped or less accessible alternatives. In the current context of global energy uncertainty, coal has been forgiven much.

Clean coal technologies represent the new and improved face of coal-based energy. Unlike its predecessor, clean coal offers a reliable source of energy while minimizing its adverse health and environmental effects. Yet, to date, political and business leaders in the United States and China have done little to advance clean coal technology. Fears of a backlash over carbon capture and storage (CCS) sites have paralyzed U.S. government and industry, while China has shrunk away from imposing the real cost of cleaner energy on its citizens. The battle for public perception has been ceded and the political hurdles dodged in favor political expediency.

As users of over half of the world's coal, with no let-up in sight through the year 2030, the United States and China have a mutual interest and responsibility in showing the world the way to a cleaner energy future that includes continued reliance on coal. In no other two countries does coal use pose a greater threat to global environmental sustainability, and nowhere else are cleaner energy solutions more urgently needed. Although other cleaner energy options must continue to be explored (solar and wind power, biofuels, etc.) and energy conservation promoted, given the political, economic, and resource realities in China and the United States, research and development of clean coal technology is crucial so that the benefits of clean coal can be realized sooner rather than later. That is not to say that there are not obstacles to clean coal—including lingering questions about emissions and a timeline for diffusion of some technologies that will reach into decades—but the costs of not moving forward for both countries, and indeed globally, far outweigh the costs associated with developing clean coal technologies, which are clear improvements over its predecessor.

Together, the two countries have both the means and the incentive to ensure a sustainable domestic energy supply. Technological exchange and cooperation could reap significant environmental, commercial, and political benefits for the world's two largest producers and consumers of coal. A sustainable energy partnership would fast-track clean coal as a viable and long-term energy solution. The United States and China should leverage their complementary knowledge and expertise to guarantee a clean and reliable energy supply for generations to come.

INTRODUCTION

As the United States and China look toward a future in which (relatively cheap and accessible) oil, natural gas, and other energy supplies are increasingly constrained, coal's abundance assures it a prominent place in both countries' national energy strategies. Both countries are blessed with vast coal supplies—each has proven reserves of hundreds of billions of tons. Even under the most optimistic projections for the development of alternative energy sources, China will continue for at least another generation to rely on coal for over half of its total energy supplies. In the United States, 50 percent of all electric power is generated from coal.

The coal option, however, also has drawbacks. Coal is the most carbon intensive fossil fuel source. In the two countries combined, coal combustion accounts for over six billion tons of annual carbon dioxide emissions, or over one-fifth of world emissions from all fossil fuel sources. China is also responsible for almost half of the world's total coalmine methane emissions, accounting for another 200 million tons of carbon dioxide equivalent.[1] In other respects as well, coal mining and use in both countries constitutes a threat to health, safety, and the environment. In China, thousands of miners die each year in coal mining accidents. Coal mining and inefficient methods of coal combustion in power plants and coke ovens have contributed to severe pollution and the depletion of surface and underground water supplies throughout China. Emissions of particulates, sulfur dioxide, and mercury resulting from the transportation, storage, and combustion of coal produce hundreds of thousands of deaths each year from lung and heart disease. Some of these effects, such as acid rain from sulfur dioxide emissions, carry to neighboring countries, and mercury pollution travels all the way across the Pacific to the United States.

Coal also has adverse environmental impacts in the United States in the eastern part of the country, the controversial new practice of mountaintop mining has disfigured the landscape, eroded hillsides, deposited silt in riverbeds, and poisoned ground and surface water supplies. In the west, coalbed methane extraction has flooded hundreds of thousands of acres of

[1] The methane issue in China is driven more by economics than technological challenges. In the United States, it is standard practice to drain methane from coal seams before extraction. The methane is captured into manifolds, sent to the surface, compressed, and sold. Methane emissions in China could be radically reduced by implementing this relatively simple procedure—but it would not be without costs.

ranchland with brine and salty water, whose release from underground seams is necessary in order to access the methane. The transportation by rail of low-sulfur coal from western mines to eastern markets—a consequence of the stringent sulfur dioxide controls imposed by the 1991 revision of the Clean Air Act—uses additional energy and results in fugitive dust emissions.

These issues have given rise to much controversy within policy circles and among the broader public in both China and the United States. Importantly from the perspective of this policy paper, they have now also begun to enter into the policy dialogue between U.S. and Chinese policy experts concerned with promoting U.S.-China cooperation on these subjects. A leading sponsor of these exchanges has been the U.S.-China Energy and Environmental Technology Center (EETC), a joint effort of the U.S. Department of Energy (through Tulane University) and China's Ministry of Science and Technology (through Tsinghua University). EETC has also joined recently with the Atlantic Council of the United States and the Institute for Sino-American International Dialogue (ISAID) at the University of Denver in organizing a series of U.S.-China Energy Security Cooperation Dialogues that includes clean coal at the state and provincial government level, the Jackson Hole Center for Global Affairs (JHCGA) has organized a clean coal partnership between Wyoming and Shanxi province, the two largest coal-producers in their respective countries.

But the heavy lifting of real technology transfer has yet to begin. This work includes policy coordination, research partnerships, and joint project development. How, then, does coal fit into the strategies of the United States and China to attain energy security while avoiding adverse environmental impacts? What comparative advantages do both countries have and how should these comparative advantages guide their future investments in climate mitigation strategies and clean coal technologies? Most importantly, what is the role of bilateral cooperation in assuring a peaceful and sustainable outcome to this process?

CHINA'S POLICY CHOICES IN CLEAN COAL

Despite the fact that China already relies disproportionately on coal to fuel its economy, the pursuit of an energy strategy based primarily on clean coal would entail a fundamental shift of priorities. A national energy security strategy based on clean coal will demand a more comprehensive system of energy policy decision-making and controls. The current system of decentralized decision-making extends extraordinary discretion to local party officials, who, through their control over local branches of banks, power companies, and environmental protection bureaus, are able to approve and

finance power projects in accordance with their own local interests and priorities. As a result, the central government finds it extremely difficult to deliver on its energy and environmental promises. Policies set at the national level with national goals in mind inevitably encounter resistance or outright disregard at local levels.

Within the coal and power sectors themselves, there are further impediments to coordinated policy. The coal industry in China has tended to be highly fragmented, while power production is concentrated in five major companies. The resulting disparity in bargaining power gives an advantage to power companies, who would therefore tend to resist moves by coal producers to gain greater control over power supplies through clean coal operations based at minemouth power plants. To this extent, the power companies have little interest in encouraging this or the other elements of a large-scale clean coal infrastructure, including electric power transmission lines and pipelines for the efficient utilization and distribution of methane, town gas, and heat derived from mining, gasification, and power generation operations.

However, increases in the price of coal over the past several years have tended to equalize the bargaining position between coal producers and power providers. As power companies find their profit margins increasingly squeezed between rising coal prices and controlled prices of power, coal companies have gained greater leverage in acquiring power production capabilities at the minemouth. Recently, a number of coal producers have sought to move “downstream” into expanded power production operations at the same time as power producers have sought to increase their profit margins by acquiring “upstream” capabilities in coal.

A further consequence of this complex and highly fragmented decision-making system is the scramble for competing energy security strategies among regions. Instead of a unified national energy security strategy, each region is left to pursue its own strategy, sometimes at the expense of the others. This competition and lack of coordination is particularly acute between the eastern and western regions of the country. The more well-developed coastal regions of the east, lacking confidence in the reliability of electric power supplied from the coal-rich western regions, have insisted on building their own power plants while relying on western China for the coal. In many cases, they have also started importing liquid natural gas (LNG) from abroad to fuel gas-fired power plants.

To overcome these conflicts of interest and priorities between local and central government agencies, the coal and power sectors, and China’s geographical

regions, the Chinese government will have to adopt a much more coordinated and streamlined approach to energy policy decision-making. Recently, China has reorganized its national energy policy structure to assign responsibility for setting strategy and priorities to a high-level energy commission while assigning administration and oversight of the energy sector to the energy bureau of the National Development and Reform Commission (NDRC).

These moves are a step in the right direction. But much more remains to be done to assure uniform compliance with the central government's mandates. A national energy security strategy based on clean coal will, under the best of circumstances, be an enormously costly and time-consuming national undertaking. Wastefulness or inconsistency in its implementation will be its death knell. Nothing less than a wholesale reordering of the system of priorities and incentives will be needed to avoid such an outcome, sending a signal to government officials and enterprise managers at every level of the bureaucracy that they are no longer at liberty to make their own policy.

No set of incentives is probably more important in this regard than that of energy prices. China's current energy pricing policy is driven largely by social concerns. In its eagerness to continue delivering the benefits of economic growth to urban populations, China has made affordability a priority over resource conservation or technological innovation.

This policy has had severe consequences in a number of areas. In the electric power and coal chemicals sectors, for example, priority is given to providing heat and power to residential and industrial consumers at subsidized rates at the expense of more efficient operations and more rigorous environmental controls (e.g., sulfur dioxide emissions, water conservation). In other areas of heavy industry, such as steel, aluminum, and concrete manufacture, huge inefficiencies are tolerated, owing largely to pressures of competitiveness that dictate keeping the cost of energy inputs low.

A very different approach toward the pricing of environmental externalities will be needed if China is to mount a successful national energy security strategy based on clean coal. The key to such a strategy will be China's capacity to set energy prices at levels that will encourage the greater conservation of energy and the more rigorous enforcement of environmental standards. The government, of course, is reluctant to impose these burdens at a time when it has based much of its legitimacy on the promise of universal access to a middle class lifestyle.

The problem is that rising social unrest throughout China already threatens the legitimacy of the regime. Much of this unrest relates to protests over conditions of environmental abuse and neglect. There is little point in a policy of continued subsidization of urban energy consumers when this can only perpetuate these conditions by adding to resource scarcities that will increase pressures on the environment. In other words, if energy security is a national security concern for China, so, too, is rising social unrest. And from a national security perspective, there is no real conflict between the requirements of energy security and the requirements of social peace. The same sacrifices that are needed to enhance energy security—higher energy prices and greater resource conservation—can also, in the long run, help to promote social stability by reducing the pressure on the environment. The appeal to patriotism offers the Chinese government a way to achieve these gains by demanding sacrifices of the Chinese people without having to put its own legitimacy on the line—and, in fact, while enhancing it.

IMPLICATIONS OF A CLEAN COAL STRATEGY FOR CHINA

Social and Political Stability

A national energy security strategy based on clean coal has implications for social and political stability in China, especially concerning widening economic disparities between the richer coastal regions and the poorer regions of the interior. A national energy security strategy based on clean coal would provide an opportunity to address this imbalance, which now poses a greater threat to social and political stability than any other single issue in China.

Specifically, a national energy security strategy based on clean coal demands will likely require a significant reallocation of resources from the energy-consuming eastern regions of China to its coal-producing regions in the west. Such a strategy would entail large-scale investments in research and development (e.g., gasification technologies, hydrogen production), human resources (e.g., managerial and technical expertise), and physical facilities (pipelines and transmission lines)—all of which could create millions of new jobs. Accelerated development of the interior regions could lead to increased public revenues to pay for expanded social services and other public goods such as education and health, thereby elevating the quality of life of the average citizen. Enhanced environmental quality would also be possible by virtue of increased public revenues to pay for environmental externalities.

In all of these respects, investment in a national clean coal infrastructure would amount to a large-scale public works program, helping to close the

growing gap between the richer coastal and the poorer interior regions of the country. The pay-off for the coastal regions would be the prospect of cleaner and more secure sources of electric power and, ultimately, coal-based transportation fuel supplied from the interior—a prospect that has thus far proven elusive. By bringing these win-win benefits to both the east and the west of China, a national energy security strategy based on clean coal could, in the most optimistic scenario, link the two regions more closely not only in terms of a shared energy future but also of shared perceptions of economic prosperity.

Opportunities for Global Technological Leadership

A national energy strategy carried out in accordance with these priorities would also present China with an opportunity to attain global technological leadership in the area of clean coal. Coal is among the oldest industrial fuels but in many respects it can also help provide a bridge to the new industrial economy of the future. China is poised for such a transition. By taking advantage of its capacity to mobilize human and financial resources on a grand scale, it can use its coal reserves to show how, in a number of areas, coal can point the way to such an economy.

First, coal gasification based "polygeneration" of multiple outputs, including electric power, coal chemicals, and other fuel sources, creates a gateway to a more broadly sustainable energy base. Other fuel sources that can be derived from syngas[2] produced from coal include di-methyl ether, a convenient substitute for liquid petroleum gas, particularly in rural regions, and methanol, a transportation fuel. In addition, retrofitting coal gasification systems (e.g., integrated gasification combined cycle) with the capability for a hydrogen "shift" reaction provides a means for separation of both hydrogen and carbon dioxide from the initial syngas stream, comprised largely of hydrogen and carbon monoxide. The carbon dioxide is then available for underground storage, in a process called carbon capture and storage (CCS), while the hydrogen can be combined with ambient oxygen in fuel cells to generate electricity. Fuel cells hold great promise as a clean source of electric power in the future and a clean and cost-effective means of producing a hydrogen feedstock is the key to their widespread deployment.

A second area where China stands poised to leapfrog into the future is in the area of coal mining productivity. In place of today's cumbersome and antiquated structures, the coal mines of the future are likely to incorporate

[2] Synthesis gas, or syngas, is a combination of carbon monoxide, hydrogen, methane, and other gases produced when coal slurry is combined under high pressure with oxygen.

features that will make the transition from coal production to coal consumption a seamless process. New technologies could be implemented in China—as they already exist in the United States—to make it possible to begin mining operations while methane drainage operations are still underway, thereby saving time and reducing fugitive methane emissions. Advanced reciprocating gas engines installed at the minemouth will make it possible to recover the methane as it is drained or ventilated from the mines and to use it as a clean-burning fossil fuel to generate electric power.[3] Modern circulating fluidized bed systems can also be installed to allow waste coal to be "recycled" for electric power production rather than simply accumulating to the point where the entire mining operation eventually becomes a huge waste site.

Looking further into the future, within 20-30 years underground coal gasification may provide the ultimate solution for a process of seamless extraction and utilization of coal. This technology, once implemented, would employ large-scale rigs to pressurize oxygen and pump it deep into the ground, where it reacts with coal seams to produce syngas. The syngas is then returned to the surface, where it can be used to produce electric power. Hydrogen can also be separated and produced through this process, as a result of the hydrogen "shift" reaction with water which takes place at high temperatures and pressure underground.

The above advances in productivity will transform the nature of modern mining operations. The new advances can help to ease the pressure on China's electric power grid; they can also ease its transition to a future based on clean energy sources (e.g., hydrogen). The possibilities of coal conversion endow coal with a dual role in satisfying the needs of the present while addressing the possibilities of the future, including, as we have seen, hydrogen production through coal gasification. By investing in this and the other processes described, China can turn its vast underground coal reserves to its advantage, bringing coal to the surface in the form of clean-burning sources of energy to meet both today's and tomorrow's needs.

The third area where China has an opportunity to show the way to the future is in the development of a clean energy infrastructure. China is relatively well-positioned in comparison with other industrial countries to move ahead decisively with the transition to the next generation of clean energy technologies. First, it is not burdened by an obsolete energy infrastructure that would constrain its future energy technology choices—there are no sunk costs to be recovered, no expensive retrofits to be made. Instead, China has the

[3] In the United States, the methane is simply manifolded, compressed, and fed into a natural gas grid.

ability, as it has already done in the area of telecommunications, to leapfrog over an entire generation of technology to the clean energy technology infrastructure of the future. Second, China has the capacity to mobilize investment capital on a grand scale. Whatever the infrastructure requirements of the next generation of energy technologies, China has the access to foreign reserves and other sources of savings needed to meet them.

These advantages create for China the possibility of a rapid transition to an advanced clean energy economy based on a set of mutually supportive systems for the distribution of energy based on coal and other sources. Instead of being transported by rail or—worse—by truck, coal can be sent "by wire"[4] from advanced clean coal power plants located at the minemouth in the western part of China to electricity markets located in coastal areas in the east, as is already done in the coal industries of countries like the United States and Australia. Carbon dioxide captured at these advanced gasification and other facilities can be transported by pipeline to underground storage sites waiting to receive it in more remote areas located further to the west. Hydrogen separated from the syngas at these facilities can be pumped into waiting tank cars to be distributed by rail to fueling stations for use in fuel cell vehicles. Heat and waste gas from other advanced clean coal facilities, located outside cities, can be delivered into district heating systems or made available for home use within the city limits.

U.S. CHOICES IN A COAL-BASED STRATEGY OF ENERGY SECURITY

The United States approaches the issue of mobilizing its coal reserves for national energy security from a completely different position of natural resource endowment. Unlike China, the United States also has vast reserves of natural gas, which are available not only for purposes of home heating and power generation but also for current and future transportation needs. The most cost-effective approach to a coal-based energy security strategy will take these other resources into account, utilizing coal in ways that will conserve them for other purposes for which they can more cost-effectively be applied.

For example, the development and deployment of coal-to-liquids (CTL) technology would appear to have little national security justification outside military uses. Although most commonly accepted CTL technologies rely on

[4] "Coal by wire" refers to the process of transmitting electric power from the source of its generation at the coal mine to the destinations for its end-use via high-voltage power lines, rather than transporting the coal by rail or other means to power plants located nearer to the destinations for end-use of the power.

coal gasification as an intermediate step, even this indirect form of CTL is very carbon intensive because, unlike coal gasification for power generation, it requires a second stage of combustion. CTL produces diesel fuel, the energy from which must in turn released through the process of internal combustion. By contrast, integrated gasification combined cycle technology (IGCC) provides a means of releasing the energy from coal gasification directly in the form of electricity, generated from a gas combustion turbine. In effect, CTL uses more energy—and therefore releases more carbon—by burning the coal twice, although it does create a transportable fuel.

Therefore, to match the carbon footprint of conventional diesel fuel or gasoline, full-scale deployment of CTL as a transportation fuel would require a very comprehensive, and probably prohibitively expensive, system of carbon capture and storage (CCS). Moreover, even taking this additional step into account, CTL as well as other conventional and even alternative transportation fuels (e.g., biofuels) still fall short of the potential for carbon reduction of compressed natural gas (CNG), which outperforms all other fossil fuel sources in terms of efficiency. A full-scale CNG transportation infrastructure—comparable in the area of transportation to the interstate highway system of the 1950s—would take advantage of this potential of CNG to provide an environmentally cost-effective basis for meeting the U.S.'s national security and energy needs. Such an infrastructure could encompass natural gas pipelines, compressors, and fueling stations, coupled with a relatively simple set of engine modifications in the U.S. automotive fleet.

That is not to say, however, that CCS has no place in a clean coal future for the United States. The United States currently relies on coal for 50 percent of its electric power. For economic, political, or technological reasons, no energy source—nuclear, solar, wind, geothermal, or otherwise—singly or in combination can come anywhere near to replacing this source of electric power in the foreseeable future. Coal gasification is not only a more efficient means of power generation than conventional pulverized coal combustion, it also provides a much more cost-effective basis for capturing carbon dioxide by separating it from the exhaust gas stream before it reaches the smokestack. Carbon capture is in turn the first step in preventing its escape into the atmosphere by burying it underground.

Many other steps then need to follow. These include characterization of the proposed underground storage sites through geological surveys and analyses, computer simulations, and so-called measurement, monitoring, and validation (MMV) through pilot projects and other technical demonstrations. All this research and demonstration needs to be conducted on a site-by-site basis, taking into account varying conditions and circumstances. In addition,

extensive public policy work is needed to build a regulatory regime addressing such issues as liability and property ownership and to build public acceptance and support for the approach of CCS in general. Then, before full-scale CCS can be undertaken, a network of pipelines needs to be developed to transport the carbon dioxide to the designated sites from its points of origin.

When all of these steps are considered in the aggregate, it is clear that nothing approaching the necessary level of national effort is currently being undertaken to build a comprehensive system of CCS addressing the country's power production and carbon reduction needs. The IGCC plants (complete with the necessary carbon-capture capabilities) are not being built. The funds are not being allocated to research and development to support the trial-and-error process of site preparation and development. And, most importantly, a system of economic incentives has not been put into place to make it prohibitive for industry—and, by extension, consumers of electric power—*not* to make these necessary investments.

In short, CCS has not been made a national priority. The true test of the U.S.'s seriousness about climate change will be its commitment to a system of legislation, budgets, program plans, and management tools—like the Manhattan project of the 1940s or the Apollo project of the 1960s—commensurate in scale to the magnitude of the challenge.

A JOINT U.S.-CHINA CLEAN COAL STRATEGY FOR ENERGY SECURITY

The Technology Sharing Option

Given the proper circumstances and choices, therefore, an energy security strategy based on domestic coal supplies could go a long way to helping both the United States and China insulate themselves somewhat from the worldwide scramble for oil and natural gas. In itself, however, such a strategy may not go far enough. Indeed, if pursued in mutual isolation, such a strategy promises only conflict in another form.

The reason is that, left to its own devices, each country will find itself facing sub-optimal range of energy choices, each of which can ultimately be pursued only at the expense of the planet. Accessing unconventional energy sources such as oil shale or tar sands or gasifying coal to produce liquid transportation fuel are very expensive processes that require very high energy inputs in relation to energy outputs. When the cost of addressing environmental

externalities like carbon controls is added, the cost of developing these sources becomes prohibitive.

Faced with the mounting pressures of the search for secure sources of energy, it is extremely unlikely that either the United States or China would chose to pay the full cost of these environmental externalities as opposed to deferring them to future generations. Sooner or later, however, these costs will need to be confronted. Worsening climate change and a deteriorating global environment will lead to resource scarcities, cross-border pollution, and other pressures on natural and human resources that can only increase the potential for bilateral conflict.

Pursued independently, therefore, energy security strategies based on clean coal are no more a prescription for avoiding conflict between the United States and China than a strategy of subsidizing urban consumers of energy is a prescription for avoiding social unrest in China. In both cases, it is the environment that stands in the way. A more feasible model for the pursuit of energy security based on clean coal may be for the United States and China to engage in a cooperative effort, each compensating for the other's clean coal vulnerabilities by sharing technologies in its areas of comparative strength.

CCS provides an obvious focus from the U.S. standpoint for such a strategy of clean coal technology exchange with China. Unlike China, the United States has many capabilities already in place for the full-scale development, demonstration, and deployment of CCS. These resources include world-class geological expertise, extensive experience in computer modeling, simulation and mathematical computation, and advanced capabilities in chemical process engineering and analysis. Even though, as we have seen, the United States has barely scratched the surface in terms of allocating these resources in the service of CCS, the lessons are there, waiting to be learned and shared with China.

This disparity in resources and expertise relevant to CCS presents an opportunity for the United States to help China accelerate its own program of CCS demonstration, development, and deployment in the interests of peace as well as the future of the planet. Although China is probably now not ready for full CCS deployment, it cannot defer this option indefinitely as it contemplates future development of CTL and other coal-based transportation fuels (e.g., methanol) in addition to its current focus on advanced clean coal power generation.

In the absence of accompanying measures for CCS, however, the prospect of China's development of CTL presents extremely serious implications for the

global environment and, ultimately, U.S security. It is at least as much in the U.S.'s long term national security interests to prevent such an outcome as it is, for example, to forestall the prospect of a world-wide grab for oil. As Gen. Richard L. Lawson (USAF-ret.) has said with respect to CCS, "We need to develop it, test it, and take it over there [to China] and share it as our investment in peace in the second half of the twentieth century."

Coal gasification fits this same description from a Chinese perspective. The Chinese are already moving forward aggressively with "polygeneration" processes based on coal gasification. These processes include not only electric power generation but also the utilization of byproducts contained in the waste gas stream, while separating the hydrogen for other uses (e.g., fuel cells) and capturing the carbon dioxide for underground storage. The byproducts of this process can also include fertilizers and other coal chemicals, methane, methanol, di-methyl ether, and other fuel sources. In addition, China utilizes waste gas from coal gasification for the heating of homes and apartments.

Why cannot this same experience be utilized and replicated in the United States? Currently in the United States, most of the contents of the coal that are not consumed in the power generation process are either vented into the atmosphere, as is the case with carbon dioxide, or processed as waste (e.g., sulfur dioxide, nitrous oxide and nitrogen dioxide). Coal gasification, by contrast, provides significant environmental advantages over conventional pulverized coal-fired power production. These advantages include 10-15 percent greater thermal efficiencies, resulting in less coal use and fewer emissions. With the installation of capabilities to conduct a hydrogen shift reaction, this process also permits the more cost-effective separation of hydrogen and capture of carbon dioxide than conventional combustion processes. Finally, it conserves water and, by separating pollutants (e.g., sulfur dioxide) from the waste stream before they reach the flue, provides a more cost-effective basis for their treatment or conversion.

This approach of "comprehensive resource utilization" obviously fits the needs of the United States for a cost-effective energy security strategy, defined in terms of full environmental cost accounting. But the United States cannot do this alone. It needs China's experience, derived over decades as the world's leading coke producer, in testing out practical alternatives that do not involve expensive retrofits. Through its experience in coke production, China has also acquired extensive expertise in determining the suitability of various coal types for purposes of coal gasification. These are fields on which the United States is only now beginning to embark. Cooperation with China provides the United States with an opportunity to leapfrog an entire phase of trial-and-error, and to

go directly to the solutions that cost least, make best use of the coal, and produce the most useful byproducts.

The Question of Intellectual Property Rights

In short, the possibility of the United States and China helping to compensate for each other's vulnerabilities in clean coal production and utilization through a strategy of cooperation based upon their own strengths is a win-win situation. But how would the rules of such an exchange of experience and expertise to be negotiated?

One set of rules that has yet to be adequately negotiated concerns intellectual property rights. The sharing of technology might be a win-win strategy for both countries as a whole, but not everyone within each country stands to benefit. Private sector investors in research and development efforts, who have put their resources at risk in the expectation of future gains, stand to see others reap these gains at their expense. Scarce public resources, initially allocated to these same purposes at the expense of other pressing priorities, will now have new applications. In the view of some, this will no longer justify the original sacrifices. Shared access to technological information and innovation, in other words, changes the rules of the game.

If the possibility exists for the United States and China to compensate each other for their respective vulnerabilities in clean coal, however, why could they not similarly compensate those who stand to lose from such cooperation within their own societies? The United States, for example, already has such a system in place to compensate those within its society placed at a disadvantage by free trade. The government compensates workers for job losses through a system of economic supports, including unemployment compensation, job retraining programs, and job placement services. Tax and other incentives help attract businesses to invest in the economic revitalization of depressed communities. Small business loans enable those who have lost their jobs to get back on their feet by starting their own businesses.

There is no reason such a system could not also be adopted in the area of clean coal technology transfer, so as to compensate technology providers for the loss of business opportunities resulting from the sharing of technology. Public funds could be used, for example, to help private sector providers of gasifiers and other clean coal technologies identify China's most lucrative markets for these products, based on assistance in testing them over a wide range of circumstances and with a wide range of coal types. Subsidies could be extended to provide broad initial dissemination of these products, thereby conditioning the development of a future infrastructure conforming to their

specifications and positioning them for de facto dominance of the market. As the first to have developed and perfected these products, technology providers have everything to gain from a competition in which their loss of an information advantage is offset by adjustments such as these.

CONCLUSION AND NEXT STEPS

Is coal, then, the answer to energy security for the United States and China? Ironically, coal provides an answer to their energy self-sufficiency only in the context of a mutual strategy of cooperation. Undoubtedly, China's capacity to mobilize capital for clean coal technology creates many future options. As noted, these include polygeneration of electric power, hydrogen, and other byproducts of coal gasification; investment in the productivity of mining operations and their byproducts; and the creation of a large-scale clean coal infrastructure. But along the way, China will also probably have to hedge its bets with the development of some less cost-effective options, particularly in the area of transportation fuels (e.g., CTL). Cooperation with the United States on CCS will be essential to the sustainable pursuit of this alternative.

The United States is in many ways the mirror image of this situation. It, too, has other options: the possibility, for example, of an alternative transportation system based on CNG, supplementing biofuels in relieving our dependence upon foreign oil supplies. CTL, as we have seen, runs a poor third to both CNG and biofuels as a source of transportation fuel. It is hard to avoid the conclusion that for sources of electric power, the United States, like China, will continue to be dependent for many years on coal.

The option of clean coal, however, is unsustainable in the absence of a large-scale transition to a system of coal gasification-based polygeneration of electric power and the conservation and utilization of its byproducts. Like the U.S.'s emerging experiment with CCS, China's experience in these areas is a work in progress that can save the United States many years and dollars in mistakes. Interestingly, this also presents an opportunity in the area of information access for the United States to effectively steal a leaf from China's book, just as China has done so often in the past with the United States. And, in a sense, China needs for this to happen as much as the United States does. It needs to be able to demonstrate that the United States, too, stands to benefit from the process of technology transfer as China has long proclaimed through its principle of cooperation based on "mutual benefits."

Given the benefits that a clean coal strategy would entail for both China and the United States, the following recommendations are made to policymakers in each country to lay the groundwork for such a transition:

For the Chinese government

- Establish a coherent national energy strategy based on clean coal and a radically improved energy infrastructure to promote coordinated distribution of electric power supplies across all regions.
- Rationalize energy pricing to provide incentives for increased investment in clean coal solutions, more efficient processing, and energy conservation.

For the U.S. government

- Support significant research and development into clean coal technologies.
- Pursue in particular coal gasification technology, including expert surveys, feasibility studies, and demonstration projects to characterize and develop storage sites for carbon capture and storage (CSS).
- Ensure CCS facilities are installed in all coal gasification plants and a pipelines infrastructure is in place to support the CCS initiative.

As pointed out by John F. Turner, former Assistant Secretary of State for Global Environmental Affairs and now a director of Peabody Energy, however, the effectiveness of these measures also hinges on the "ingenuity, creativity, and resources of the private sector" on both sides of the Pacific. Even in advance of governments on both sides taking the necessary steps to reduce uncertainties and to assure that energy prices fully reflect environmental costs, the private sector needs to anticipate and, wherever possible, to precipitate these moves. This means:

For the private sector

- *Chinese enterprises:* anticipate public policy reforms by adopting proactive business strategies, including innovation in clean coal technologies through increased investment for R&D.
- *U.S. electric utilities:* anticipate public policy reforms by adopting proactive business strategies, including asset diversification through increased investment in coal gasification-based generation and carbon capture facilities.

- *U.S. and Chinese enterprises:* create increased incentives for joint ventures in clean coal technology development through market sharing agreements in China.

The key to a U.S.-China strategy for energy security based on clean coal is the recognition of mutual vulnerabilities. Each needs to recognize areas of vulnerability in the other—CCS for China, coal gasification-based polygeneration technologies for the United States—that its own comparative advantages can help overcome. Each needs to be sufficiently open to the other to be willing to channel its own strengths into this effort in the interests of both mutual security and the future of the planet. To this end, each also needs to be prepared to relax its guard over trade secrets and to compensate those disadvantaged by their loss of control over information. Only then, perhaps, can both emerge from the lengthening shadows of a competition for world energy supplies into a new dawn of confidence building, technology sharing, and energy saving based on clean coal. Thus, the following recommendations are made to promote cooperation on clean coal technology:

- Utilize Chinese expertise in coal gasification to promote 'polygeneration' processes from coal.
- Accelerate the trial-and-error process of CCS site preparation and development in the United States and engage Chinese government, industry, and research partners in applying the results of this process.
- Establish an agreed framework for intellectual property rights compensation to offset commercial losses from technological exchange and facilitate cooperation.

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