JACKSON HOLE CENTER FOR GLOBAL AFFAIRS

U.S. Clean Energy Cooperation with China: A Test Case for "Thinking Locally and Acting Globally"

Final Report of the U.S.-China Clean Energy Initiative

Executive Summary

The environmental consequences of China's growing energy needs illustrate the realities of today's world, where pollution knows no borders. In this world, local efforts to control emissions of carbon dioxide and other greenhouse gases no longer represent an adequate or cost-effective response to threats of global pollution, which can now originate from many sources. In other words, "thinking globally" while "acting locally" may no longer be enough to forestall threats of global climate change.

Under these circumstances, a new strategy of "thinking locally" while "acting globally" calls for global partnerships to address distant sources of threats to local environments. But China is also the world's largest consumer of coal. Fittingly, therefore, in working with China to address the environmental consequences of its inevitable continued reliance upon this oldest of industrial fuel sources, the U.S. will need, as well, to revisit that most local of strategies: i.e., recycling, specifically of waste energy sources and products.

This need in China's case to attend to the special requirements of coal through the recycling of waste energy from coal production and use relates to four areas: waste coal use, coalmine methane recovery and utilization, and more efficient use of coal byproducts, including town gas from coke production and heat from power generation. New advances in coal separation and circulating fluidized bed (CFB) boiler technologies now enable large-scale utilization of waste coal that otherwise constitutes a growing source of fugitive dust emissions.

Likewise, recovery and utilization of methane needing to be vented, for safety reasons, from coal mines provides a clean source of energy that would otherwise constitute a potent greenhouse gas when simply released into the atmosphere. Other needs for improved utilization of waste energy from coal include use of waste products from coal processing to supply heat to urban homes. Opportunities in this area include waste gas from coke production, available as a fuel source for residential furnaces, and waste heat from power generation, available for distribution through district heating systems.

Implementation of these strategies will require policy reforms by China and technical assistance by other countries, including the U.S. China has already made great strides in these areas, as demonstrated, for example, by

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its success in achieving an average reduction in intensity of energy use of 4% per year over the past 25 years. But further progress will require increased refinement of policy tools in such areas as emissions trading and other market-based approaches to environmental management.

It is here that the U.S. may have the greatest lessons to share in terms of its own policy experience. By gradually building and improving upon this experience (as China has already done in the area of automotive fuel economy standards), China should be able to continue compressing into a very few years the equivalent of decades of environmental progress in the U.S. That investment in environmental cooperation is good for China, good for the U.S., and good for the world.

Many of the "lessons learned" by the U.S. in implementing market-based approaches to environmental management over the past several decades are also relevant to challenges of clean energy development in China. One of these is the importance of getting the prices right. In order to encourage better utilization of waste coalmine methane and waste heat from coke production and power generation, for example, it will be important to price these resources at sufficiently high levels to assure adequate incentives for investment, while also assuring their continued affordability to consumers. Another lesson, deriving from U.S. experience in establishing a trading system for sulfur dioxide emissions credits, involves the need for strict "caps" or standards as a means to drive the market for the sale and purchase of such credits.

A final lesson – still very much a work in progress in the U.S. – is the need for large-scale public and private investment in advanced technologies to solve energy and environmental problems. Well-targeted, up-front investments in such areas as fuel cell vehicles and other flexible fuel vehicles (FFV), including compressed natural gas (CNG) and possibly methanol, can go along way in assuring China's future energy security as well as economic competitiveness in these areas. China will need to overcome its own impediments to investment – including inadequate protection of intellectual property rights – to assure adequate long-term incentives for foreign partners with needed technologies to join in these investments.

Coal gasification presents special opportunities for China to gain diverse capabilities in clean energy production and utilization, through a process called polygeneration. The end-products of this process include not only electric power and town gas for heating, but also other fuel sources, such as di-methyl ether (DME), a potential substitute for liquid petroleum gas (LPG) in rural areas, and methanol, as well as chemical feedstocks including ammonia and acetate. Most importantly, coal gasification-based polygeneration provides a basis for the production of hydrogen and the capture of carbon dioxide, two essential pillars of the emission-free fossil fuel systems of the future.

The latter capability in turn provides a basis for the sequestration of carbon dioxide in geologic sinks. Other, near-term options for carbon sequestration – not dependent upon carbon capture -- include land management technologies and practices which enable the enhanced storage of carbon in soils. These so-called "terrestrial sequestration" options lend themselves readily to immediate U.S.-China clean energy cooperation. The combination of these near-term and long-term technologies offer an exciting agenda for U.S.-China cooperation in research and development of clean energy technologies, beyond the options for waste utilization already discussed.

For all these reasons, U.S. involvement in addressing the environmental consequences of energy production and use in China will continue to be a global environmental imperative in the years to come. The value of such involvement is five-fold. First, it shows how it is possible to address the local impacts of some significant global environmental conditions that would otherwise be outside our control. Second, it indicates the relevance in addressing new global environmental problems of older, more local environmental solutions, such as the recycling of waste energy from coal production and use.

Third, by providing a means of applying the lessons of U.S. policy experience to challenges of clean energy development and use in China, it can help to compress decades of trial and error in the U.S. into a relatively few short years, thereby enabling the U.S. to achieve significant global environmental benefits at relatively little cost. Fourth, it provides both countries with a roadmap to addressing future challenges in energy and environmental management, thereby enhancing benefits and easing insecurities on both sides. Finally, U.S.-China cooperation on issues of common interest involving the planet can help lay a foundation for deeper cooperation in other areas, where otherwise competing interests could pose even greater threats to mutual stability.

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I. Introduction

Recycling and reuse of commodities was a concept that emerged in the 1970s, an era that witnessed the birth of a significant environmental movement in the U.S. "Think globally, act locally," the slogan that inspired this movement, expressed the straight-forward logic embodied by this concept. According to this early logic, in order to fulfill our global environmental responsibilities, it was necessary for each of us to take some small piece of the action, corresponding to our own backyards.

Now, however, our thinking on the global environment has changed. We now know, for example, that greenhouse gases and other emissions know no boundaries. With this realization has come a growing awareness that threats to local environmental conditions can arise from outside our localities. At the same time, we have become increasingly aware that our response to these threats must be coordinated with the responses of others, so that the corrective actions of one community will not be negated by the lack of response of others. In other words, better than "thinking globally and acting locally" is the opposite approach: "thinking locally" to recognize the impact of global environmental conditions on our localities, and "acting globally" to address these conditions at their sources.

It is in the spirit of this approach that the Jackson Hole Center for Global Affairs has convened over the past year a group of policymakers and technical experts from the U.S. and China to examine the shared challenges faced by the U.S. and China in energy development and use. The findings and recommendations that follow constitute the principal conclusions emerging from those discussions.

China's current reliance on coal for over sixty percent of its total energy supplies places it at the forefront of the world's consumers of this most carbon-intensive of fossil-fuel sources. At China's current rates of economic development and coal consumption, the country stands under any set of circumstances to overtake the U.S. as the leading emitter of carbon dioxide during the next ten to fifteen years. U.S. cooperation with China in addressing this challenge has therefore become a global imperative.

The response to this challenge must take many forms, including development of alternative energy sources. The most important immediate concern, however, is the more efficient use of existing sources. In the case of coal, the latter approach involves not only the more efficient combustion of coal, but also a variety of other strategies for utilizing coal more effectively. As a response to new imperatives of global activism, the effort to assist China in finding new uses for this oldest of industrial fuel sources will, ironically, compel the U.S. to take a new look at that most local of environmental solutions: i.e., recycling, specifically of waste energy from coal production and use.

II. Opportunities and needs for clean energy technologies and strategies in China's Shanxi Province

Like Wyoming in the U.S., China's Shanxi province is the leading locality in its country for the production of coal and coal byproducts, including coke for steelmaking. Shanxi's 450 million tons of annual coal production represents a third of China's total. Its 60-70 million tons of coke account for two-fifths of China's entire annual output, as well as four-fifths of China's and half of the entire world's total volume of coke exports. The environmental consequences of this preeminence in coal and coke production include one billion tons of accumulated waste coal, which is contaminating groundwater supplies, generating fugitive dust emissions, and posing risks of spontaneous combustion. Other emissions resulting from coal production and use in Shanxi province include somewhere between one and five billion cubic meters per year (provincial government estimates vary) of methane and waste gas from coking operations, consisting of hydrogen, carbon monoxide, and hydrogen sulfide. Clearly, Shanxi is emblematic of the environmental consequences which stem from China's overall reliance upon coal.

<u>Waste coal utilization</u>. In earlier years, low-grade coal was rejected for use as stoker in standard boilers or for use in conventional (pulverized coal-fired) power plants because of its lower thermal value. However, now modern technologies make it possible to separate the coal from clay, rock, tramp iron, and other residual ingredients and to significantly reduce its sulfur content. On the basis of these new coal "washing" or preparation technologies, it is possible to burn the coal in new circulating fluidized bed (CFB) boilers which can operate at a much higher level of efficiency, thereby producing a comparable level of thermal output to that previously available only on the basis of higher-grade coal.

The low cost of utilizing the already-mined fuel compared to the cost of mining higher-grade coal makes this method of power generation economically feasible, despite its relatively higher capital and preparation costs. The residue from cleaning the waste coal is also available as a feedstock for the manufacture of lightweight building materials. Recently, Shanxi province has placed significant emphasis on the development of new projects in both areas, including the purchase of two new 50 MW CFB power generating units from a Japanese company. The province plans to expand its investment in CFB technology to include development of a 300 MW waste coal power plant.

<u>Coalmine methane</u>. Like waste coal, coalmine methane is a potential energy source which, unutilized, is also a source of environmental pollution. Methane is a highly combustible gas that accumulates within coal seams, and is discharged from the seams in order for them to be mined. But it is also a greenhouse gas with twenty three times the heat-trapping capacity of CO_2 when released into the atmosphere.

The coal mines of Shanxi province are rich in their concentrations of this dense and dangerous gas. Each year, hundreds of millions of cubic meters of methane is vented from coal mines in Shanxi – probably as much as from the rest of China combined, and very nearly as much as total coalmine methane emissions from the next leading emitter altogether, the United States. Yet, if this most potent of greenhouse gases were to be recovered, it could be used as an exceptionally clean-burning fuel source.

At present, this is not occurring, for a variety of reasons. One reason is the difficulty of transportation. In the Yuanquan coal mine, located 150 km east of Taiyuan, there is no way to transport the methane vented from the mine beyond the immediate locality where it is used for home heating. At one time, mine officials considered using the methane as an additional fuel for power generation, only to abandon these plans for another idea involving conversion of the methane to methanol for use in vehicles. They have now returned to the idea of installing a natural gas-fired power generator. In another mine operated by the U.S. firm Asian American Coal, there are plans to use methane vented from the mine to operate a cogeneration facility to supply heat to the mine as well as power to run the ventilation equipment. For now, however, the methane is simply released from the mine into the atmosphere.

From a climate change perspective, coalmine methane recovery and utilization is perhaps the most readily-available of the clean energy options relating to coal production and use in Shanxi province. Methane recovery and utilization is also an issue of increasing interest to the U.S. government, as indicated by the recent launching of the "Methane-to-Markets" initiative, a partnership with 15 countries including China. Given the seriousness of the U.S. and Chinese commitment to address this issue and the volume and accessibility of coalmine methane resources in Shanxi, there is no reason why the very first project out of the starting blocks in the Methane-to-Markets Partnership should not be a joint U.S.-China coalmine methane extraction project in Shanxi province.

Utilization of coking gas. Another highly polluting feature of Shanxi's coal industry involves the production of coke, used in steelmaking. This process involves not just the combustion but also the gasification of coal, resulting in the production as byproducts of methane, carbon monoxide, hydrogen, hydrogen sulfide, and other gases. Almost two thirds of these gases are currently being captured and recombined and/or recycled as fuel for the coking furnaces or used for other purposes, such as heating city homes. But the remaining one third is simply burned as an exhaust gas. Other consequences of coke production in Shanxi, in addition to the waste of these potentially useful resources, include the emission of particulates and benzopyrene and the effect of another byproduct, ammonia nitrogen, in contaminating surface water supplies.

Progress in limiting these emissions and utilizing these wastes will require a shift in production methods from smaller, less efficient, more polluting units to larger, more efficient enterprises. Provincial officials can in fact point toward significant gains in pursuing this priority in recent years, largely as a result of a new rule requiring larger land holdings for production facilities. Provincial officials have also capped overall coke production in the province at eighty million tons per year, with the result that smaller, less efficient units have been forced out of production as newer, more efficient facilities have come on line.

The expansion of one plant financed by the Asian Development Bank, for example, will add to the plant's current capacity of 600,000 tons coke and 350,000 cubic meters of coking gas another 1 million tons capacity for coke production and 500,000 cubic meters of coking gas. Indicative of the change in production methods is the fact that six tons per day of particulates will now be recycled as fuel for the plant instead of being emitted. While this is a trivial amount from a production standpoint, it represents a significant reduction in air pollution.

This consolidation of the coke making industry is part of the "low-hanging fruit" that is available to economic planners in Shanxi province in encouraging the shift to less polluting, less wasteful methods of production. Other, more distant, goals include promotion of efforts to develop flexible fuel vehicles (FFV) capable of utilizing methanol from coking gas. The realization of this prospect will require large-scale research, development, and investment in cooperation with industry. Significantly, the province is already making progress in this direction through a collaboration with Ford Motor Company.

Cogeneration. Another emerging success story in Shanxi's efforts to put clean energy policies and technologies into place involves the promotion of thermal power plants as a source of heat as well as power throughout the province. As in the case of coking gas utilization, recycling of byproducts plays a key role in this emerging strategy for more efficient energy conservation. In this case, steam generated and used by thermal power plants to drive turbines is also distributed on a centralized basis to urban homes and factories, replacing thousands of smaller, less efficient, and more polluting coal-fired boilers, each with its own smokestack or chimney.

Currently, these efforts are concentrated mainly in Taiyuan, Shanxi's capital. Overall, the province utilizes roughly a fourth of the power it generates for this dual purpose of so-called "cogeneration." By the province's own estimates, this is a percentage which is still well below that of most industrialized countries. The province plans to replicate the success of Taiyuan's experience with cogeneration in other large and mid-sized cities throughout the province, and to place increasing emphasis upon the construction and/or retrofitting of thermal power plans utilizing the more energy-efficient CFB technology as a basis for enhanced cogeneration of heat and power.

III. Barriers to clean energy development and use in China and "lessons learned" in the U.S.

Implementation of many of the strategies and technologies for clean energy production and use just described will require reforms at many levels. It is not surprising that China is at a relatively early stage in the implementation of these reforms. Indeed, what is surprising is that compared with other countries at similar stages in the history of their industrialization, China has come so far so fast. Fifteen years ago, it was not uncommon to encounter views among policymakers, commentators, and analysts in

China equating increased pollution with success in achieving progress toward industrialization. Since that time, there has been a complete turnabout in public and official attitudes.

China's experience has been, if anything, to telescope decades of progress in pollution abatement into a few short years, by seeking means of "leapfrogging" technologies and priorities embraced at similar periods in their history by Western countries. At the same time, by taking advantage of opportunities typically available to developing countries to achieve savings in resource use at much lower cost than those available to developed countries, China has reduced the intensity of its energy use by an average of 4% per year over the past 25 years. During this same period, by contrast, reductions in intensity of energy use in the U.S. have fluctuated from .7% to 1.2% per year, depending upon energy prices.

Yet it is clear that China still has a long way to go. New market-based approaches to energy and environmental policy, for example, are currently at a very early stage of implementation. Only very crude tools are currently available for the allocation, measurement, and monitoring of emissions.

What is not in doubt is China's commitment to tackle these problems. China's leaders and people are clearly resolved upon a path of increasing prosperity while mitigating the adverse environmental trends associated with this prosperity. At the same time, leaders of the province have consistently expressed a need for help from the U.S. and others in the international community in addressing these problems. For the U.S., cooperation with China in the mitigation of some of these adverse trends offers the prospect of helping to achieve significant global environmental benefits at relatively little cost – i.e., of "thinking locally" while "acting globally." It is this shared interest in sustainable energy development and use in China which gives rise to prospects for mutually beneficial U.S.-China cooperation in this area.

Given China's relatively early stage in the process of economic and policy reform, one of the areas where this cooperation can make the greatest difference concerns the sharing of policy experience. Increased grasp of U.S. policy experience in these areas is needed by policymakers and decision-makers in Shanxi province and elsewhere in China because the U.S. has taken major steps toward substituting more effective policies for the "command and control" approach to environmental management where appropriate. The U.S. therefore has some "lessons learned" to offer from this experience.

<u>Pricing structure</u>. The first of these "lessons learned" – and one that we are still learning in the U.S. – is the importance of getting the prices right. Economics plays a crucial role in determining the signals that lead to the adoption of one approach over another. For example, the reason that power generation from waste coal has a future in Shanxi province and elsewhere is that waste coal is less expensive than standard-grade coal. On the other hand, to develop a similar market for the recycling into productive use of methane vented from coal mines, it will be necessary to price this resource, too, at a level that will make it worthwhile for producers to capture and sell it.

The same is true for cogeneration and the distribution of coking gas to city homes. Currently, in order to make heating from these sources affordable to urban residents, it is necessary to price it at levels at which it is subsidized from the power generation or coke production side of the operations. This provides incentives for consumers to substitute central heating for more polluting and wasteful stand-alone furnaces, but it removes incentives for producers to allocate additional resources to these energy-saving technologies. Experience in the United States has shown that to create a market for environmental goods and services, these products must be priced at levels that will allow profitable investment. As with other market-based approaches to environmental problems, these competing pricing pressures can only be resolved on the basis of careful, case-by-case analysis of the issues.

Regulatory framework. Experience in the U.S. has also demonstrated the importance of environmental standards and regulations in driving the demand for environmental goods and services. This is most clearly evident in the area of rights in pollution trading. This is an approach to environmental management that holds great promise for China's progress in limiting emissions of sulfur dioxide, as well as potentially for global progress in limiting carbon dioxide emissions.

Like several cities in China, Taiyuan and other cities in Shanxi province have already begun experimenting with "trades" of sulfur dioxide emissions credits among selected large-scale industrial enterprises. This innovative approach to least-cost emissions reductions, first incorporated in the 1990 revision of the Clean Air Act in the U.S., involves first setting overall "caps" or limits for sulfur dioxide emissions within a geographical area or region, and allocating those limits in terms of allowable "permits" or quotas for emissions for each industrial enterprise within that region. It then leaves it to those individual enterprises to determine how those overall targets will be met by "trading" their allowable quotas according to which ones are able to reduce their emissions at least cost. It does this by allowing those who are able to cut their emissions below their quotas (at relatively low cost) to sell the extra credits to others who would otherwise be unable to stay within their allowable quotas (except at relatively high cost).

Despite a promising start on this system, involving a few trades among selected enterprises, Taiyuan and other cities in Shanxi province still have a long way to go. The main issue is the government's capacity to establish, measure, monitor, and enforce mandatory limits. As demonstrated also by the United States' experience in establishing a system of voluntary trading in carbon dioxide emissions, a strictly voluntary system lacks the impetus to drive the market. Market-based tools and methods of economic analysis are keys to the future of this system for controlling sulfur and other emissions in Shanxi province, but political will remains the real test of the province's success in instituting such a system.

R&D Infrastructure. While these "lessons learned" from U.S. policy experience are critical for China in addressing its energy/environmental challenges, technology will remain an indispensable part of the solution. Here it is evident from discussions with enterprise managers in Shanxi and provincial and central government policymakers that China is not only pursuing its own R & D for advances particularly suited to China's situation, but is also open to bringing technological advances elsewhere to bear on its problems.

Like China's growing reliance upon foreign oil supplies to feed its growing appetite for cars, this reliance on foreign technology is at once a vulnerability and an indication of the growing expectations of the Chinese people for higher living standards and quality of life. Foreign companies will of course seek to safeguard their intellectual property rights in negotiating licensing arrangements for their technologies with China. The lack of clear and consistent protections for these rights constitutes one barrier to the transfer of these technologies. The fact that many enterprises in China do not even have their own R&D divisions constitutes another. It means that research organizations in the U.S. and other countries have no real partners with whom to engage in exploring opportunities for joint R&D ventures with these enterprises.

The formation of such R&D partnerships will be critical for China in seizing the opportunities presented by technology to solve its energy/environmental problems. China's abundant coal reserves offer the prospect of widespread production and utilization of transportation fuels based on coal gasification, including methanol and hydrogen for use in fuel cells. The availability of these fuel sources in turn suggests the feasibility of large-scale mobilization and deployment of automotive technologies enabling their utilization. Investment in these technologies could help to establish China as a leader in the automotive industry of the future, while helping to enhance the energy security of China's own transportation system. But the development of these alternative fuel vehicles will require a massive R&D effort, comparable in scale to the Manned Moon Mission in the U.S. A successful response to this challenge will require the collaboration of many foreign and Chinese partners, including enterprises and universities as well as government agencies on both sides.

The municipality/province of Chongqing provides an instructive model in organizing such an R&D consortium. Chongqing has developed an entire automotive industry centered around a fleet of vehicles powered by compressed natural gas (CNG). The consortium includes pipelines, compressors, and fueling stations, as well as the vehicles themselves. Chongqing, however, is unique among major Chinese cities in the access it enjoys to this valuable, clean-burning fuel source. Other municipalities and provinces will have to focus their scarce R&D resources on other priorities, including hybrid and other alternative fuel vehicles and, of course, public transportation systems. Nevertheless, Chongqing has clearly shown the way. If other large concentrations of population in China can emulate Chongqing's example of focused R&D efforts, China will be launched on the path of conquering its twin challenges of energy security and preeminence in R&D.

IV. Long-term challenges in China's energy and environmental future

These policy and technical challenges are also the first steps in addressing some of the longer-term challenges to China's energy and environmental future. Since China's dependency on coal is likely, under any scenario, to remain over fifty percent until the year 2050, that future must involve new ways of utilizing coal as a clean energy resource.

One technology that holds great promise in this regard is the approach of "polygeneration," based on coal gasification.

Polygeneration goes beyond the conventional approach of cogeneration to include other byproducts in addition to heat from the processing of coal. These byproducts are made possible through the process of coal gasification, resulting in a "syngas" consisting largely of carbon monoxide and hydrogen, which can then be separated and further processed. Additional byproducts include town gas (already mentioned in connection with gasification processes used to produce coke) di-methyl ether suitable for use as a fuel in rural areas, liquid fuel products (e.g., methanol for vehicles), various forms of feedstock for fertilizer production (e.g., ammonia), and, most importantly, hydrogen as a source for fuel cells. Not the least of the other advantages provided by this forward-looking technology is the capacity it provides to "capture" and "sequester" carbon dioxide, for purposes of control of this primary greenhouse gas source.

The superiority of this technology lies in its greater efficiency over other technologies as a means of generating power from coal (45-55% conversion efficiency, compared to maximum 45% efficiencies for superpulverized supercritical boilers and 40% efficiencies for circulating fluidized bed boilers), and in total system efficiencies (including waste to energy ratios) of 80%. For a country as dependent as China on coal reserves for the bulk of its energy supplies for the foreseeable future, this combination of advantages is ideal. Shanxi province, which has invited investment in a 150 MW gasification/polygeneration in the northern industrial city of Datong, is already betting on this promising technology of the future. It makes sense for the province to exploit the technological potential of its comparative advantage in coal by proceeding in this way, just as it has made sense for Chongqing to capitalize on its comparative advantage in access to natural gas through development of a CNG-based automotive industry.

The other advantage of polygeneration, as mentioned, lies in its potential for the capture and sequestration of carbon. To the extent carbon emissions cannot be further reduced on the basis of initial investments in energy efficiency and renewable energy, these emissions can be captured and stored in geologic reservoirs or, more simply, in plant matter and soils. Particularly in the latter case, U.S.-China cooperation can significantly advance prospects for this greenhouse gas mitigation strategy. China's vast soil resources offer abundant reservoirs for carbon storage through afforestation and other improved crop and land management practices. These are priorities that China would need to pursue irrespective of climate change, for reasons of flood control. The U.S. has a 135 year history of government involvement in promoting increased crop yields and soil and water conservation through state agricultural extension and research services. These issues for the U.S. are not rocket science. Their pursuit should present an easy win for U.S.-China cooperation on the global environment.

V. Conclusion

How, then, does U.S. clean energy cooperation with China illustrate the value of "thinking locally and acting globally" in the 21st century? It does so, first, by calling attention to the inexorable impact in the United States and elsewhere of continued global emissions of greenhouse gases, including carbon dioxide, of which China will be the leading emitter within the next 10-15 years. The continued accumulation of these gases within the atmosphere will have consequences for the climate of every locality throughout the world.

Second, U.S.-China cooperation on clean energy illustrates the importance of this approach by showing how it can give new meaning to older approaches, such as recycling. Far from being confined to a limited approach of resource conservation within communities, as we have seen, the concept of recycling now has applications which extend all the way to China. “Recycling” in this broad sense can include finding new ways to utilize waste coal and the methane that must be vented, in any case, for safety reasons from coal mines. It can also include developing improved means to tap the syngas produced through coke manufacturing and the heat produced through power generation for urban heating. All these new approaches to an old concept hold great promise for China’s near term progress in limiting the emissions of sulfur dioxide, carbon dioxide, and other pollutants resulting from the dependence of its growing economy on coal.

Third, “thinking locally and acting globally” as an approach to global energy and environmental management illustrates the relevance of applying U.S. policy experience to other countries’ problems. After over thirty years of experience with clean air legislation, energy deregulation, and other approaches to energy/environmental management, the U.S. has now accumulated a storehouse of policy experience that is a potential resource for China as well in responding to its energy and environmental challenges. Lessons learned – both positive and negative – from U.S. efforts to develop approaches to energy pricing policy, sulfur dioxide emissions trading, and investment in new energy/environmental technologies are all directly relevant to China’s efforts to find ways to cope with the environmental consequences of its rapid industrialization.

Fourth, an approach of “thinking locally and acting globally” can help China to seize new opportunities to build the energy/environmental infrastructure of the future. Investments in public transportation, alternative fuel vehicles, polygeneration based on coal gasification, and carbon sequestration can all help position China to deal with energy/environmental pressures of the future. These pressures will create new threats to global stability and security. It is directly in the interest of the U.S. to see China make progress in its efforts to attain energy security, and to test out new approaches (e.g., carbon sequestration) for dealing with the emissions that will inevitably remain from even best-case emissions reductions scenarios.

Finally, U.S. cooperation with China in developing cleaner sources and uses of energy is another step in building a common global future. Under the best of circumstances, China and the U.S. will continue to have many differences as their two societies and economies develop in the 21st century. Cooperation in preserving the planet we all share can help build trust between these two great countries. This can in turn enhance prospects for cooperation in other areas, where our common interests may be less obvious or more elusive, and where threats to our security and prosperity may be even more immediate and direct than those posed by climate change.

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