Foreword

Aaron Frank, Editor

Over the past year and a half, environmental issues have emerged as a central component of strengthened relations between the United States and the People's Republic of China. From the creation of the U.S.-China Forum on Environment and Development in March 1997, to the signing of the Energy and Environment Cooperation Initiative during the October 1997 Presidential Summit, to President Clinton's recent speech on the environment in Guilin, China, environmental issues have continued to be a bridge between the two countries while other items of engagement have produced difficulties. In a June 19, 1998 press briefing, Stanley O. Roth, U.S. Assistant Secretary for East Asian and Pacific Affairs, noted that environmental and energy issues have provided "an example of one of the most dramatic shifts in Chinese policy" over the past decade. Indeed, opportunities for change in China's management of its environmental problems are promising; recent governmental restructuring, a push to reform the industrial sector, and the current Chinese leadership have created a climate within which environmental concerns can be incorporated into larger structural and economic reforms. Chinese decision making in the upcoming year will therefore be critical in determining China's future energy, environmental, and overall development strategies, and the role that environmental issues will play in future bilateral relations.

The articles in this second issue of the *China Environment Series* cover three critical aspects of the burgeoning environmental partnership between the United States and China: energy, water, and increased public awareness of environmental issues. The *Series* opens with an article by Robert S. Price, Jr. of the Department of Energy, which traces the history of U.S.-PRC cooperation on energy issues, providing a historical context for future activities in this area. In the second part of a two-part series on the role of nuclear power in China, Jeffrey Logan of Pacific Northwest National Laboratories and Jiqiang Zhang of the W. Alton Jones Foundation argue that natural gas and renewable energy technologies will not only be more economically sound than nuclear power for energy growth in China's southeastern provinces, but that the development of alternative energy technologies will also provide future export opportunities for the Chinese. Baruch Boxer of Rutgers University and Resources for the Future describes the role that water quality and quantity—the environmental issues of utmost concern to the Chinese—play in U.S.-PRC relations, and suggests areas for continued U.S.-PRC cooperation on water issues. Crescencia Maurer and Changhua Wu of the World Resources Institute, Yi Wang of the Chinese Academy of Sciences, and Shouzheng Xue of Shanghai Medical University examine perhaps the most important connection associated with China's water problems: the impact of water quality and quantity on the health of Chinese citizens. In an article on the role of the Chinese media in raising environmental awareness in China, Wen Bo of *China Environment News* describes the media's success in promoting public and governmental action on environmental issues.

This issue of the Series also features summaries of Working Group on Environment in U.S.-China Relations meetings, a listing of conferences on environmental issues in China, an updated inventory of government and nongovernmental work on the environment in China, and an updated bibliographic guide to the relevant literature. Combined versions of the inventory and bibliography from issues 1 and 2, and the full text of both issues of the *Series*, can be found on the Environmental Change and Security Project web site at http://ecsp.si.edu. I encourage you to register for a username on our web site so that you can participate in our on-line discussion group. Please take the opportunity to use this on-line forum to post comments or questions about the articles or summaries which appear in the *Series*.

Lastly, I would like to thank our funders, the National Oceanic and Atmospheric Administration, the Summit Foundation, and the W. Alton Jones Foundation for their generous support. I would also like to thank Working Group co-chairs Elizabeth Economy and P.J. Simmons, Environmental Change and Security Project director Geoffrey Dabelko, Working Group members, and the Wilson Center's Asia Program, whose assistance, guidance, and contributions have been central to Working Group activities and the publication of this *Series*. I hope you find this issue useful, and we look forward to receiving your comments and suggestions.

Contents

A History of Sino-American Energy Cooperation

by Robert S. Price, Jr.

Over the past twenty years, cooperation on energy issues between the People's Republic of China and the United States has remained a constant source of success and accomplishment. Beginning with only a handful of agreements, bilateral cooperation on energy issues has blossomed in recent years, expanding to include twenty-six active agreements. The genesis of these agreements has generally followed the same pattern: informal cooperation between scientists at respected agencies has led to more formal agreements signed during high-level government delegations in both Washington and Beijing. Another trend to emerge from expanding cooperation on energy issues is the increasing connection between energy and the environment in Department of Energy agreements with a variety of Chinese agencies. Culminating in the Energy and Environment Initiative signed at the October 1997 Presidential Summit, the focus of cooperation has shifted from assistance on coal utilization to clean energy production and efficiency.

This article traces the evolution of cooperation on energy issues between the United States Department of Energy (DoE) and institutions of the People's Republic of China. Documenting the activities of the two countries for two decades, the article identifies the key parties on both sides, the successes and setbacks encountered, and lessons for how the United States and China can strengthen their relationship on energy issues as it enters a third decade.

The Department of Energy, created in 1977 as an amalgamation of several agencies, inherited a number of diverse missions: energy security, national security and nonproliferation, basic scientific research, and environmental protection. In connection with these missions and in working with the Department of Commerce, DoE has also worked to expand export markets for U.S. energy, and energy-related goods, services, and technology. The diversity of the department's mission is reflected in its statutory responsibilities[1] to establish and implement international energy policies, and to advise the president on international negotiations involving energy resources, energy technologies, and nuclear weapons issues.

DoE has integrated these missions into its cooperation with China, which can be divided into three distinct phases. A broadening of cooperation characterized the first decade (1978-1987) of Sino-American relations on energy issues. During the second phase (1988-1991), work progressed under agreements already signed, but no new agreements were concluded. Although cooperation was curtailed following the June 1989 Tiananmen Square incident, during the last phase (1992-1997), cooperation was again broadened and deepened.

While bilateral agreements define formal cooperation, scientific and technical cooperation often emerges from the interaction of individuals at international conferences. Scientists pursuing similar research may informally exchange information. If this exchange is beneficial, informal relationships between the scientists' sponsoring institutions may develop. If this institutional relationship proves advantageous, the institutions may formalize the relationship or may elevate cooperation to the governmental level. Finally, if the cooperative activity conforms with the priority goals of both governments, a formal governmental agreement might follow. High-level visits in either direction tend to be forcing events that concentrate on the signing of agreements or other forms of commitments, but usually after a long gestation period at the technical level.

Phase One: 1978-1987

A year after becoming the first U.S. secretary of energy, James R. Schlesinger traveled to China in October 1978. Schlesinger took with him a 16-person technical team of experts including representatives from the DoE, Bonneville Power Authority, Tennessee Valley Authority (TVA), the U.S. Army Corps of Engineers, the U.S. Geological Survey, and the Department of the Interior. This team reached agreements with their Chinese counterparts on a broad agenda of possible cooperation.

The bilateral agenda included modernization and expansion of China's coal production; assistance in the planning, design, and construction of hydroelectric power in China; technical and information exchanges on renewable energy sources, including solar, biomass, geothermal, and ocean energy; and joint programs in high energy physics, nuclear physics, and magnetic fusion.

Interestingly, the U.S. team did not include energy efficiency experts, nor was the environment raised as an issue. Reflecting its composition, the U.S. contingent focused on energy supply options. The Chinese expressed interest in clean coal technology, but appeared to lose interest when they discovered that the clean coal technologies discussed were costly.[2]

While the U.S. government had the resources to undertake many of the actions in this bilateral agenda, the scope and nature of additional actions would require the participation of the U.S. private sector.[3] Thus, the need for both the U.S. public and private sectors to cooperatively engage China was apparent from the very beginning of DoE's activities.

At the conclusion of his trip, Schlesinger noted, "We have common objectives in assuring that the economic performance of the industrial world and that of the developing countries will not be impeded by prospective energy shortages."[4] Schlesinger's own priority in discussions with senior Chinese officials was opening China to oil and gas exploration and production by U.S. companies. The most pressing concern of the Chinese was when U.S. firms would be able to sell nuclear power plants to China.[5]

Since normalization of U.S.-Chinese relations had not yet occurred, no official documents were signed during Schlesinger's visit. However, intensive discussions on energy issues between the two countries were underway at the time. Some weeks after Schlesinger's return, diplomatic relations were established and in January 1979, Chinese vice premier Deng Xiaoping visited the United States. During his visit, Deng and President Jimmy Carter signed an umbrella "Agreement on Cooperation in Science and Technology." At the White House ceremony welcoming Deng, Schlesinger signed the first implementing accord under this umbrella agreement: a five-year agreement for cooperation between DoE and China's State Science and Technology Commission (SSTC) in high energy physics.

In March 1980, TVA chairman S. David Freeman signed an annex to the bilateral protocol on hydropower development that provided for exchanges of visits organized around Chinese-American river pairs. These pairs included: (1) multipurpose development of the Hongshui River, including the Datengxia and Longtan hydropower projects, and the Columbia River and surrounding area; (2) the Three Gorges Project and multipurpose use of the Tennessee and Colorado Rivers, and operational control of river systems and hydroelectric power stations in the Cascades; and (3) regulation problems, including sedimentation, of the estuary of the Changjiang River and the Mississippi and similar U.S. estuaries. In addition, the annex established cooperative study of design alternatives, including navigation feasibility, for the Ertan hydroelectric power project.

As a follow-up to Schlesinger's trip, DoE gave China background information and proposed specific areas for potential fossil energy cooperation in July 1981. DoE received no official response, but various Chinese officials made queries about the subject over a number of years. Consequently, in August 1983, at the invitation of the Chinese Academy of Sciences (CAS), DoE Assistant Secretary for Fossil Energy Jan Mares, and a delegation including representatives from the department's Energy Technology Centers in Pittsburgh and Morgantown, traveled to China to discuss coal preparation, coal gasification, coal liquefaction and magnetohyrdodynamics, and to tour coal research institutes in Beijing, Taiyuan, Xian, and Shanghai. Two years later, DoE and China's Ministry of the Coal Industry (MOCI) entered into a Protocol on Cooperation in the Field of Fossil Energy Research and Development.

In 1983, DoE entered into a protocol with the SSTC that covered cooperation in nuclear physics and controlled magnetic fusion research. China entered into this protocol with a clear long-term objective to develop and use fusion as an energy source. However, during a nearly three-year negotiation between the two countries of an annex on intellectual property rights, cooperation was limited to informal university-level exchanges.

On the heels of this protocol, President Ronald Reagan initialled a Peaceful Uses of Nuclear Energy agreement during his April 1984 visit to China. This agreement was formally signed by Secretary of Energy John Herrington and Li Peng in Washington on 23 July 1985.[6] In March of the following year, Secretary Herrington led a delegation of department officials on a visit to China to examine the scope for China to use nuclear and hydropower as alternatives to coal, examining sites such as the proposed location of China's Three Gorges Project.

On 19 August 1987, DoE and CAS entered into an agreement for a cooperative research program on the possible effects of CO_2 on climate change entitled Annex III to the Fossil Energy Protocol, Cooperation in the Field of Atmospheric Trace Gases. It is interesting to note, particularly given the different positions of China and the United States at the December 1997 United Nations Framework Convention on Climate Change's Third Conference of the Parties in Kyoto, that the very first annex DoE entered into with China under the Fossil Energy Protocol was on climate change, rather than coal production or utilization.[7]

Later that year, DoE signed two further fossil energy annexes. The first covers coal preparation and waste stream utilization. While U.S. research focused on high-risk, long-term technologies in contrast to China's goal of targeting near-term improvements, there were common activities in coal characterization for beneficiation and coal surface chemistry. The annex also recognized that Chinese technology for using coal with low calorific content could provide a useful connection with the U.S. need to use coal preparation reject materials. In the second annex, DoE and MOCI agreed to an atmospheric fluidized bed combustion (FBC) information exchange, marrying the extensive database on Chinese operational FBC units with U.S. modeling capabilities and understanding of erosion of metal surfaces.

Thus, at the end of the first decade, China and DoE had established cooperation in three major areas: high energy physics, nuclear physics and fusion, and fossil energy, with work underway in all three of these areas.

Phase Two: 1988-1991

As in the previous period, unofficial technical interaction expanded bilateral cooperation during these three years, even in the absence of new formal agreements. Technical cooperation under the existing agreements continued, except in the areas of nuclear power (the Peaceful Uses of Nuclear Energy Agreement had not entered into force) and fusion research, where cooperation was limited until intellectual property rights issues were resolved.

Although no formal bilateral cooperation existed in energy efficiency, in 1988 DoE's Lawrence Berkeley National Laboratory (LBNL) jointly organized a Sino-American conference on energy demand, markets, and policy in Nanjing. The following year, LBNL established an exchange program with the State Planning Commission's (SPC) Energy Research Institute and conducted an assessment of China's energy conservation. As a result of this collaboration, in 1989, LBNL published the first-ever assessment of China's energy conservation done outside of China, revealing that China—unlike the Soviet Union and Communist countries in central and eastern Europe—had combined vigorous economic growth with a low corresponding rate of energy demand increase at the macro level. In 1991, LBNL released initial studies of three industries in China—iron and steel, building materials, and chemicals—that demonstrated opportunities for large energy efficiency improvements.

Beginning in March 1989 (prior to the Tiananmen Square incident) there was a substantial reduction of activities with China due to the pending resolution of intellectual property rights (IPR) issues between the two countries. On 30 April 1991, the United States and China extended the umbrella Science and Technology Cooperation Agreement for five years and added a new Annex I on IPR, which superseded all previous IPR references in individual protocols. This extension permitted DoE to plan and negotiate with its Chinese counterparts new tasks under the existing protocols. However, a post-Tiananmen requirement still remained in effect, necessitating State Department approval for high level contact with the People's Republic of China, travel to China, and for invitations for Chinese to visit the United States.

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Phase Three: 1992-1997

During 1-12 June 1993, the Departments of Energy and Commerce jointly sponsored a two-week mission to China, led by DoE Assistant Secretary for Fossil Energy Jack S. Siegel, for U.S. companies to promote their electric power technology and services. In August 1993, the industry mission members briefed Energy Secretary Hazel R. O'Leary and Commerce Secretary Ron Brown on what U.S. industry perceived as U.S. government policies that impeded their competitiveness in China. The industry representatives identified a potential for $13.5 billion in U.S. electrical power exports during 1994-2003 (not including nuclear power), equating to 270,000 high-salary U.S. jobs, and an opportunity for introducing cost-effective, environmentally sound U.S. technologies into China's electric power industry.

The realization of the size of the potential export market to China, the potential for environmental improvement by upgrading China's electric generating equipment, and the fact that U.S. industry perceived U.S. government policies to be as much an impediment as Chinese policies, energized Secretaries O'Leary and Brown to set up an interagency group, led by DoE's Siegel, to examine removal of these barriers and to plan their own missions to China. The interagency group's efforts led to removal of the restriction on U.S. firms selling to China "balance of plant" equipment, i.e. the non-nuclear portions of nuclear power plants; an increase in the power of computers allowed for export to China—important for geophysical and seismic analysis as well as for gas and electricity dispatch and monitoring systems; and the offering of limited recourse financing by the U.S. Export-Import Bank for projects in China.

On 3 December 1993, the Beijing Energy Efficiency Center (BECon) was formally established. LBNL, Battelle-Pacific Northwest National Laboratories (PNNL), the World Wide Fund for Nature, and China's Energy Research Institute assisted in creating BECon with core fund-

Timetable of Sino-US Cooperations

ing provided by DoE, the U.S. Environmental Protection Agency (EPA), and the World Wide Fund for Nature, and with support from the SPC, the State Economic and Trade Commission (SETC), and the SSTC. BECon, a nongovernmental, not-for-profit organization, promotes energy efficiency by providing advice to central and local government agencies, supporting energy efficiency business development, creating and coordinating technical training programs, and providing information to energy professionals.

During 1994, two annexes were added to the Fossil Energy Protocol. The first covered cooperation in clean coal technology utilization and paired DoE and the SSTC "...in order to enhance the Parties' capabilities to make positive contributions toward improving process and equipment efficiency, reduce atmospheric pollution on a global scale, advance China's Clean Coal Technologies Development Program, and promote economic and trade cooperation beneficial to both Parties." The second opened cooperation in coal-fired magnetohydrodynamic (MHD) power generation.

In March 1994, China's State Council approved its Sustainable Energy Programs under Agenda 21. Song Jian, chairman of the SSTC and of China's National Climate Committee, invited Secretary O'Leary to a climate change conference held in June 1994 in Beijing, at which China presented its Agenda 21 document. Although Secretary O'Leary could not attend due to her impending presidential mission to India, DoE's Siegel gave a keynote address for the U.S. administration, beginning assistance to China through DoE's Climate Change Country Studies and Support for National Action Plans programs. By the end of 1997, China had received U.S. financial support totaling more than $1.9 million from these programs and had itself made in-kind contributions valued at $300,000.

Secretary O'Leary's Presidential Mission on Sustainable Energy and Trade to China began on 19 February 1995 in Shanghai. She not only included a cross section of U.S. government and industry officials on her delegation to reflect policy, commercial, and environmental interests, but also included representatives of U.S. nongovernmental organizations, primarily those with an environmental focus.[8] At the conclusion of her mission, seven new agreements were signed on 23 February 1995, in the Great Hall of the People in Beijing.[9]

In addition to these governmental agreements, commercial arrangements were reached by some representatives of the U.S. business delegation[10] and the mission succeeded in reaching several significant other accomplishments:

•Five ministerial level oil and gas organizations[11] met under the auspices of the SPC for a breakfast at the invitation of Secretary of Energy O'Leary and relevant members of her delegation. This group agreed that DoE and SPC would facilitate a forum for ongoing meetings between these five organizations and U.S. petroleum representatives in China.

•DoE would cooperate with China to develop its infrastructure for natural gas, recognizing that the expanded use of natural gas could help China to deal with many environmental problems that are exacerbated by the heavy use of low-quality coal.

•DoE and SPC agreed to jointly develop a project plan for mapping China's renewable energy resources.

•DoE and SPC would—with the Chinese and U.S. Export-Import Banks—develop strategies for facilitating State Bank approvals and financing of U.S. renewable energy project investments in China.

•DoE and EPA agreed to coordinate their follow-up discussions with China's National Environmental Protection Agency (NEPA) and China's Petro-Chemical Corporation (SINOPEC) on reducing and phasing out lead in gasoline.

•DoE would work with the United Nations and China's MOCI to organize a technical seminar on the spontaneous combustion of coal.

Two months after Secretary O'Leary met Chinese premier Li Peng in Beijing, he proposed a high-level bilateral dialogue on energy, the environment, and sustainable development. The U.S.-China Forum on Sustainable Development, Energy, and the Environment occurred on 24-26 April 1996, in Washington, D.C. Vice President Gore opened the Forum, which addressed sustainable development strategies, China's Agenda 21, energy, environmental protection, sustainable agriculture and food security, development of sustainable communities, natural disaster prediction and mitigation, global environmental issues in multilateral fora, and commercial cooperation. Agencies taking part in the Forum included China's SSTC, Ministry of Electric Power (MOEP), MOCI, NEPA, SPC, Ministry of Construction, Ministry of Foreign Trade and Economic Cooperation, and State Seismological Bureau, and the U.S. Office of Science and Technology Policy, DoE, Department of State, Department of Agriculture, Commerce's National Oceanic and Atmospheric Administration and International Trade Administration, and EPA.

On 27 June 1996, the first annex under the Energy Efficiency and Renewable Energy Protocol was signed between DoE and China's Ministry of Agriculture (MOA) for Developing Cooperative Activities in the Area of Renewable Energy under the Hundred Counties Integrated Rural Energy Development Program in China. The Annex covers testing and demonstration of biomass gasification/electricity generation technologies at the village level, and medium- and large-scale biogas plants; photovoltaic and solar water heaters; small wind mills; and small and micro hydropower.

On 25 October 1996, three additional annexes to the Energy Efficiency and Renewable Energy Protocol were signed. These annexes reinforced the growing connection between energy and the environment in the bilateral relationship and added the element of commercial development and deployment of these technologies.

DoE took an innovative approach to its energy efficiency cooperation with China, establishing U.S. teams composed of representatives from industry, state agencies, energy associations, DoE national laboratories, and other interested parties to address opportunities and barriers in ten areas: (1) energy policy; (2) information exchange and business outreach; (3) district heating; (4) cogeneration; (5) buildings; (6) motor systems; (7) industrial process controls; (8) lighting; (9) amorphous core transformers; and (10) finance.

Although assembling the ten teams on both the U.S. and Chinese sides required more time than the traditional government-to-government approach, significant concrete accomplishments have resulted, including a demonstration project for heat metering and regulation, drafting of a model cogeneration contract, creation of a Steam Energy Conservation Research Center, and commercial ventures in the areas of industrial process controls and amorphous core transformers.

The link between energy and environment in the bilateral relationship became institutionalized as Vice President Gore and Chinese premier Li Peng co-chaired the U.S.-China Environment and Development Forum in Beijing in March 1997. The Forum met in plenary session and then broke into four working groups: Science for Sustainable Development, Energy Policy, Environmental Policy, and Commercial Cooperation. The first subsequent meeting of a Forum working group occurred in May 1997, when the Energy Policy Working Group met in Washington; this served simultaneously as the first meeting of the annual bilateral energy policy consultations agreed to during Secretary O'Leary's 1995 mission to China.

The pending autumn summit in Washington between China's President Jiang Zemin and President Clinton once again provided a forcing event to reach agreements between the two countries. In the energy area, Secretary Peña signed two agreements during the October 1997 Summit. The first, an Agreement of Intent on Cooperation Concerning Peaceful Uses of Nuclear Technology between DoE and the SPC, paved the way for exchange of information and personnel, training, and participation in research and development in the field of nuclear and nuclear nonproliferation technologies. The second, a joint Energy and Environment Cooperation Initiative, targets urban air quality, rural electrification and energy sources, and clean energy sources and energy efficiency.

The Energy and Environment Initiative represents three new aspects of the bilateral relationship: (1) the initiative makes clear that, although it is signed by Secretary Peña for the United States government and SPC Vice Chairman Zeng Peiyan for the People's Republic of China, its implementation involves other governmental agencies in both countries; (2) although formally a governmental agreement, it specifically calls for "...participation of the business and other sectors..."; and (3) it explicitly links energy development and environmental protection.

A month after the October 1997 Summit, Robert S. Kripowicz, DoE's principal deputy assistant secretary for Fossil Energy, presided at the formal opening of an Energy and Environmental Center at Tsinghua University in Beijing, which is operated in part by DoE, the SSTC, Tulane University, and Tsinghua University. During his visit, Kripowicz also signed new annexes to the Fossil Energy Protocol: one with the Ministry of Chemical Industry in fossil fuel utilization for the production of chemicals, and the other with MOCI which opens cooperation on bilateral consultations and exchanges on coal industry development and information.

The following week, two annexes under the energy efficiency and renewable energy protocol were concluded: Annex V between DoE and SSTC on Electric Vehicle and Hybrid-Electric Vehicle Development establishes technical cooperation in the areas of advanced batteries; AC motor control systems; fast charging, electric vehicle body design; and residential and fleet charging. The annex also provides for exchange of information on electric vehicle infrastructure requirements, building codes and safety standards, non-financial and regulatory incentives, and electricity rates. Annex VI between DoE and SSTC creates a framework for cooperative activities in geothermal production and use.

During 1997, hardware for the first pilot project under the agreement on rural energy development—for solar home systems in Gansu Province—was delivered to China and the first 300 of 600 home installations, plus installations in ten schools, were completed. The initial success of this program inspired China's MOA to plan expansion of the project to 10,000 homes in Qinghai and Xinjiang provinces in 1998-2000. The Gansu solar home project was equally cost-shared by DoE and MOA, with more than 80 percent of the U.S. funds expended for American-made equipment.

Under the agreement on grid-connected wind power development, DoE's National Renewable Energy Laboratory (NREL) trained MOEP personnel in wind resources assessment, utility wind-farm modeling and project development, and hybrid village power system development. DoE and EPA jointly sponsored wind resource assessment and mapping in Jiangxi, Fujian, Guangdong, and Shanghai.

Under the same agreement, NREL and MOA completed an assessment of village-scale biogasification technologies and markets based on the use of agricultural wastes in Sichuan, Shandong, and Zhejiang provinces. A technical-economic analysis of gasification of crop straw to produce cooking fuel resulted in ten demonstration projects, with another twenty-four planned.

During this period, cooperative activities in basic plasma and fusion physics were modest, but productive. Achievements included substantial contributions by Chinese scientists in improving Electron Cyclotron Heating capabilities at the DIII-D experiment at General Atomics in San Diego; U.S. participation in the startup of the first superconducting tokamak in China; Chinese contributions to alpha particle orbit calculations on the Tokamak Fusion Test Reactor experiment at the Princeton Plasma Physics Laboratory; and Chinese contributions at Argonne National Laboratory to the first test of the effects of insulating coatings on the flow characteristics of a liquid lithium blanket concept.

All of these accomplishments were gained despite significant reductions in funding for the U.S. fusion program during the mid-1990s, and a concomitant restructuring of DoE's domestic program. Seeking to develop multilateral collaboration as a means of leveraging diminished domestic resources, DoE encouraged Chinese fusion program leaders and the Chinese government to join International Energy Agency (IEA) fusion implementing agreements as an Associate Contracting Party. In October 1996, the IEA and the SPC signed a Memorandum of Policy Understandings for energy cooperation, enabling China to join the agreements. As a first step, China joined the fusion materials agreement.

Conclusions

As DoE enters its third decade of cooperation with China, a review of past cooperation reveals several trends. First, the relationship has been unfailingly progressive. While the pace at which cooperation increased has varied in response to many factors, there has been no retrograde period. In fact, only one of the twenty-six agreements that DoE has with various Chinese government agencies has ever been canceled.[12]

During 1992-1997, agreements in energy efficiency, renewable energy, statistical exchange, policy consultation, and the environment further broadened bilateral energy cooperation. In addition, and in particular beginning with Secretary O'Leary's mission to China in August 1993, a pattern of a deepening relationship occurred through the signing of specific annexes under the more general protocols. Of the twenty-six agreements (including agreements, protocols, annexes, etc.) concluded over the twenty-year period, sixteen were concluded during 1995-97.

Consistent with the broadening of the bilateral relationship, Sino-American energy cooperation has engaged an increasing number and variety of government agencies and research institutions on both sides. The U.S.-China Environment and Development Forum institutionalized the integration of both countries' agencies for energy, science and technology, and trade and the environment in bilateral cooperation. Beginning with the O'Leary mission in 1995, DoE increasingly involved both the U.S. private sector and U.S. nongovernmental organizations in its China energy cooperation. This involvement became explicit in the Energy and Environment Initiative Secretary Peña signed in October 1997.

The increasing environmental component in Sino-American energy cooperation constitutes another trend over the period. This component not only manifests itself in the agreement on climate change and the more recent Energy and Environment Initiative, but also in a number of annexes concluded in recent years on energy efficiency and renewable energy, and, more subtly, in the shift in focus of cooperative coal activities from basic production and conversion technologies to technologies for coal washing, beneficiation, cleaner and more efficient combustion, emissions control, and conversion to gas and liquids.

Finally, the level of U.S. government attention to the bilateral relationship has markedly increased during the Clinton administration. Although the bilateral energy relationship could be said to have commenced with the visit of U.S. Energy Secretary Schlesinger to China in 1978, the next secretarial visit did not occur until 1986 and then again, due in part to the U.S. reaction to the Tiananmen Square tragedy, not until Secretary O'Leary's mission in 1995. The last, however, was clearly part of a greater administration effort to constructively engage China in issues where both countries have common interests and presaged the direct engagement of the president and the vice president.

The future of Sino-American energy cooperation depends upon domestic policy developments on both sides. In China, the pace of deepening of the relationship depends upon meaningful reform of state-owned enterprises, particularly the state energy sectors; development of effective enforcement of environmental regulations, especially at the provincial and local level, which would make more environmentally benign technology commercially competitive; and reform and opening of the financial system, thus facilitating the financing of environmentally sound energy technologies.

In the United States, critical developments include the recent entering into force of the 1985 Peaceful Uses of Nuclear Energy agreement; lifting of restrictions on U.S. agency involvement in China, such as the Trade and Development

Agency, the Overseas Private Investment Corporation and the Agency for International Development, especially its U.S.-Asia Environmental Partnership; and finally, congressional funding to support demonstration of U.S. environmental technologies in China, as well as congressional and private funding to support U.S. governmental and nongovernmental efforts, respectively, to continue the building of environmental institutions in China.

Robert S. Price, Jr. is director of the Office of International Science and Technology Cooperation, U.S. Department of Energy. He was editor and principal author of Natural Gas: Prospects to 2000 (OECD, Paris, 1982) and has published several articles on the politics of international natural gas trade. Mr. Price wrote this article with the generous assistance of numerous current and former DoE officials.

Endnotes

1 Department of Energy Organization Act (1977), Title I, Section 102(10), 42 USC 7112.

2 Private communication between James R. Schlesinger and the author, 12 December 1997.

3 Transcript of Press Conference of James R. Schlesinger, Secretary, Department of Energy, Peking, China, Monday, 6 November 1978, 2.

4 "US. and PRC Officials Develop Agenda for Energy Cooperation," U.S. Department of Energy press release #N-78-041, Peking, 4 November 1978, 1.

5 Schlesinger communication, 12 December 1997.

6 The Agreement has only recently taken effect due to the Joint Resolution (PL. 99-183) that Congress passed on 16 December 1986, requiring Congressional approval for implementation of the Agreement. The Joint Resolution stipulated three certifications that the President needed to make to Congress before the Agreement could be implemented. Further, in response to the June 1989 suppression of demonstrators in Tiananmen Square by Chinese authorities, Congress in the Foreign Relations Authorization Act, Fiscal Years 1990 and 1991 (P.L. 101-246) required an additional certification from the President regarding China's assurances that it is not and will not assist nonnuclear weapons states in acquiring nuclear explosive devices or the materials and components for such devices. On 19 March 1998, these certifications successfully passed the mandatory thirty day Congressional resolution of disapproval period, allowing the Agreement to become formally effective.

7 Annex I was simply the provision of intellectual property rights that would govern work under the Protocol and Annex II was concluded not by DOE, but by the U.S. Department of Labor for cooperation with the Ministry of Coal Industry in a mine safety study.

8 NGOs represented on the delegation were the American Council for an Energy-Efficient Economy, the Environmental Defense Fund, the Institute of Gas Technology, the Joint Institute for Energy and the Environment, LBNL, the Natural Resources Defense Council, PNNL, the Rockefeller Family Trust, and the World Resources Institute.

9 See table of agreements for particular agreements signed.

10 Immediately after the Presidential Mission to China, DOE reported that the mission culminated in the signing of 34 business agreements totaling more than $6 billion ($4.6 billion of U.S. content). This estimate, based on information supplied to DOE by business members of the delegation, became the subject of some controversy.

11 The five organizations were the Ministry of Geology and Mineral Resources, China National Petroleum Corporation, China National Offshore Oil Corporation, China Petro-Chemical Corporation (SINOPEC), and China National Chemicals Import-Export Corporation (SINOCHEM). Some observers noted that just having the heads of these five organizations meet together constituted a major accomplishment.

12 The annex on coal-fired magnetohydrodynamics (MHD) was terminated as both countries had eliminated funding for their domestic MHD programs.

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Powering Non-Nuclear Growth in China with Natural Gas and Renewable Energy Technologies

by Jeffrey S. Logan and Jiqiang Zhang

Energy shortages in the booming eastern and southern coastal provinces of China have led Chinese planners to consider large additions of nuclear power to fuel future economic growth. This paper demonstrates that a less capital intensive and cleaner solution lies in a combination of natural gas, renewables, and advanced power generation technologies. After introducing the problem, Sections II and III of this paper provide a scenario of how China will most likely meet future power demand. Section IV describes why gas and other power technologies are superior to nuclear power. Finally, Section V presents an alternative scenario that has lower capital costs and fewer carbon and sulfur dioxide emissions.

I. Introduction

Maintaining rapid economic growth while protecting the environment will be a critical challenge for China in the coming decades. Economic reforms initiated in the late 1970s have quadrupled incomes and alleviated some of the grinding poverty across China, but the associated environmental damage has raised local, regional, and global concern. Coal has fueled much of China's remarkable growth: China consumes about 1.4 billion tons of coal each year and relies on coal more than any other country in the world (Table 1). [1]

This article is the second of two which discusses the environmental implications of nuclear power development in China. Please go to the ECSP website at **www.ecsp.si.edu** *to read Yingzhong Lu's article from Issue 1 on "The Role of Nuclear Energy in the CO_2 Mitigation Strategy of the People's Republic of China."*

China's energy resources are also poorly distributed. Most of the country's high-quality coal is currently mined in the north-central provinces of Shanxi, Inner Mongolia, and Shaanxi while demand is heaviest along the southeastern coast. Huge volumes of coal, most of it unwashed and consisting of up to 20 percent inert material, must be transported to these demand centers each year. There is also a general shortage of energy in the coastal provinces: local coal is scarce and of poor quality; hydroelectric power from the southwest and "coal by wire" from the northern coal fields are too distant to be competitive; and imported coal is expensive. Due to these energy imbalances, nuclear power has been proposed as a solution to the coast's future power needs, and China has initiated an ambitious program to plan the construction of forty to fifty nuclear power plants over the coming decades to meet this demand. It is believed that natural gas, renewables, and advanced power generation technologies are superior to nuclear power in China, and that the alternative scenario presented in this paper will also help China develop key high-technology export markets for the future.

II. Future Power Reqirements

Based on a recent study from China's Energy Research Institute (ERI), China's electricity demand growth is projected to quadruple between 1995 and 2020 (Table 2).[2] Much of the growth in power demand is projected to occur in Shandong, Zhejiang, Jiangsu, Shanghai, Fujian, and Guangdong along the eastern coast. This forecast assumes that China will maintain an elasticity of electricity demand of approximately 0.7, far below most developing countries. Indeed, the successful energy conservation program China established in the 1980s has prevented the combustion of additional hundreds of millions of tons of coal each year.[3]

III. Current Baseline Growth Scenario

Based on the country's Ninth Five-Year Plan and current energy policies, future power needs will most likely be met as indicated in Table 3. Power capacity will grow to 725 GW in 2020 from 217 GW in 1995, the equivalent of bringing online a 780 MW plant every two weeks for twenty-five years. Coal use will continue to grow, but its share in supplying total demand

TABLE 1

TABLE 2

TABLE 3

will fall slightly. Likewise, hydropower will achieve a substantial absolute rise in output by 2020, but its share of total demand will fall to 12.5 percent. Nuclear and combined cycle gas technologies will make up for most of the decline in coal and hydropower, generating about 5 percent of the total demand each. Even in this conservative baseline scenario, wind and other renewables will generate a combined 4 percent of the country's electricity in 2020.

Carbon dioxide emissions from the power sector in 2020 will reach 774 million tons of carbon (MtC) per year. Total cumulative emissions over the years 1995 to 2020 will be approximately 12,370 MtC. Cumulative capital investment costs will range from a low of $54 billion over the period 1995-2000 to a peak of $110 billion from 2010-2015. These costs are for generation only and do not include transmission and distribution costs. The total capital requirement over this period will equal $504 billion, or an average of $20 billion per year. This compares favorably with the ERI baseline estimate of $19 billion per year.[4]

One reason coal will continue to generate nearly three quarters of the country's electricity is because China is a world leader in producing 300 MW and smaller coal-fired generator sets. In 1998, capital costs for these units, without sulfur control equipment, averaged about $600/kW, approximately one-third lower than equivalent technology in industrialized nations. China is also developing domestic versions of larger, high-pressure units that are more efficient and more expensive than the 300 MW versions.

The abundance of coal and of these inexpensive small generator sets has rendered coal the lowest cost electricity generation option for much of China. However, one region where coal may not provide the lowest levelized cost power due to high transport costs is along the eastern and southern coasts.[5] As a result, China has an ambitious plan on paper for accelerating use of nuclear power in these fast-growing provinces. Nuclear power may also be able to reduce some of the environmental damage in this region from coal combustion, especially acid rain.

There are currently three nuclear power units in operation in China with a total capacity of 2.1 GW. Four other plants with a combined capacity of 6.65 GW are expected to be on line by 2004 (Table 4). In addition to the plants under construction, the government has stated that it hopes to boost nuclear capacity to 20 GW in 2010, 30 GW in 2020, and 50 GW in 2050. Given the difficulties in financing these plants, however, most independent experts find these targets overly optimistic.[6]

China currently has the capability to domestically manufacture about 70 percent of the components (by value) of advanced pressurized

TABLE 4

water reactor nuclear power systems. It imports the remaining 30 percent of large stainless steel pipes, condensers, and other specialty metals in order to meet technical requirements. The Chinese-manufactured components can be up to 40 percent cheaper than imported equipment, although the quality may also be lower.

Pressurized and boiling water reactors have average capital costs of $1,810/kW in China.[7] These capital costs could drop to $1,400/kW if China learns to manufacture all reactor components domestically, but levelized costs would still be over 40 percent higher than combined cycle systems. In the United States, where the supply of electricity may soon be open to competition, many electric utilities are maneuvering to avoid the "stranded costs" of nuclear power plants that will not be able to compete with other forms of power supply.[8] China should carefully study the reasons that no nuclear plants are, or have been, under construction in countries where competition in the supply of electricity is being considered.

IV. Alternative Energy Possibilities

Natural gas, fuel cells, wind, biomass, photovoltaics, and other renewables could play a much larger role in powering future growth in China. The Chinese government must take an active role in localizing these technologies, increasing their availability, and bringing down their costs.

Natural gas could play a much larger role in China's energy sector, even though it currently accounts for only 2 percent of primary consumption. China's economically recoverable natural gas resources amount to 38 trillion cubic meters[9] (TCM), while proven reserves range from 1.2 to 5.3 TCM. Based on the country's large reserves of coal and oil, most geologists believe there will be more significant discoveries of natural gas deposits in China because the formation processes of coal, oil, and natural gas are so similar.

China could dramatically boost production and use of gas if it had a strong champion within the government. The China National Petroleum Corporation (CNPC), responsible for on-shore gas development, has historically placed petroleum production far above that of gas. Nevertheless, gas consumption, which surpassed 20 billion cubic meters per year (BCMY) in 1997, is conservatively projected to more than triple by 2010 to 70 BCMY and exceed 90 BCMY by 2020. Coal bed methane, imported pipeline natural gas, and liquefied natural gas (LNG) can further add to China's natural gas resource base. Technological, economic, political, and environmental drivers could easily double or triple these figures.

Drivers of Greater Natural Gas Use

Natural gas and other methane-rich gases have distinct advantages over coal. First, a new variety of gas-powered technologies are, or will soon be, entering the market. These technologies are efficient and have low capital costs. China could also lower its bill for imported oil by developing proton exchange membrane (PEM) fuel cells for the booming vehicle market. Greater natural gas use would additionally help alleviate the energy imbalance and supply shortages mentioned

TABLE 5

earlier. Finally, gas is a clean energy source with a minimal number of harmful environmental externalities.

Advanced Technologies

Technological advances are improving efficiencies and lowering capital costs for natural gas-based power systems faster than coal-based ones. Combined cycle gas turbines generate power at efficiencies approaching 60 percent.[10] Efficiencies continue to rise as material properties and overall designs improve. Capital costs for combined cycle units are already competitive with coal-fired systems in the southern and eastern regions of China where coal is expensive.

Levelized costs for a number of power generation technologies are shown in Table 5. Fuel costs for Fujian are used because this province is typical of the rapidly growing, yet energy deficient, coastal provinces considering nuclear power in the future. All data and assumptions used in the levelized cost calculations are presented in Table 8. Natural gas prices for the power sector are assumed to be $3/GJ, a higher level than in most countries.

Combined cycle systems are already easier to finance in many coastal regions.[12] They can be constructed faster and with greater modularity than coal-fired plants, important points in power-hungry and finance-poor China.

A new generation of fuel cells will soon enter commercial markets in developed countries and will help revolutionize transportation and power markets. These devices create electricity through chemical reactions without combustion. They are efficient, super-clean, and can operate on hydrogen, methanol, natural gas, or even gasified coal.

China has the capability to quickly "internalize" these high-value technologies: Chinese scientists have a strong theoretical background in many advanced power generation technologies and China is at a stage of development where infrastructure costs would not be overwhelming. China could help ensure strong growth and a cleaner environment by initiating an accelerated research and development (R&D) program for gas and wind turbines. Other R&D focusing on gasification processes for biomass power; thin film technologies for photovoltaics; and membranes, catalysts, and hydrogen production for fuel cells would round out the program. Institutional barriers such as poor interagency cooperation will be more difficult to overcome than the technical difficulty of making the hardware for these technologies effective.

China could establish more stable export markets without having to devalue the yuan by developing attractive energy technologies for overseas markets. By acting now to begin developing wind turbines, fuel cells, and other advanced power generation technologies, China will ensure greater efficiencies in the domestic power and transportation sector, less environmental damage, and more secure export markets.

Expanding Oil Imports

Rapid economic development combined with stagnating petroleum production forced China to become a net oil importer in 1994. By 2000, forecasters predict the country will be importing nearly 1 million barrels of oil a day (2.1 EJ/year). This figure could rise to 3 million barrels a day by 2010.[13] China is reluctant to use foreign currency to import this much oil, but it has few alternatives. One partial solution would be for the country to begin developing the PEM fuel cell for use in the transportation sector. By initiating fuel cell research and development programs now, China could create a domestic manufacturing base for these fuel cells, leading to decreases in hard currency spending on imported oil, and opening the possibility to export modular fuel cells to other countries. China should also initiate research for clean and inexpensive methods to produce hydrogen, the ultimate source of energy for fuel cells. For example, China already has a strong hydrogen production capability in its fertilizer sector. Given a breakthrough in coal to hydrogen conversion, at least 2,000 small fertilizer plants, mostly fed by coal, could be converted to clean, inexpensive hydrogen production with little investment.

Energy Supply Imbalance

The main coal production areas in Shanxi, Inner Mongolia, and Shaanxi are at least one thousand kilometers from industrial centers such as Shanghai, meaning that China must transport one hundred million tons of coal a year over 500 kilometers. Coal accounts for 40 percent of all commodity shipments on Chinese trains. As a result, passenger and other cargo lines are overburdened. China plans to build more mine-mouth power plants to send electricity rather than coal to consumption centers, but transmission is either too expensive or too inefficient beyond 1,500 kilometers. Greater use of natural gas, coal bed methane, and LNG can reduce this supply imbalance and free up the rail system for people and other commodities. Introducing more gas can also alleviate energy shortages and, consequently, the production losses these shortages cause.

Environmental Benefits

Regardless of combustion method, natural gas emits virtually no sulfur or particulate emissions. An 800 MW power plant burning low-sulfur Chinese coal (1.0 percent sulfur) for one year produces approximately 130,000 more tons of sulfur dioxide than a natural gas plant of the same size. Nitrogen oxides and reactive organic compound emissions are also lower than in coal-fired plants. Carbon dioxide emissions are 60 percent lower per kWh in a 50 percent efficient combined cycle power plant.

Other negative environmental impacts associated with coal plants but largely avoided by natural gas powered plants include particulate and mercury emissions, land subsidence, ash disposal, and thermal pollution.

Sources of Gas

Normally conservative Chinese planners forecast rapid growth in the domestic production of natural gas. New exploration and development technologies ranging from three-dimensional seismic imaging to advanced deepwater drilling processes promise to increase domestic natural gas production. Restructuring the natural gas sector will also give developers incentives to supply more gas. As incomes continue to rise, consumers will demand cleaner sources of energy. Cooperating with multinational gas companies could also help China find, develop, and transport new supplies.[14]

Coal Bed Methane

As the world's largest producer of coal, it is natural for China to take a strong interest in coal bed methane (CBM). Currently recovered volumes of CBM amount to only about 500 million cubic meters per year (MCMY), but reserves are tallied at 35 TCM. A major multinational oil company signed a $500 million contract with the China United Coal Bed Methane Corporation in January 1998 to produce an additional 500 MCMY from coal and gas fields in Anhui province.[15] This area alone is thought to contain more than 60 BCM of methane reserves. Because China's coal mines are extremely gassy and prone to explosions, worker safety and productivity are low. China could raise productivity and reduce the number of miners killed each year by first tapping the methane in these mines.[16] Carbon dioxide injection may be an effective way to produce more CBM in the future while slashing greenhouse gas emissions.[17]

Imported LNG

China has yet to begin importing LNG despite relatively strong potential demand in Guangdong, Fujian, Jiangsu, Zhejiang, and Shanghai. Japan, on the other hand, accounts for over 60 percent of the world's trade in LNG, importing enough of the fuel to power over 25 percent of its electricity generation. Compared to coal-fired plants, LNG-fueled plants would operate at higher efficiencies, require less start-up capital, and create a fraction of the environmental damages caused by coal-fired plants. Levelized cost power would be about the same. As part of the Ninth Five-Year Plan, China began scoping studies to build three LNG terminals in southern China. These terminals could begin operation in the 2002-2005 timeframe. Current technology for producing and transporting LNG is capital-intensive and relies on economies of scale, but much less so than nuclear power.

International Pipeline Trade

Importing natural gas to China via pipeline has received heightened attention over the past few years. With proven reserves of over 56 TCM, countries of the former Soviet Union are a logical first choice of supply. The Irkutsk Basin gas fields near Lake Baikal in Siberia lie about 3,000 kilometers from Beijing. Multilateral discussions are underway over a pipeline that would transport 30 BCM of natural gas per year from Siberia to China's east coast. Talks are also proceeding regarding a pipeline from Kazakhstan that would reach over 6,000 km to China's east coast. A 1996 World Bank study on natural gas trade estimates that the fuel can be brought from Central Asia to China for about $3.00/GJ at the rate of 27.6 BCM per year.[18] Over a distance of 7,600 km, the delivered price would rise to $3.75/GJ. There are barriers to overcome before pipeline projects of the scale mentioned above can be implemented. Financing is probably the most difficult hurdle; even short pipelines (from Siberia or Irkutsk, for example) would cost nearly $7 billion to construct.

Chinese economists realize that the power sector is not the first priority for natural gas use. Since coal use in the residential and small industrial sectors damages human health and the local environment more than in the power sector, switching from coal to natural gas should have priority there. By initiating an accelerated gas development program, however, China could switch over more coal to gas

TABLE 6

than in the baseline case and still have gas available for power generation. Table 6 presents future gas availability estimates in the baseline and accelerated policy development scenarios. We estimate that one quarter of China's gas can be used to generate power without impacting the required fuel switching if supplies are boosted as shown in Table 6. In 2020, this would amount to 90 BCM, or enough to power approximately 85 GW of electric power.

TABLE 7

V. An Alternative Scenario

In the alternative policy case presented in this paper, gas supplies are assumed to reach the total amount indicated in Table 7 and gas-fired and renewable energy technologies are assumed to have been strategically developed with the aid of a strong government policy. Still, coal plays a smaller, yet dominant, role. First, it is assumed that the government will maintain its strong commitment to energy efficiency. Specifically, the elasticity of electricity demand is assumed to decline by 0.5 percent each year from its 1997 level of 0.69. By 2020, these yearly efficiency gains would lower demand by almost 13 percent, from 4,000 TWh to 3,497 TWh. Market forces now entering the Chinese industrial sector, exemplified by the new performance contracting energy management companies, or ESCOs, could help achieve this elasticity reduction at little or no cost.[19]

Coal in this scenario would be used to generate 47 percent of the total demand, significantly less than the baseline case. Hydropower and natural gas account for about 16 percent, while wind and other renewables would each be responsible for about 9 percent. No new nuclear plants would be added and nuclear power's share would decline to under 2 percent.

Cumulative greenhouse gas emissions would be 23 percent lower, amounting to 9,501 MtC. A total of $466 billion in capital investment costs from 1995 to 2020 would be required, $38 billion lower than the baseline scenario. These savings could be used to finance construction of the power sector's share of the needed natural gas infrastructure, pipelines, and LNG terminals. Even if it is assumed that the power sector provides half of this capital investment (while using only one quarter of the output), it could help finance $25 billion worth of domestic natural gas infrastructure, three international pipelines ($10 billion each), five LNG receiving terminals ($400 million each), and $20 billion in R&D for renewables and advanced power generation technologies. Costs to achieve the energy efficiency savings in this scenario, if any, would also come from the $38 billion in capital savings. This scenario would also reduce damage to health and the environment, and position China to be a leading exporter of advanced power generation technologies.

VI. Conclusions

China can meet the rapidly growing demand for power in the coastal provinces by accelerating the development of natural gas, renewables, and other advanced power technologies. Nuclear power cannot compete with these power generation technologies. A champion of natural gas must emerge from within the government to further boost its development and use. The government must also begin developing its educational, training, and R&D capacity so that China can "localize" gas turbine, fuel cell, wind, photovoltaic, biomass, and other renewable energy systems and thus bring down their costs. By acting on these issues now, China will lay the groundwork for a clean future, and secure the high technology export markets that it will need to become a true world power.

TABLE 8

Jeffrey Logan is a research scientist in the Advanced International Studies Unit of Pacific Northwest National Laboratory. Mr. Logan focuses on energy technology and manages projects in China relating to energy efficiency, climate change, and information exchange. Jiqiang Zhang is a program officer at the W. Alton Jones Foundation. Dr. Zhang specializes in air pollution control, and has worked on environmental policy, development of environmental information systems, integrative environmental planning, and energy and climate change since 1984. He previously worked for the Chinese Academy for Environmental Sciences and the Rockefeller Foundation.

Endnotes

1 Energy Information Agency, U.S. Department of Energy (Washington, DC: http://www.eia.doe.gov).

2 The Energy Research Institute (ERI) estimated electric power demand for 7 regions in China through 2020 using the MEDDEE/ENV model. For more details, see William Chandler and Jeffrey Logan, *China's Electric Power Options: An Analysis of Economic and Environmental Costs* (Washington, D.C.: Pacific Northwest National Laboratory, 1998).

3 China has held energy growth at half the level of economic growth since initiating reform in the late 1970s. Energy elasticity, defined as the rate of growth in energy use divided by the rate of growth in the economy, is thus 0.5. Without this unique achievement, China would be consuming much more energy than it does today. Electricity elasticity, although slightly higher, is still lower than in most developing countries.

4 ERI assumed a mix of generation technologies with a higher percentage of coal-fired plants in their baseline case, accounting for the difference in the capital investment cost estimates.

5 Levelized cost analysis spreads out all costs involved in building a facility and producing electricity over its life, allow-

ing direct comparison of different generation technologies.

6 *The Economist Intelligence Unit*, "Nuclear Power in China: Slow Breeder," 19 January 1998.

7 Estimates for new plants in the short term by China's ERI and PNNL.

8 Stranded costs refer to economic assets in the electric power sector that would lose a portion of their value in a restructured, or deregulated, environment. In a competitive power supply environment, power generated from nuclear plants and other expensive sources would not be able to compete with cheaper generators using gas and coal. Owners of these assets would not be able to recover their investment costs, leading to "stranded costs."

9 Divide by 35.3 to convert cubic meters to cubic feet. To convert billion cubic meters (BCM) to exajoules, divide by 26.5 (that is, 26.5 BCM = 1 EJ). To convert BCM to Quads, divide by 27.9 (that is, 1 Quadrillion BTU = 27.9 BCM). In general, 1 BCM of natural gas will fuel an 800 MW combined cycle plant for one year at a 70 percent capacity factor and 50 percent efficiency.

10 Lower heating value (LHV) is one of two common measures of efficiency. The lower heating value of the fuel refers to the direct heat energy produced when burning the fuel. Additional energy is available in the form of the condensation heat of steam present in the combustion gases. When this is added to the LHV it yields the higher heating value (HHV) of the fuel. For gaseous fuels, LHV is about 10 percent higher than HHV.

11 Assumes sulfur emission control will be required for all new coal-fired power plants in coastal regions by 2010.

12 See Allen Blackman and Wu Xun, "Climate Impacts of Foreign Direct Investment in the Chinese Power Sector: Barriers and Opportunities," Preliminary Draft (Washington, D.C.: Resources for the Future, November 1997) for a discussion of why combined cycle systems are easier to finance.

13 See David Fridley, "China: Energy Outlook and Investment Strategy," presented at the *Oil and Money Conference*, London, United Kingdom 18-19 November 1997 (Berkeley, CA: Lawrence Berkeley National Laboratory, 1997).

14 Jeffrey Logan and William Chandler, "Incentives for Foreign Participation in Natural Gas Development in China," forthcoming in *China Business Review*, June/July 1998.

15 See "Companies Cooperate to Develop Methane Resources," *China Business Net*, 9 January 1998.

16 Approximately 10,000 coal miners die each year due to explosions and accidents in China's mines.

17 Robert Williams, "Fuel Cells, Coal and China," Paper presented at the 9th Annual U.S. Hydrogen Meeting, Washington, D.C. (Princeton, March 1998) 10-15.

18 MMBtu, or million British thermal units, is a natural gas measure equivalent to 985 cubic feet of gas, or approximately 1 gigajoule. See World Bank, "Natural Gas Trade in Asia and the Middle East," IEN Occasional Paper No. 8 (Washington, D.C.: World Bank, 1996).

19 The Global Environment Facility (GEF) and the World Bank are currently introducing private energy management companies (EMCs) in Beijing, Liaoning, and Shandong. These companies will identify, design and finance energy efficient plant upgrades at host facilities in exchange for a portion of the monthly energy savings, so called "performance contracting."

20 See Debra Lew and others, "Industrial-Scale Wind Power in China" (Princeton, NJ: Center for Energy and Environmental Studies, November 1996).

Environmental Work at the Sinological Institute of Leiden University

Researchers at the Sinological Institute of Leiden University (Holland) are engaged in a number of projects on environmental issues in China:

• Research is currently being conducted on the formulation and implementation of rangeland policy in the Ningxia Hui Autonomous Region. This project attempts to trace constraints in the implementation of rangeland conservation policies, particularly related to desertification of pasture. A quantitative survey of 200 farmers in four counties in Ningxia has been conducted, as well as various interviews with officials and farmers. This research covers ten different villages located in both the desert-steppe region, as well as the loess area of Ningxia. The research is being conducted in cooperation with the Ningxia Science and Technology Commission and the Ningxia Academy of Social Sciences.

• Extensive research has been performed on industrial pollution, water conservation, the rural paper industry, and rural environmental issues in China.

• There are preliminary plans to undertake a project on soil and water conservation policies in China in cooperation with the University of Liverpool and the Chinese Academy of Agricultural Sciences, and to expand research on rangeland conservation to the Inner Mongolian region.

For more information on these projects, please contact Peter Ho of the Sinological Institute at PPSHO@rullet.LeidenUniv.nl.

China's Water Problems in the Context of U.S.-China Relations

by Baruch Boxer

As the millennium approaches, China's phenomenal economic growth is a major driving force in the global economy. But failure in the coming decades to conserve and improve the quality of water resources will seriously undermine China's growth prospects and threaten its political stability. Water shortages, increasing flood damage, and rampant pollution threaten to undermine both short- and long-term modernization goals. It is uncertain, moreover, if sufficient fresh water will be available in the coming decades to accommodate China's growing water demands for agriculture, industry, energy development, and domestic supply.

This paper briefly reviews the cultural and physical aspects of China's precarious water situation, and discusses Chinese perspectives on problems and solutions. It then describes some successful public and private sector U.S. water-related initiatives in China, and concludes with recommendations for enhancing U.S. contributions to China's water conservation efforts in the overall framework of U.S.-China relations. This is an especially opportune time to expand cooperative water-focused scientific and technical programs that enhance China's capability to address problems while broadening the experience of the U.S. water management enterprise. To these ends, both sides have recently begun work on a framework for a comprehensive bilateral water resources management program.

The magnitude and implications of China's water problems are recognized in China and abroad, yet it is unclear whether China will be able to deal adequately with a host of water supply, water control, and water quality maintenance issues. With the problems acknowledged, the task now is to determine how remedial engineering, economic, and institutional measures specific to China's needs can be most effectively employed. Some limited steps are being taken in the critical agricultural, industrial, and energy sectors to conserve water and enhance water quality. Efforts to monitor and combat water pollution are taking on new urgency. It is nonetheless difficult to assess the efficacy of short- and long-term remedial measures, especially as they may benefit from official and private U.S. participation in water-related scientific, technical, and institutional development programs in China. There are two main reasons for this difficulty.

First, attempts to modify and reform water supply, conservation, control, and financing practices are strongly influenced by traditional values and perspectives. The organization and implementation of China's water program is still governed by long-standing assumptions that define a special place for water institutions and water knowledge in state governance and national security. In this period of rapid modernization, however, national water planning and management strategies must respond imaginatively to dramatically changing social and economic conditions. China's ability to create a water system that can adapt to these conditions will be a key determinant of China's ability to preserve the integrity of critical terrestrial and marine ecosystems.

New planning approaches, engineering strategies, and economic incentives are needed to quickly improve a rapidly deteriorating water situation. It is striking, however, that even in this heady period of free-for-all marketization, some basic Marxist ideological tenets, which have guided water policy for over fifty years, remain prominent. Despite some softening, these principles still assign to the central government primary responsibility for overcoming contradictions between land, population, water availability, and capital investment in attempts to achieve optimal economic productivity and societal well-being in the face of physical and "national land economic" constraints.[1]

The second reason why it is difficult to appreciate the scope and implications of China's water problems as they relate to U.S. interests is that, until recently, attempts to understand problems and their ecological and health implications have been confounded by political tensions in U.S.-China relations. Critical, and sometimes politically self-serving, accounts of China's environmental program were common throughout the early 1990s. While foreign observers now recognize China's growing commitment to developing a law-based, scientifically-informed, and technologically proficient environmental protection regime, many remain skeptical about its ultimate prospects given weakening central authority, bureaucratic obstacles, and intensifying water-related problems.

Most outside accounts of China's efforts, for example, still ignore factors that explain China's response, in its own terms, to pressing water problems: there are distinctive Chinese perspectives on these problems, which focus on the potential for improving the balance between national water policy goals and the specific institutional and programmatic adjustments essential for improved coordination of regional and local responses to water challenges. China is dealing with problems in its own way. The important task is to understand China's criteria for priority setting, its assumptions that guide scientific and technical work, and its allocation of human and financial resources. Increasingly serious conditions are fostering new approaches to problem assessment and remediation. These range from more sophisticated hydrological analysis as a basis for supply and demand estimates, to multiple objective optimization modeling of economic, demographic, and physical factors in support of national and regional water resources planning, management, and environmental protection.

Cultural Context

Ideas about the unique role of water in Chinese society are deeply rooted. In ancient times, for example, the physical properties of water were metaphorically associated with Confucian notions of good and bad attributes of human behavior.[2] Institutional and technological adjustments to contemporary development-related water problems clearly reflect historical and cultural perspectives that shape problem definition and response.

Earlier notions of the effectiveness of water supply and control as a measure of the emperor's legitimacy, for example, are now expressed in the modern concept of *shuili wenhua*, or "shuili culture."[3] The Ministry of Water Resources (MWR) promotes this concept as a rallying cry for popular identification with state efforts to recast its still dominant water engineering and development role in order to take advantage of newly emergent market opportunities and technological advancements.[4] This illustrates how earlier ideas have been recast to support current political objectives. The MWR, through its research, engineering construction, and media programs, perpetuates the traditional role of water agencies at all levels as influential arms of government with special responsibility for supporting, nurturing, and sustaining society. The Ministry's self-appointed role as facilitator of harmonious relations between state and society, and guarantor of domestic stability, is as prominent today as in pre-modern China.

Throughout the Maoist period until the late 1970s, for example, the water enterprise was spurred mainly by a strident ideology that emphasized the high priority of water resource development and control in the party's program, and the special role of these activities in linking state and society in the quest for national political and social consolidation.[5] The government now recognizes the threat to modernization from inadequate water supply, excessive pollution, and poor water control. It is therefore trying, with some success, to develop strategies that build on existing institutions, attitudes, ideologies, and engineering practices. New market-based approaches to more effective water supply, conservation, and quality maintenance are also being introduced. These, however, confront entrenched assumptions and practices that deter effective change.

Physical setting

Physical and climatic factors in China influence water availability and undermine supply and control measures. A key determinant is the sharp contrast between North and South China in the volume, frequency, and distribution of precipitation. Especially in North China, surface and groundwater supplies are unevenly distributed, and there is marked disparity and seasonal variability in water supply. Supply problems are compounded by widespread pollution.

In South China, in contrast, there is excessive precipitation. Frequent flooding occurs despite herculean flood prevention and control measures that have been vigorously pursued since the 1930s. Since the founding of the present government in 1949, China has constructed over 80,000 reservoirs for water detention, hydropower, and/or aquaculture. 245,000 kilometers (km) of dikes protect about 30 million hectares of farmland, 470 cities, 600 million people, and two-thirds of the country's industrial and agricultural production base. Despite these protective measures, China frequently suffers enormous physical and economic damage from extreme climatic events. Flood control is a major focus of the 1996-2000 Five-Year Plan. Floods threaten half of China's population, one-third of its agricultural land, and major cities that account for 70 percent of national industrial and agricultural output value.[6]

Problems stemming from imbalances in water availability and extreme weather conditions are compounded by fast-growing water demands for housing, transportation, industry, and other urban and rural development activities. Rural industrialization, construction of energy-generating facilities, and rail and road transportation networks disrupt water supplies and increase pollution. These activities also aggravate flood damage and intensify the harmful effects of soil erosion, deforestation, drought, and flood plain and wetland loss. Rampant development thus makes it more difficult to manage the health, economic, and environmental impacts of floods and other wa-

Failure in the coming decades to conserve and improve the quality of water resources will seriously undermine China's growth prospects and threaten its political stability.

ter-related hazards. There is major investment in hydraulic infrastructure such as dams, dikes, and water diversion projects since structural remedies are still viewed as the best short-term response to pressing water supply and control problems.

Chinese Perspectives

It is instructive to examine Chinese perspectives on problems and their remedies in order to gain a better understanding of China's water problems. This can provide a framework for evaluating present and future U.S. involvement in the China water scene, and perhaps suggest new approaches. Insight into how China perceives its water problems and sets priorities can be gained from several sources. These include MWR (Ministry of Water Resources) programmatic statements on objectives and activities in support of "sustainable utilization" goals; local and regional activities that respond to national policies; and assessments by leading scientists about the interplay of economic, engineering, ecological, and human factors in meeting water challenges.

To begin, the MWR recently outlined its water conservation and control objectives in an Agenda 21 review, which is part of China's comprehensive Agenda 21 statement on environmental commitments and plans following the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The review emphasizes the ministry's dominant role in delineating problems, it defines programmatic objectives and activities, and stresses the urgency of water problems and their socioeconomic implications. An important feature of the statement is its setting of priorities, both in terms of broad areas of concern as well as specific steps that need to be pursued.

As is customary in Chinese presentations of environment-related data, the magnitude of the water crisis is initially presented in comparative per capita terms. China's per capita water reserve of 2,500 cubic meters (m^3) is only one-fourth of the world's average. Thus, the immediate challenge is to devise long-term supply and conservation measures while simultaneously confronting immediate problems in seriously water-deficient areas such as North China, the Jiaozhou Peninsula in Shandong, and the Northwest. Regional shortages are also compounded by an annual national agricultural water deficit of 30 billion m^3. This deficiency could be even greater, given variability in water sources and quality, and the notoriously inconsistent criteria used for measuring "effectively irrigated" agricultural areas, the standard Chinese accounting unit.[7] Agriculture consumes approximately 80 percent of China's water supply, and drought-prone agricultural areas amount to roughly 20 million hectares. This results in heavy overdependence on groundwater.

Groundwater is also a major source of water for cities and industry, and growing agricultural dependence on groundwater has led to critical urban water shortages. In 1990, 26 percent of China's population was considered urban, and it is estimated that by 2000, urban population will increase to about 500 million, roughly 35 percent of China's total population. Urban population growth and industrialization have already resulted in a daily water deficit of about 16 million m^3 in over 300 cities. In southern cities, moreover, 60-70 percent of water shortages are pollution-related.

The MWR overview attributes urban shortages to four factors: (1) "resources limited," (2) "engineering induced," (3) "pollution triggered," and (4) "facility constrained." Seventy percent of water shortages in cities are attributable to the first three factors; supply deficiencies are rarely attributed to "facility constraints." This ranking may be intended to substantiate official claims that enormous construction efforts since the 1950s have been relatively successful, while implying the need for continued dependency on short-term structural measures for water storage and supply. Nonstructural approaches to enhancement of water supply, such as the introduction of more realistic water pricing, water-use valuation, and land-use zonation, are only beginning to be introduced. In some water-deficient urban areas in North China, for example, enforcement of new pricing policies which might lead to more realistic allocations of water in response to its real economic value (i.e., urban vs. agricultural) could quickly help to ameliorate the present critical situation.[8]

The magnitude of water shortages and deficiencies is dramatically highlighted in the context of economic growth projections. From this perspective, prospects for effective remedial measures at the national level seem increasingly problematic. It is predicted, for example, that at China's expected GNP level, annual water demand will reach 600 million m^3 by 2000, assuming "conservation and rational use of water" and "medium-drought weather." Rational use of water and medium drought weather, however, are poorly defined concepts and their meaning is unclear. Rational location of economic activities in relation to physical and human resources, in particular, has been a frequently stated objective since the 1950s, but remains an elusive theoretical concept that has had little formal application in planning. This is especially true after China's opening in the late 1980s when market forces were unleashed. Water demand will probably grow 2-3 percent annually in the first decade of the 21st century, and by 2010 will reach about 720 million m^3. This means supply capacity will have to increase by about 120 million m^3 in ten years—an overwhelming task.

Given its immense responsibilities, and the obstacles it faces in achieving realistic goals at a time of declining central government authority and the vagaries of the market, the MWR has laid out a framework for action that encompasses seven broad areas that must be addressed at the national level. These include: (1) long-term supply and demand planning and assessment; (2) water source, water quality, and ecosystem protection; (3) groundwater conservation and sustainable use strategies; (4) assured domestic and industrial water supply; (5) pollution control and wastewater recycling; (6) the need to cope with the effects of climate change; and (7) the need for management reforms.

While the MWR's program is mainly a national blueprint, recently there have been successful attempts at provincial and local levels to translate these broad goals into workable programs. Qingdao, for example, introduced an integrated water management program in 1993. It implemented the recommendations of several local research projects on urban water supply planning and mid- and long-term supply and demand projections. Research data were applied in the development of a regulatory program that coordinates water supply from diverse sources while facilitating a comprehensive city-wide approach to water distribution, conservation, and pollution control in cooperation with the local environmental protection bureau. A permit system allocates water for industrial and agricultural users, domestic supply, and environmental protection in accordance with "rational" use values that reflect economic priorities. The Qingdao program is in its early stages and needs to be carefully managed to ensure sufficient water to meet growing demands as the economy develops, but it nonetheless illustrates the potential for effective integration of national and local efforts.[9]

At the provincial level, Guizhou's "water sector assessment" is a good example of the forthright response of a severely water-stressed area to opportunities for combining modern engineering and economic strategies to develop water resources on a sustainable basis while preserving ecological integrity in a fragile mountainous environment. Guizhou recognized early on that institutional and macroeconomic factors were the main obstacles to beneficial use and development of limited water resources.

To better understand the specific nature of physical and economic constraints of Guizhou's water resources, the provincial government undertook a series of short- and medium-term assessment programs. These activities initially focused on various aspects of cost recovery in water use, and the development of a demand management system in tandem with physical infrastructure consolidation and rehabilitation. These studies were designed to help improve the quality and effectiveness of investment decisions for the water sector while balancing environmental protection and economic development needs.[10]

The Guizhou assessment seeks to improve provincial capability in financing water sector activities, and to reduce dependency on central technical and financial support. In this regard, it illustrates how a powerful center-province relationship in water matters still shapes policies and programs. In China, national and local problems are closely linked through common perspectives on their human impacts, constraints on development, and strategic goals. Even at a time of increasing provincial autonomy in development policies and investment decisions, when it comes to water supply, conservation, flood and drought relief, and infrastructure investment, policy decisions are still strongly influenced by national perspectives and priorities reflecting a very strong party role in water engineering education and training, construction planning and management, and international programs.

The scientific and institutional foundation of national water policy provides the context and defines the scope for official and private sector U.S. involvement in China's water affairs. Before turning to specific examples of this involvement, however, it will be helpful to briefly explore some theoretical perspectives that govern national priority setting and investment decision making in water matters. In China, hydrological and economic assumptions governing water planning and policymaking, and the choice of engineering solutions, are framed by theoretical perspectives on the human ecology of water supply, demand, and control. These perspectives reflect China's demographic and physical realities, and the pressing need to think creatively at the national level about how planning and engineering strategies can best address numerous constraints.

A 1996 interview with a leading hydrologist/physical geographer, Liu Changming, in the main general interest journal of the MWR, *Zhongguo shuili* (*China Water Resources*), is suggestive of these perspectives. It confirms the necessity in China of taking into account the human dimensions of problems and their impacts in the process of developing engineering solutions. As a hydrologist, Liu seeks better understanding of the physical characteristics and dynamics of China's water regime. As a geographer, he applies scientific knowledge about water supply, movement, hazard, and uncertainty in considering the implications, for China, of changing relations among "people, water, and the environment" in the context of China's rapid development. Integration of "people, water, and the environment" has, of course, always been the primary goal of water management in China, and the success or failure of these efforts is a primary measure of the effectiveness and legitimacy of state governance.[11]

Liu suggests that the key to achieving water "sustainability" is overcoming contradictions between natural and human landscape features and adjusting to the uncertainties implicit in the fact that water in China is simultaneously beneficial and harmful in an unusually tightly circumscribed spatial and temporal framework. Priorities such as urban water supply, therefore, must be addressed in a manner that acknowledges the difficulties of engineering the environment while using economic criteria to shape "national land use" in keeping with regional variability in water supply. This is manifested, for example, in the urban water supply problem in what he calls the "strong water" and "weak water" phenomenon. Here, extensive reservoir construction over forty years has supported urban development and agricultural production in peri-urban areas by concentrating and regulating urban supply. In so doing, however, it has undermined the benefits of the natural rhythms of "weak water," which is defined as ground and surface water supply, soil nutrient replenishment, and pollutant dilution and dispersal.

According to Liu, the essence of China's water management challenge is how to balance "strong" and "weak" water so that the benefits of engineered solutions such as increased reservoir capacity, dike reinforcement, and inter-basin water transfer projects are enhanced through improving the natural ability of river systems to supply water, disperse or detain excess water, dilute pollution, and generate power. This can be accomplished, for example, through expansion of "low head" hydropower generation facilities, better wetland protection, and slowing the rate of land reclamation.

U.S. Involvement

Given the diversity, complexity, and the unique physical and cultural contexts of water problems in China, what should be the nature and extent of U.S. involvement in China's water science, engineering, planning, and policymaking? What are the mutual benefits of such involvement? At what level should they be fostered? And, what can be learned from the recent experience of public and private sector groups?

> Integration of "people, water, and the environment" has, of course, always been the primary goal of water management in China, and the success or failure of these efforts is a primary measure of the effectiveness and legitimacy of state governance.

There have been extensive official U.S. contacts with China since the early 1980s relating to water issues. These include high level discussions in support of broad environmental sustainability goals; cooperative scientific research programs at national and regional levels; information generation and dissemination through research conferences and publications; and technology-focused trade development in the water supply, agricultural, pollution control, and energy sectors.

About a dozen U.S. government agencies have cooperative programs with China that focus on various aspects of water supply, quality enhancement, planning, and control. Some programs were originally developed under the aegis of the 1979 U.S.-China umbrella agreement on science and technology. Over the years, they have facilitated productive contacts between Chinese and U.S. scientists and engineers in diverse fields including hydrogeology, hydrology, fluvial hydrodynamics, dam engineering, flood monitoring, estuarine studies, industrial site remediation, pollution control, agricultural meteorology, ocean-atmosphere dynamics, and other areas.

While these programs have helped build close personal ties between American and Chinese scientists and engineers, they have not for the most part directly benefited short-term water management efforts in China. Part of the problem is inadequate financial support and jurisdictional disputes among sponsoring agencies in China and the United States. This undermines the strong commitment of many Chinese and American scientists and managers who wish to ameliorate the impacts of water shortage and poor water quality on people and the environment, and improve conditions at regional, prefectural, and local levels through timely application of research results and technical knowledge.

A few exemplary programs, however, appear to have surmounted these obstacles. These programs have the potential to build upon standard information exchange and technical assistance activities to help Chinese managers deal more effectively with water problems. Several relatively low-cost program development, technical training, and scientific cooperation initiatives are already having an impact in China while spawning new initiatives that will further expand mutually beneficial ties.

A good example is the U.S. Geological Survey's (USGS) joint project with the MWR's Hai River Commission. This project was initiated under the water quality annex of the Surface Water Protocol between USGS and MWR's Department of Hydrology. The project supports water quality management efforts in a rapidly developing 5,000 square kilometer agricultural and urbanized area of the North China coastal plain around Tangshan. Water quality in the Tangshan area will be compared with the Delmarva Peninsula and the Sacramento Valley using similar assessment procedures. The project ultimately will improve understanding of the effects of land use on groundwater quality in drainage basins with similar hydrogeological characteristics, but with varying climates and land use patterns.

Chinese participants are enthusiastic about this cooperative effort because it will help managers and scientists in the Hai River Commission apply methodologies for determining water quality conditions and trends similar to those used in the USGS National Water Quality Assessment Program. To facilitate comparison, USGS scientists are helping Chinese counterparts develop a Hai River database to analyze several aspects of the relationship between land use, groundwater flow, and water quality in the context of overall ground and surface water exchange processes.

While the USGS program is designed mainly to improve water quality monitoring and assessment in a critically water-deficient region, a recent Bureau of Reclamation (Department of the Interior) initiative has laid the foundation for further contacts between China and the United States in several other important water management domains. In May 1995, the Bureau cosponsored a "Symposium on Sustainable Water Resources Development" with the MWR. The symposium involved officials from both countries responsible for municipal water supply, regional water planning and management, agricultural water use, and other research, regulatory, and training activities in support of water sustainability goals. The symposium addressed water issues of major importance to both the United States and China, and provided an opportunity for officials on both sides to share perspectives and experiences in specific areas such as irrigation, urban water demand management, river basin planning, and water policy and law.

The symposium has had beneficial results that go well beyond scientific and technical information exchange. It directly facilitated contacts, for example, between Chinese officials and American firms interested in applying state-of-the-art low volume irrigation technology. One result of these contacts has been the establishment in China of about a dozen projects by a leading American international irrigation technology firm. The first project is well established in several fruit growing areas of Shandong. The success of the Shandong operation has led to additional open field, horticultural, and fruit growing irrigation projects that involve equipment purchases, installation, and transfer of technical knowledge in Liaoning, Ningxia, Heilongjiang, Hainan, and five other Chinese provinces.

The background of this firm's operations in Shandong is instructive. It illustrates the mutual benefits that can result from a well-managed U.S. government program when implemented at a scale and cost level commensurate with Chinese short-term water saving needs in a specific locale. Success also reflects U.S. and Chinese sensitivity to the importance of integrating technical aspects of the program with a realistic assessment of appropriate ways to overcome institutional barriers on the Chinese side while still promoting economic benefits for both China and the United States. In this case, the short-term economic benefits of water conservation and increased fruit production became so obvious to Chinese water officials, that one MWR official began to work part-time for the American firm to improve administrative and financial relations between the MWR in Beijing and its provincial counterpart.

There are two other exemplary U.S. programs in China that complement and enhance Chinese work by clarifying agricultural water needs and bringing technical, scientific, and management expertise to bear on specific agricultural water supply and river pollution problems. The first involves data collection and analysis of agricultural water availability and use in the Hai River basin by the U.S. Department of Agriculture's Economic Research Service (ERS). ERS field reporting primarily supports analysis of Chinese grain markets and growing conditions to help estimate potential U.S.-China trade in agricultural commodities, especially Chinese grain import needs. Assessment of Hai basin water needs and recommendations for improving the efficiency of water use through technical and economic measures, however, can also support Chinese efforts to improve water planning and management.

Another U.S. program which targets technical assistance with immediate application is the Environmental Protection Agency's technical cooperation agreement with China's State Environmental Protection Administration (SEPA). Initiated in 1995, this program has been designed to help improve industrial pollution monitoring and wastewater treatment as part of the SEPA-directed Huai River regional water pollution control program. Supported by the World Bank, the program is probably the most extensive inter-provincial environmental initiative in China.[12]

The program was established to develop cooperative basin-wide regulatory authority in Jiangsu, Anhui, Henan, and Shandong provinces to control untreated industrial wastewater discharges along the Huai River and its tributaries, and to force closure of firms that violate emission standards. It was established by the central government after a serious pollution event in 1995 caused massive fish kills and threatened the drinking water supplies of millions of Chinese. It is the first inter-province agreement with authority to allocate allowable pollution discharge levels by province. In late 1997, EPA organized and supported a workshop on monitoring techniques and has also contracted with an American environmental consulting firm to work with provincial officials to improve monitoring of industrial pollutants and to support enterprise-based industrial pollution prevention measures. Some polluting factories have already been closed. Institutional arrangements for pollution monitoring, assessment, and regulation developed for the Huai may also be applied in other areas such as the Hai River basin.

Conclusion

China's water problems are a major threat to its modernization drive. Worsening water shortages and vulnerability to natural hazards are an inevitable outcome of the dramatic transformation of rural landscapes accompanying market driven urbanization and increasing industrialization. Water surplus and deficits have always posed special challenges for state and society in China. These challenges were addressed locally through effectively implemented programs that sustained social and economic development while maintaining the biological integrity of food production systems despite the disruptive effects of floods and droughts, internal conflicts, external pressures, and environmental degradation. Engineering and institutional measures that counter water shortages and mitigate natural hazards build upon a long tradition of experimentation and knowledge to better understand how the water environment can be best managed to support a growing population on limited arable land. Earlier perspectives on state responsibility for managing the water enterprise are being modified to facilitate the integration of traditional center-directed technical and institutional approaches with modern, market sensitive, economic, engineering, and planning strategies. In a sense, China's water resources have always been in a state of "crisis." Water "crises," however, have been the driving force for adjustments in the relations between people and nature that have supported the longevity of Chinese society.

In this context, China's water problems present unusual challenges and opportunities in the wider frame of U.S.-China relations. Mutual efforts to address problems can help develop and maintain the quality of a critical resource. It is evident from two decades of official exchanges in water-related fields that there is growing interest among water professionals on both sides in furthering cooperative research and assessment programs, and in sharing information on engineering, economic, and scientific strategies for addressing short- and long-term problems. In the early 1980s when bilateral contacts were initiated, there was some resentment on the U.S. side that Chinese partners were taking advantage of the exchange protocols to improve their science and engineering after a long period of isolation from international science. U.S. participants found work with Chinese colleagues stimulating, but there was consensus among participants that the Chinese were probably benefiting the most.

This is no longer the case. In recent years, the most active programs have stimulated interest on both sides in expanding activities in China and the United States to help strengthen the Chinese water enterprise. A main goal is to improve understanding of how new approaches to water control, supply, conservation, and quality maintenance being developed in the United States can be most efficaciously applied in China. This is exemplified in the USGS water-quality monitoring activity described above, as well as in other areas. Both sides see that mutual benefits from the programs can be best achieved through clearly defined, precisely targeted, low cost activities that have immediate application in China and provide opportunities for U.S. companies to market technology and equipment.

A main obstacle to expanded activity on both sides is limited funds. This is unfortunate, as U.S. officials have indicated that small increases in funding could enable significant expansion of existing programs into new localities and increase Chinese participation. Chinese and American program managers are enthusiastic about extending programs.

There are many short- and long-term benefits to the United States from an expanded program of cooperation in water resources management. Water issues in China are closely tied to other important aspects of political and economic relations between the United States and China. For example, improved water conservation and hydropower expansion in support of a less coal-dependent energy policy will have a direct bearing on China's ability to meet emission reduction targets of the Framework Convention on Climate Change. Enhanced communication and mutual respect in water affairs will also benefit discussions in sensitive areas such as military cooperation and national security, as well as in attempts to resolve trade disputes.

The challenges U.S. agencies must overcome in sharing technical knowledge, engineering, and policy applications with China will also enhance the ability of U.S. federal and state water managers to address domestic water supply, control, conservation, and pollution prevention concerns. This experience will additionally help expand international commercial opportunities for U.S. management and consultant firms, and equipment manufacturers in areas such as irrigation technology, waste water treatment and pollution control, and ecosystem protection and restoration.

Perhaps the greatest benefit for the United States from this program will be the positive contribution it will make to strengthening the ecological foundation of China's economy at a time of rapid growth. Cooperation on water issues will help define specific opportunities and limitations in plans to achieve vague "sustainability" objectives in both countries' efforts to develop new technical and institutional strategies for water management. China's economic performance and political stability is closely dependent upon a stable, clean, and well-controlled water regime. U.S.-China cooperation in this area will contribute importantly to achieving these objectives.

As the global environment becomes increasingly stressed by human activity, the international community is faced with the difficult task of transforming rhetorical calls for multilateral action into practical programs that can mitigate pressing problems in specific places. The provision of fresh water and maintaining its quality have been a major focus of multilateral United Nations and national efforts since the early 1970s. It is clear, however, that inadequately funded and poorly administered global programs have not had a significant impact. The ecological and human effects of water development projects have become intolerable in many places and are having adverse effects on people and the environment. Basic sanitation facilities are unavailable for millions susceptible to waterborne disease. Prospects for increasing agricultural production and improving nutritional levels are problematic because of decreasing supplies of water for irrigation.

China's water problems pose an enormous challenge with global implications. As U.S. discussions with China focus more extensively on domestic and international environmental matters, existing water-related bilateral programs can serve as a foundation for the development of further ties to explore water dimensions of energy, agriculture, and other environmental concerns by building on successful small programs to expand opportunities into other problem areas. While broadly sketched, well-intentioned pronouncements on both sides of their commitment to poorly-defined "sustainable development" goals are appealing, good intentions are seldom transformed into productive programs.

Even when there is substantial high level dialog, as illustrated by the October 1997 promulgation of the U.S.-China Energy and Environment Initiative, it is becoming more evident that ongoing discussions of various approaches to enhanced U.S.-China environmental cooperation must include consideration of water dimensions of pollution, public health, ecosystem protection, land use planning, agriculture, and other areas.

Water concerns are, in fact, becoming a central focus of the U.S-China environmental dialog. Official efforts underway in the United States and China to develop an agenda for a late 1998 bilateral workshop on water resources management illustrate the difficulties on both sides of balancing technical and institutional goals in efforts to build cooperative programs. It is especially important that technical approaches to problem solving are framed so that they are sensitive to uniquely Chinese institutional and cultural constraints.

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Water Pollution and Human Health in China

By Crescencia Maurer, Changhua Wu, Yi Wang, and Shouzheng Xue

Over the past forty years, China has transformed itself from a rural economy to an industrial giant with a significant presence in the world economy. This rapid transformation boosted annual GDP growth to an average of 9.3 percent between 1980 and 1995, with forecasters predicting similar rates of growth in the near- to mid-term.[1] Unfortunately, China's rapid economic development has exerted a significant toll on its natural resource base, particularly water resources. Inadequate investment in basic water supply and treatment infrastructure has resulted in widespread water pollution. Today, approximately 700 million Chinese — over half the population—consume drinking water contaminated with levels of animal and human waste that do not meet minimum state drinking water standards,[2] and more than half of Chinese cities are experiencing severe water supply shortages. Official government statistics also record a steady increase in the total annual volume of wastewater produced, growing from 29 billion tons in 1981 to 37 billion tons in 1995. By the year 2000, the volume of wastewater produced could double from 1990 levels to almost 78 billion tons per year.[3]

However, the full health impact of this industrialization and modernization process—and its associated water pollution—has yet to manifest itself. The health consequences that result from changes in environmental conditions only begin to appear in health and epidemiological records after a decade or two.[4] This begs the question: *What are the implications of China's severely polluted water resources and the current economic development for public health?* This report analyzes this question, and points to the importance of adequate investment in environmental management to avoid irreversible damage to China's most important resource: its people.

I. Water Resources and Human Health

Water pollution and scarcity affect human health in three primary ways (Table 1). First, access to a minimum per capita amount of water is necessary to ensure physical survival and promote hygiene. Second, water serves as a pathway for exposure to microbial and contagious diseases. Therefore, drinking or bathing in water contaminated by animal or human excreta facilitates transmission and proliferation of disease vectors. China's water pollution exacerbates waterborne infectious and parasitic diseases such as hepatitis A, diarrheal diseases, typhoid, roundworm, guinea worm, leptospirosis, and schistosomiasis. Third, surface and groundwater can act as sinks or transportation routes for chemicals, heavy metals, algal toxins, and organic substances that produce chronic systemic illnesses, malignancies, and birth defects, and impair immune system function as a result of direct (drinking contaminated water) or indirect (consumption of plants or animals harvested from contaminated waters) exposure.

As countries begin to industrialize, they often undergo a health risk transition. Changes in environmental conditions alter the type of environmental health risks to which a population is exposed and, over time, influence the overall pattern of disease in the population.[5] This transition usually encompasses a shift from a predominance of traditional diseases (infectious and parasitic) to a predominance of modern diseases (cancers, heart disease, and respiratory diseases).[6] However, China's modernization has been unique in combining traditional environmental health risks, such as sewage irrigation, with modern environmental health risks, such as increased use of pesticides and fertilizers, creating a double health burden.

The beneficial effects of China's risk transition have already become evident. Social and economic development has led to clear health benefits for the Chinese people, and average life expectancy has increased from 35 years in 1949 to 70 years in 1997. During the same period, infant mortality fell from 200 per 1,000 live births to 31.4 per 1,000 live births. Reviews of available morbidity and mortality statistics also indicate that many chronic infectious diseases have declined significantly. Yet, as is indicative of a country in transition, chronic infectious diseases are still persistent.[7] For example, diarrheal diseases are still common (accounting for 6 percent of all mortality in 1990),[8] and cancers linked to infectious agents—liver, stomach and esophageal cancers—are the leading cause of cancer mortality in rural China.[9] Relative to other developing countries, Chinese deaths from communicable diseases are considerably low, (15 percent versus 31 percent in Latin American countries and 51 percent in India), while deaths from non-communicable diseases are much higher (73 percent versus 55 percent in Latin American countries and 40 percent in India).[10] These statistics demonstrate that China has relatively low, but still significant, mortality from traditional risks, while mortality from modern risks approaches levels of developed countries (87 percent in mature market economies).[11] The relationship between water and health in China may hold the key to how environmental factors will shape China's present and future patterns of disease. This double burden of traditional and modern

Table 1: Health Risks Associated With Water Pollution

REMOVE BOXES

*Water—particularly discharge of untreated industrial sludge or wastewater into water bodies—is just one of several potential exposure routes. Source: *Health and Environment in Sustainable Development: Five Years After the Earth Summit*. Geneva: World Health Organization, 1997.

ailments poses a significant challenge to China's health care system.

II. The Health Impacts of China's Declining Water Quality

The water resources and public health literature indicates three principal contributors to water pollution and degraded water quality in China that threaten human health: (a) rapid and unregulated expansion of industrial activities; (b) growth of urban and suburban areas without adequate investment in water supply infrastructure; and (c) increased use of pesticides and fertilizers combined with a continued reliance on sewage irrigation.

A. Rapid Industrialization

The transition from a command economy to a market economy has brought tremendous change to China. Indicative of this transformation, the contribution of state-owned enterprises to overall economic production in China has declined, while township-village enterprises (TVEs), and other parts of the private sector, are playing a larger role. The economy's high growth rate (largely fueled by TVEs) coupled with structural shifts in the economy, has exerted extraordinary pressure on a variety of natural resources, particularly water.

These pressures are perhaps best exemplified by China's slow yet steady increase in the production of wastewater.[12] Between 1981 and 1995, the volume of wastewater produced in China increased 27.8 percent, an average annual increase of 1.65 percent. In 1995, China discharged 37.29 billion cubic tons of wastewater into rivers, lakes, and reservoirs, with industrial wastewater discharges accounting for approximately 60 percent of this total. However, an interesting trend has developed in recent years: the contribution of industrial wastewater to overall wastewater discharges has declined, mainly due to shrinking state-owned enterprise production levels (Figure 1). As SOE discharges have decreased slightly, though, discharges from TVEs have more than made up for the difference. Largely unregulated TVEs have not only increased overall wastewater discharges in China, but their emissions also generally contain a higher level of pollutants than emissions from SOEs.

Figure 1

Sources: *China Environment Yearbook*, 1996; *Collection of China Environmental Statistics*, 1981- 1996.

Township and village enterprises, by definition, are the various enterprises established in villages and towns with the majority of investment (more than 50 percent) garnered from rural collective organizations or farmers. Started in 1958, TVEs are playing an increasingly important role in all sectors of the Chinese economy. A subset of TVEs, township and village industries (TVIs), account for the majority of China's phenomenal increase in industrial output. In 1994, TVIs accounted for 42 percent of the total national industrial output (compared to 23.8 percent in 1989), and for 55.4 percent of the total rural GDP.

A conservative estimate holds that TVIs discharge approximately half of the total industrial wastewater that is monitored, or more than 10 billion tons. In 1994 alone, TVIs discharged 4.3 billion tons of wastewater, or 16.6 percent of the total discharged nationwide. Most of these TVIs have no wastewater treatment facilities, and are widely scattered across rural areas. As a result, the contribution of TVIs to the total share of water-borne pollutants is substantial. In 1989, the average discharge densities of TVI wastewater for organic matter (COD), heavy metals, cyanide, and phenol were respectively 3, 2.2, 3.3, and 9 times higher than urban industries.

Three particular types of TVIs account for the majority of wastewater discharges: paper and pulp mills (806 million tons of wastewater, or 30.03 percent), chemical industries (159 million tons, or 5.93 percent), and metal dyeing and staining plants (123 million tons, or 4.57 percent). Table 2 displays the contribution of TVI wastewater discharges to overall industrial pollution.

Not surprisingly, wastewater released by TVIs appears to be linked to adverse health effects. A 1989-91 study[13] of ten major TVIs in Beijing, Liaoning, Jiangsu, Shandong, Guizhou, Guangdong, and Hubei concluded that discharges from these small enterprises were affecting local drinking water systems. COD, acids, alkalis, nitrogen, phosphate, phenols, cyanide, lead, cadmium, mercury, and bichromate were among the major water pollutants released by the TVIs studied, and the pollutants were consequently found in bodies of water near rural residential areas. Monitoring results proved that all of the major pollutants analyzed exceeded levels necessary to meet national standards for water quality. Among them, mercury concentrations were between 45 to 700 percent in excess of the government standard, and concentrations of lead were 3,600 to 5,216 percent greater than the standard allowed.

Several studies also suggest adverse effects on pregnant women and young children living in areas with high levels of industrial wastewater discharge. One study compared pregnancy outcomes in a heavily industrialized township (Zhenzhe Township, Wujiang County, Jiangsu Province) with those in nearby Songling Township (15 miles away) that is of comparable size but is absent of heavy industrial activity.[14] Zhenzhe township has ten dying and staining

Table 2. Major TVIs and Their Contribution to Wastewater Discharge, in thousands of tons.

Source: Cao, Fengzhong. 1997. "TVIs Air and Water Pollution in China." Internal White Paper Report. Policy Research Center for the Economy and the Environment. State Environmental Protection Administration.

plants that discharge 13,356 tons of untreated wastewater every day into a local river, which has high average concentrations of aniline (0.393 mg/L) and phenol (0.05 mg/L). In 1991, the overall abnormal pregnancy outcomes (including spontaneous abortion, fetal death, premature birth, still birth, and infantile death) in the surveyed area were 108 out of 610 pregnancies (17.7 percent). In contrast, abnormal outcomes recorded in Songling Township totaled 23 out of 336 pregnancies (6.85 percent).

A second study concentrated on populations living in and around Weishan Lake, where there has been phenomenal growth of TVIs. This study found that birth defects in the Weishan Lake area had sharply increased between 1981-83.[15] In those three years, sewage and industrial discharges correspondingly increased to approximately 130 million tons per annum, and levels of COD, phenol, mercury, lead, and arsenic exceeded national water quality standards. The Department of Environmental Health of Shandong Medical University surveyed major birth defects (27 out of 1,747 births) among residents living around the lake, and determined that 28 percent of malformations were significantly associated with the pollution of lake water, while 19 percent were considered related. The overall relevance between birth defects and water pollution was 47 percent.

A third study points to adverse effects on the physical and mental development of children residing in the same Weishan Lake area.[16] Results from a set of physical and mental tests (height, weight, bone, hemoglobin levels, immunoglobin levels, IQ tests, and running and jumping exercises) performed on children living in the Weishan Lake area were compared to results from children residing in a control area. The children in the control group consistently outperformed those who lived near Weishan Lake. For example, results from IQ tests averaged 97.57 among the control group, but only 91.33 among Weishan Lake children.

Elevated cancer rates have also been associated with industrial pollution of drinking water supplies. A 1987-88 study of two villages (Xujia and Xizhou), located in an area where drinking water supplies were polluted by petroleum industries, examined gastro-intestinal diseases and cancer mortality rates among local residents.[17] Deep groundwater, the source of village drinking water supplies, was heavily contaminated by hydrocarbons such as aliphatic and aromatic alkenes, phenolics, aldehydes, ketoses, acids, and esters. The concentration of petroleum derivatives was 0.078-0.500 mg/L, volatile phenolic 0.001-0.003 mg/L, and sulfides 0.059-0.451 mg/L. A significant increase in the rate of hepatomegaly among adults and children was found, as were increases in overall cancer mortality, particularly cancers of the gastro-intestinal tract (Table 3).

B. Urbanization

Each year, over 30 billion tons of urban sewage in China is discharged into rivers, lakes, and seas, with less than 2.7 percent receiving any prior treatment. Untreated sewage usually contains large numbers of pathogenic micro-organisms such as schistosomial ova, cercaria, and ova of parasitic flukes and worms.[18] The majority of urban river sections are also polluted to varying degrees by chemicals and toxic compounds, including petroleum, volatile phenol, permanganate, and mercury. These discharges have had a significant impact on urban water quality: in 1994, 131 out of 135 monitored river sections in urban areas failed to meet designated water quality standards. Furthermore, 34 out of 66 urban river sections in the north and 18 out of 69 in the south failed to meet even the lowest water quality standard, Grade 5.[19]

Most water pollution in urban areas is caused by woefully inadequate treatment of municipal organic sewage directly entering water bodies.[20] In 1995, only 100 centralized sewage treatment plants were in operation nationwide, with an annual treatment capacity of one billion tons. This treatment capacity is less than 5 percent of the total Chinese sewage discharged annu-

Table 3. Effect of Drinking Water Supplies Polluted by Petro-Chemical Industrial Wastewater on Village Residents.

Source: Zhe, Shenyong et al. "Investigation of the Effect of Drinking Water Polluted by Petroleum Chemical Industrial Waste Water on Village Residents." *Journal of Environment and Health* 8(5) (1991):193-195.

ally.[21] Beijing, for example, is served by only one secondary sewage treatment plant with an annual capacity of 500,000 tons: this capacity is far too low to handle the increasing discharge of household sewage in the city.[22] Low sewage treatment levels result in widespread contamination of drinking water supplies, and in turn significant episodes of illness (Table 4).

Low levels of sewage treatment are exacerbated by inadequate treatment of drinking water. Of the twenty-seven largest Chinese cities, only six supplied drinking water that met government standards; groundwater did not meet state standards in twenty-three of these cities.[23] The situation is just as bad—or even worse—in Chinese rural towns and medium-sized cities. A survey of drinking water plants in Hubei Province found that only one in eight consistently chlorinated water. As a result, half of the people served by these plants suffered from infectious intestinal diseases between 1986 and 1988. The lack of chlorination in Hubei Province continues to expose citizens to traditional health risks, even when piped drinking water systems are in place (Table 5).[24]

Given the lack of water infrastructure and treatment in China, it is not surprising that several million people are afflicted with intestinal diseases every year. Approximately 1.5 million Chinese contract schistosomiasis annually, and several thousand of these suffer acute schistosome infections. Hepatitis A, bacterial dysentery, infectious diarrhea, para-cholera, and typhoid are also common. In 1991, the average incidence of typhoid fever in China was 10.6 per 100,000 people—any incidence greater than 10 per 100,000 is considered high by the World Health Organization (WHO). Yet, nine of China's thirty provinces had average typhoid fever incidence rates above this already high national average. In addition, most of the prevailing strains of bacteria prevalent in China are drug resistant due to the widespread use and abuse of antibiotics to combat infectious diseases.

Inadequate water and sewage infrastructure is not the only problem plaguing urban water resources. The growth of new agricultural activities in and around urban areas is also aggravating drinking water supply problems. The cultivation of "vegetable baskets" in suburban and urban areas

Table 4. Cases of Illness Associated with the Contamination of Water Supplies

Source: Cao and Xu, 1989, p.27.

Table 5. Intestinal Infections from Drinking Treated Piped Water vs. Untreated Well Water in the City of Baoji, 1990

Source: Li, Y. et al, 1994, p.109.

has expanded rapidly to satisfy the produce needs of city residents. These plots are usually irrigated with sewage, and fertilizer and pesticides are often applied to raise productivity. Furthermore, urban poultry farms and small-scale household husbandry have also expanded rapidly to meet the demand of city residents for meat, eggs, and milk. These operations generate considerable animal waste inside or in proximity to cities. Research studies on the links between sewage irrigation in urban areas and cancer mortality point to serious health effects.[25] A study of Baoding City, which constructed a sewage storage and drainage project that disposes of 250,000 tons of sewage per day into Baiyangdian Lake, examined cancer mortality in 1994. Comparing their data with that obtained from a control group, it was found that the rates of esophageal and liver cancer were three times those of the people living in the control area (Table 6). In addition, people in the Baiyangdian Lake area exhibited higher incidences of anemia and elevated immune responses.

An increased reliance on groundwater supplies in many urban areas has also become problematic. Many urban areas are dependent on groundwater as a source of drinking water because they lack the treatment facilities necessary to adequately filter surface water supplies. However, the pollution and over-exploitation of groundwater has become more common, creating crises in many Chinese cities. More than 300 of China's 640 cities are facing water shortages, with a total annual shortage of nearly six billion cubic meters. According to NEPA, of these 300 cities, 100 are experiencing severe shortages. This problem is most acute in northern China, where many cities have been forced to increase their extraction of groundwater due to annual water shortages. In 1995, seventy-seven large and medium cities extracted 8.1 billion cubic meters of groundwater within their city limits. While there is very little data about recharge rates, anecdotal evidence suggests that urban water tables are dropping significantly. Groundwater extraction is contributing to surface subsidence and salt water intrusion along coastal zones, and is increasing the cost of pumping drinking water.[26]

C. *Intensification and Modernization of Agriculture*

China's agricultural economy has undergone rapid transformation in the past fifteen years. Beginning in the 1980s, farmers were permitted by the state to sell surplus produce on the open market. This created incentives to increase agricultural productivity, and to adopt green revolution technologies such as intensive fertilizer and pesticide use combined with improved hybrid seeds. Between 1990 and 1996, China's production of active ingredients for pesticides increased from 210,000 tons[27] to 230,000 tons.[28] After Japan, China is Asia's largest user of pesticides, most of which are hand sprayed over more than 100 million hectares of cropland.[29] Fertilizer use has also increased dramatically: NEPA reported that the use of fertilizers rose from 25.9 million tons in 1990 to 33.1 million tons in 1994.[30]

Increased pesticide and fertilizer use has resulted in dramatically worsening non-point source pollution in China. The increase of nitrates in China's groundwater has been directly linked to the increased use of nitrogen fertilizers, and to the inefficient application or over-use of these substances. One problem is that only 30 percent of fertilizers applied to agricultural crops are used effectively, and most of what is applied is lost through soil erosion and run-off caused by rainfall.[31] A survey by the Chinese Academy of Agricultural Sciences of nitrate levels in the drinking water of fourteen counties in northern China found that 37 of 69 groundwater monitoring sites had nitrate levels in excess of the maximum allowable content for drinking water.

Excessive use of fertilizers, the prevalence of phosphate based detergents, and the discharge of human and livestock excreta into the lakes of intensively farmed provinces is leading to their eutrophication.[32] Lakes in many intensively farmed provinces south of the Yangtze River are choked with dense algal growth. Nitrogen and phosphorus levels in Chaohu Lake and Dianchi Lake exceed the maximum safe limits by two to eight times. Taihu, the third largest freshwater lake in China, has become a large sink for agricultural and rural effluents generated in Jiangsu and

Table 6: Pollution and Health Effects on Residents of a Sewage Storage Area

Source: Hu, Jinran. "Status of Ground Water in the Sewage Storage Project in the Upper Reach of Baiyangdian and its Influences on the Health of Residents." *Journal of Environment and Health*. 14(1) (1994):3-5.
*Other pollutants, such as cyanide, arsenic, lead, chromate, and mercury were frequently detected in part of the wells in this area.
**Adjusted mortality per 100,000 (10^{-}). Figure in bracket is the standardized mortality ratio (SMR).
***Rate of phagocytosis of polynucleated white cells. These indicated an immune system response.

Zhezhiang Provinces.[33,34] Many freshwater lakes are in advanced stages of eutrophication, leading to the extinction of aquatic species in some cases. In turn, the proliferation of algae has affected water supply sources and forced the temporary closure of drinking water plants.[35]

Algal blooms, however, are the source of another far more serious threat to human health: algal toxins. Blue-green algae produces toxins that have been associated with increased incidences of liver and other cancers. The suspected association between algae and cancer began with the identification in the late 1970s of increased liver cancer among people drinking heavily polluted water.[36] In particular, a Chinese survey of cancer mortality found that the county with the highest cancer mortality rate was also the one with the most polluted surface water.[37] Analysis of the correlation between organic pollution in drinking water (measured as chemical oxygen demand or COD), and liver cancer mortality in twenty-nine provinces (2,072 counties) also showed a very strong association.[38]

Microcystins and nordularin, which belong to a set of toxins known as phycotoxins, are the two main toxins present in eutrophic water that have been linked to liver and other cancers. These two toxins, however, represent only a few of the phycotoxins present in eutrophied waters. In fact, more than 80 percent of 480 algae samples taken from surface waters collected throughout China were found to contain a variety of toxins.[39,40] A number of studies, including short-term assays, intact animal experiments, chronic feeding assays, and epidemiological surveys, have demonstrated the etiological role that algal toxins have played in the pathogenesis of liver cancer.[41,42] Even when the presence of hepatitis B viral infections, ethnic or genetic susceptibilities, and alcohol consumption were factored in, the risk of liver cancer associated with the consumption of polluted drinking water taken from eutrophied sources was still over two times greater than from unpolluted sources.[43,44]

In addition to widespread fertilizer and pesticide use, Chinese farmers continue the traditional agricultural practice of irrigating crops with human and animal excreta. Acute water shortages have also led to a relatively new practice: the use of industrial wastewater for irrigation. Tests carried out in the Dongxiang area of Tianjin, where sewage irrigation has been common for more than 30 years, revealed that sewage mixed with industrial wastewater had been used to irrigate the region's farmland. As a result, carcinogens had accumulated in soil, groundwater, and vegetation, creating the potential for bioaccumulation in humans.[45]

The threat to human health from the use of industrial wastes to irrigate agricultural crops is illustrated by the example of the Shengfu irrigation area near the city of Shenyang. In the early 1960s, a seventy kilometer irrigation canal was built in this area to supply 13,000 acres of land with water. The canal drained approximately 400,000 cubic meters of untreated wastewater from coal mines, petrochemical, power, and chemical plants each day. According to a study in the late 1980s, the area

Table 7. Cancer Mortality and Birth Defects among Residents in Shengfu Irrigating Area.

Source: Deng, Shujun, Shushen Yang, and Shuchiao Zhao. "Epidemiological Study of Cancer Mortality and Congenital Malformation in Petroleum Sewage Irrigated Area." *Chinese Journal of Preventive Medicine*. 21(5) (1987):265-267.

* The mortality statistics provided are adjusted to take into account differences in cancer mortality among different age categories of the population.

served by the canal consequently had a strikingly higher incidence of liver cancer, lower average age of death from cancer, and higher numbers of birth defects than other areas of the country (see Table 7). Evidence of a relationship between industrial wastewater irrigation and elevated rates of birth defects is provided by a separate health study. From 1985 to 1988, a village that relied on industrial wastewater for irrigation experienced an elevated number of congenital deformities per thousand births (67.42) than a control village (20.07).[46]

Similar to the pattern observed in urban areas, China's rural populations are exposed to a mixture of traditional and modern health risks. In rural areas, however, these risks appear to be more severe because drinking water sources are largely unregulated, and pre-treated piped water supplies are not as widely available. Nearly 610 million people—mostly from rural areas—secure drinking water by carrying it from a source near their home. In 1993, a national survey of rural drinking water revealed that groundwater accounts for approximately 70 percent of rural drinking water (both piped and well water sources), representing only a slight increase from 1985. The share of the rural population with access to piped water supplies grew to just 47 percent. However, only 55 percent of these piped water supplies received any form of pre-treatment.[47] In sum, only one quarter of China's rural population has access to drinking water supplies that can reasonably be deemed safe for consumption.

D. Interactions and Compounding Effects

The decline in China's water quality is the result of several important managerial and technical shortcomings. The two main managerial deficiencies are: (1) China's failure to manage or balance competing water uses, and (2) China's failure to make protection of public health a priority. Woefully inadequate investment in drinking water supply and sewage treatment infrastructure is the chief technical deficiency. The outcome of these shortcomings is increased numbers of "water pollution accidents" in China. These accidents are usually triggered by hydrological crises (floods or droughts) that overwhelm the existing infrastructure (e.g. force the release of industrial waste or cause sewage overflows) or limit the supply of freshwater available to meet the demands posed by competing uses.

Water pollution accidents in China are becoming more common and producing increasingly adverse impacts on human health. Approximately 2,000 to 3,000 environmental accidents are recorded annually in China, of which more than 1,000 are related to water pollution events—more than the fraction attributed to severe air quality problems (see Table 8). Water pollution accidents affect human health largely by contaminating drinking water. An investigation carried out by the Chinese Academy of Preventive Medicine surveyed environmental pollution accidents in a set of provinces and cities between 1981 and 1987.[48] This survey indicated that 115 of the 199 recorded environmental pollution accidents led to human health damage. Approximately 77 percent (88 cases) were directly linked to the pollution of drinking water. A survey covering the 1986-1990 period reported that 111 out of a total of 164 environmental accidents that adversely affected human health were linked to the pollution of drinking water.

Flooding associated with water pollution accidents also creates conditions that potentially lead to disease outbreaks or, in the worst case, epidemics. Massive flooding can result in the overflow of pits or holding tanks used to store animal and human excreta, and can also carry dead animals into surface water supplies. Incidence of hepatitis A, dysentery, and diarrheal diseases usually increase after flooding incidents. One study indicated that hepatitis A increased more than two-fold among adults and almost eight-fold among children in areas that experienced flooding.[49]

III. Conclusions

Mortality and morbidity statistics for diseases associated with traditional risks in China are low in relation to those of other developing countries such as India, and those in Latin America,[50] but the evidence gathered in this study indicates that human exposure to infectious agents is increasing the rate of diseases not normally associated with traditional risks. Industrial growth, particularly from TVIs, has occurred outside of central government environmental management systems, and is only regulated to the degree that local bureaus and authorities choose to exercise such authority. In addition, agricultural modernization has led to large increases in the production and application of agro-chemicals, further degrading water quality. Traditional and modern sources of disease risk appear to share many of the same exposure routes or pathways. Examples of combined traditional and modern pollution sources include: (1) the explosive growth in pesticides and fertilizer use combined with a continued reliance on sewage irrigation; (2) the practice of applying industrial wastewater to agricultural crops in regions with severe water shortages; and (3) increased agricultural activities in urban areas with high population densities.

The implications of this combined set of traditional and modern risks on China's environmental health risk transition are significant. First, morbidity and mortality associated with infectious and parasitic diseases may not continue to decline in China. In fact, the evidence assembled points to the potential for actual increases in infectious diseases. Worsening water supply shortages, more intensive use of agro-chemicals, and continued industrial expansion will increase the amount of human, animal, and industrial waste entering surface and groundwater streams. These trends do not bode well for the protection of drinking water supplies. Second, the combined exposure to both traditional and modern risks could drive increases in non-communicable disease. For example, deaths from liver and gastric cancers in China account for approximately 40 percent of all deaths from malignant neoplasms. This is far higher than the rate in developing countries (roughly 11 percent of all cancer deaths in India) or established market economies, where they account for 10 percent of all deaths.[51] Stomach and liver cancers are linked to exposures of infectious agents (H. pylori and hepatitis B), and some of the studies reviewed have noted associations between gastric diseases and elevated cancer rates in areas irrigated with human excreta as well as industrial wastes.

In sum, the evidence assembled indicates that water pollution is playing a highly significant role in shaping China's environmental risk transition. Attention to, and correction of, the water pollution problems discussed would generate large public health benefits for the

Table 8. Environmental Pollution Accidents and Episodes.

Source: NEPA, *Environment Statistical Survey*, p.12, 1996.

Chinese people while also cleaning water supplies for industrial and agricultural use, and economic growth.

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International Fund for China's Environment

The International Fund for China's Environment (IFCE) was established by a group of concerned scientists and professionals in 1996. The mission of IFCE is to help ensure the protection of the world's environment and its biological diversity by providing assistance to aid China in resolving its environmental problems. IFCE is a non-profit organization with its main office in Washington, D.C., and a branch office in Beijing, China.

IFCE develops projects in three main areas: environmental education, nature conservation, and technological and information transfer. In environmental education, IFCE is developing training centers for natural resource and environmental management, and is helping Chinese universities develop environmental programs. In nature conservation, IFCE cooperates with the Chinese Wildlife Detection Center of the Ministry of Forestry and the Chinese Wildlife Association to preserve Siberian tigers and other endangered animals and species. In technological and information transfer, IFCE organizes symposiums and seminars on China's environmental issues both inside and outside China. IFCE is also cooperating with agencies in China to introduce cutting-edge technologies that will help improve nature reserve management, air and water pollution control, and solid waste and hazardous materials treatment. In addition, IFCE publishes a quarterly newsletter that covers China's environmental problems, conservation practices, and IFCE activities.

IFCE consists of a Board of Advisors, a Board of Directors, and a membership network. For further information, please contact Dr. Ping He, President, IFCE, P.O. Box 3280, Fairfax, Virginia 22038. Telephone: 703-222-1280; Fax: 703-830-3951. You can also find additional information on the IFCE home page at http://www.ifce.org/.

Greening the Chinese Media

By Wen Bo

THE CHINESE MEDIA IS UNQUESTIONABLY A POWERFUL AND VALUABLE channel for disseminating environmental information and shaping public opinion: with its nearly 1.3 billion population, China has over 300 million radios, 250 million television sets, and 5,500 newspapers. Newspaper circulation in China exceeds 20 billion copies per year, with over 50,000 journalists covering daily events. Television is also a major source of news, reaching 84.5 percent of the Chinese population.[1] The media's strength lies in its ability to reach millions of people regardless of their rank, place in society, or affluence. Chinese urbanites, as well as residents of remote Chinese villages, rely on television, radio, and printed media news coverage for knowledge about both global and domestic environmental events. Newspapers and television have correspondingly become powerful networks and the largest means of disseminating information on environmental protection.

Environmental reporting in China first emerged with coverage of international environmental events, including worldwide Greenpeace demonstrations. In the mid-1980s, news about Greenpeace could often be found on all the major Chinese broadcasting stations, particularly Chinese Central Television (CCTV), as well as prominent newspapers. The goal of this reporting was not to raise awareness of environmental issues in China, but to highlight the opposition of the demonstrators to major industrial complexes and western governmental policies. Since this type of reporting was not harmful to Chinese authorities, it was prolific and supported by the central government.

However, beginning in August 1995 when five foreign Greenpeace activists demonstrated in Tiananmen square against nuclear testing in China, and continuing with the journey of the Rainbow Warrior into Shanghai Harbor to protest China's nuclear testing in the summer of 1996, Greenpeace's protests were no longer considered appropriate by the Chinese government for media coverage. Chinese authorities realized that the public was learning about western advocacy and dissent through coverage of environmental issues, and that the actions of Greenpeace and others were harmful to Chinese government policy. Consequently, all coverage of Greenpeace was banned, and reporting of international environmental activities was concurrently reduced.

With the Chinese media no longer allowed to focus on international environmental movements, it began to increase coverage of burgeoning environmental activities within China. After the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro, the Chinese government embarked on an environmental publicity campaign and increased awareness of many public holidays and events such as Earth Day, World Environment Day, World Water Day, World Ozone Day, Bird Loving Week, and Wild Animal Protection Awareness Month. At the same time, the amount of environmental reporting on official conferences and government-organized activities in China increased.

Although such media coverage improved the knowledge of environmental issues among the Chinese public, it was rarely able to promote public involvement in environmental activities. Media coverage of environmental issues was limited to lecturing the public on the need to protect the environment, but failed to inform people on how or what they should do.

The early signs of grassroots initiatives nonetheless began to emerge as the public started to organize itself and take part in activities such as picking up trash around Hangzhou's West Lake, planting trees in the Engebei Desert of Inner Mongolia, or watching birds in the outskirts of Beijing. Media coverage of these activities raised general environmental awareness and encouraged environmental action and involvement.

As general interest and government involvement in the environment increased, so did media coverage of environmental issues. Results of this increased coverage can be seen through the volume of articles produced in 1996: China's seventy newspapers carried 17,555 environment-related articles in that year, and environmental reporting accounted for 1.01% of the total news coverage in 1996, almost double that of 1995.[2]

Stories about individual environmentalists also grasped the attention of the media and the public. The actions of these environmental leaders were influential, provoking many others to follow suit. In the past few years, the media has provided the support necessary for environmental initiatives to gain public and governmental backing.

Structure of the Chinese Media

Chinese media has developed very differently from Western media. While most Western media organizations are private, and have been developed independently from governmental influence, Chinese media organizations are started by government agencies and primarily act as agency spokespeople. These state-owned media groups, which include the large and influential Xinhua News Agency, Chinese Central Television

(CCTV), and China Central Radio Station, serve as the framework for the entire Chinese media structure and exercise a great deal of power in determining which stories can be covered and what approach journalists should take when reporting a story. Descriptions of some of these influential state-owned media groups are listed below.

Xinhua News Agency

The largest news group in China, Xinhua News Agency has established a vast media network that covers every region of the country. The agency not only provides news to nearly every national and provincial newspaper in China, but also controls several influential newspapers and magazines such as *Xinhua Daily Telegraph*, *Reference News*, and *Outlook*. Xinhua News Agency has become an authoritative voice for the Chinese government, forcing other news agencies to conform to its perspective when covering large events or sensitive issues.

Chinese Central Television and the Central Broadcasting Station

Due to its popularity and vitality, Chinese Central Television is the most influential media outlet in China. Its broadcasts reach a total population of 0.9 billion, ranging from large cities to small villages. The Central Broadcasting Station (CBS) of China is another main source of information. According to a survey conducted in October 1997, the three channels of CBS reach a total population of 659 million Chinese between the ages of twelve and seventy-nine.[3]

Internal Reference

Special memos, called Internal Reference (*Nei Can*), are also very influential. Written by the major newspapers solely for government leaders, the memos are usually limited to issues of utmost importance to the government. The Internal Reference only circulates 50 to 100 copies each day at the central level, with its distribution focused on the highest levels of office. The information contained in these Internal Reference documents is therefore more influential than the stories in public newspapers because the Internal Reference directly reaches Chinese decision makers.

Other Influential Media Outlets

A few popular newspapers such as *China Youth Daily* and *Southern Weekend* are also well received by readers. Recently, *Southern Weekend* significantly increased its coverage of in-depth environmental reporting, drawing a great deal of public attention.

Another form of Chinese media is professional newspapers (*hang ye bao*), which are started by ministries and governmental institutions. These papers focus on a specific field. For example, the National Environmental Protection Agency (NEPA) set up its own official newspaper, *China Environment News*, in 1984.

From a Western point of view, almost no media group in mainland China can be considered independent. Most newspapers are sponsored by Communist Party Committees at different levels or ministries, as well as the newspaper's regional level offices. Therefore, media groups have ranks (*ji bie*) and administrative levels similar to those found in the government. The higher the status of a Chinese newspaper, the greater its relative independence. For example, the Xinhua News Agency and *People's Daily* have reached a ministerial level, and the *China Daily*, *Guangming Daily*, and *Economic Daily* have reached a vice-ministerial level, enabling them to report more freely than other, lower-ranking papers. Government agencies and enterprises are required to subscribe to these "party newspapers" (*dang bao*), and the highest ranking officials at these papers are promoted to their posts due to their loyalty to the party or to higher level officials, rather than for their journalistic talents or management skills.

The relationship between the government and the media can sometimes hamper environmental reporting. In the 1950s and 1960s, misguided governmental policies caused serious ecological destruction. Most of the forests in Xishuangbanna of Yunnan Province, for example, were clear-cut for a monoculture rubber plantation. In other parts of the country, lakes and wetlands were converted into farmland. Though many villages and wildlife fell victim to these government actions, the media, acting as a propaganda machine for the government, reported these events as significant achievements, without regard for their environmental impact. With government-controlled coverage as the sole source of information, the entire country was engaged in a development plan that was severely detrimental to the environment.

Newspaper and Print Media

Several Chinese newspapers and newspaper columns have emerged during the past two decades to report specifically on environmental issues. These papers and columns have not only been important in raising public awareness of environmental issues, but have also served the vital purpose of promoting and publicizing government- and NGO-led efforts. Some examples of these newspapers are listed below.

China Environment News

The first national newspaper specializing in environmental issues, *China Environment News* (CEN), began publication in January 1984 after its inauguration at the Second National Environmental Protection Conference. During the 1980s, *China Environment News* was a groundbreaking newspaper, reporting on a broad spectrum of environmental issues that other papers were reluctant to cover. As the only outlet for coverage of environmental issues, *CEN* quickly became popular: in the late 1980s, *China Environment News* was published three times a week, with a total circulation of approximately 500,000.[4]

Since its establishment, *China Environment News* has been the easiest means for the Chinese public to obtain environmental information. Even today, environmental journalists from across the country consult current and back issues of *China Environment News* for story ideas and research assistance.

China Environment News currently publishes four issues per week, and a weekend edition named, "The Weekly." The daily editions of *CEN* focus on important domestic, and even global, environmental issues, with additional columns discussing issues such as environmental education, environmental literature, environmental law, environmental science and technology, and international environmental news.

The weekend edition breaks away from the traditional structure of the daily *CEN*. While the articles which appear in the daily conform more closely to government policies, the front page of The Weekly usually publishes at least one in-depth story per week which is often critical of government policy. Last year, The Weekly published a series of reports on vehicle emissions, which were the first public outcry against air pollution from leaded gasoline. These reports raised public awareness about the health impacts from vehicle emissions and led government officials to begin exploring the possibility of banning leaded gasoline in urban areas.

Green Weekly

At the end of 1994, Liu Zhenwu of *Science and Technology Daily* started a four-page column entitled *Green Weekly* covering both domestic and global environmental issues. The broadly-based readership of a comprehensive paper such as *Science and Technology Daily* exposed an entirely new group of citizens to environmental concerns. Although the column received a great deal of public support, it failed to turn a profit for the paper and, after the departure of Liu Zhenwu, shifted its focus from environmental protection issues to environmental industry concerns.

China Green Times

Formerly known as *China Forestry News*, *China Green Times* is a daily newspaper that operates in cooperation with the Forestry Bureau. The newspaper originally focused on the forestry industry, but in 1995 it began publishing *Green Weekend*, a weekly edition that focused on nature conservation. Beginning in late 1997, the entire newspaper shifted its focus from forest industry issues to conservation. In 1998, the newspaper changed its name to *China Green Times*, and widened its scope to cover every aspect of environmental protection.

China Green Times was founded with the purpose of engaging in China's environmental movement, and has quickly emerged as a respected voice against wide-spread ecological destruction.

Environmental Protection Herald

Based in Chongqing, which is now the fourth municipality directly under the central government, *Environmental Protection Herald* was established jointly by a number of major environmental agencies in Southwest China. The newspaper focuses primarily on environmental issues in the region but has recently expanded its focus to cover issues far beyond the Southwest.

Media and NGOs

It has been said that 99 percent of the global environmental movement is built on the media.[5] Likewise, the Chinese environmental movement and NGOs depend heavily on the media to promote and publicize their environmental activities. Positive media coverage is crucial for environmental NGOs: it can raise their profile, garner public support for their cause, and bring them recognition from the government.

A good example is the NGO Global Village Environmental Culture Institute, established by Liao Xiaoyi in 1994 and registered as a nonprofit company under the Chinese Commercial Agency. While the organization operates as an NGO, it also functions as a media group that produces environmental programs which are regularly aired on CCTV and written up in an environmental column appearing in several newspapers. For instance, a program about battery recycling informed people how to dispose of batteries, where and how they should recycle them, and whom they should contact for more information on battery recycling. Print and television media coverage has become an essential instrument in promoting Global Village's activities and has given audiences an opportunity to become aware of, and involved in, Global Village's programs and beliefs.

Another successful example of the link between NGOs and the media can be seen in the case of Friends of Nature (FON), which was established by Liang Congjie in 1993 as a Western-style NGO under the Academy of Culture. Many of the over 400 members of FON are journalists, reporters, and teachers who are also environmentalists. Activities such as the 1995 Free the Caged Bird to the Blue Sky Campaign brought people together to question the long-time Chinese tradition of rearing songbirds, many of which are caught in the wild. During the campaign, FON's release of several birds attracted widespread media coverage and sparked public debates on the issue. The campaign not only questioned the captive raising of birds, but also provided the answer—bird watching. FON subsequently organized groups of citizens to go bird watching in the green outskirts of urban Beijing. FON's activities attract wide media coverage because of its media-based membership and the regular publication of a FON newsletter. This newsletter informs members about issues and events, and provides new material that many of the media-based members write about in their respective newspapers or magazines. Other members have used the information contained in the newsletter to start their own projects or campaigns.

The joint effort of media and NGOs to raise environmental awareness and instill a sense of personal responsibility for the environment should not be underestimated. In the past, the government maintained that environmental protection was the responsibility of each citizen. However, people generally felt that environmental protection was the government's duty and that they lacked guidance as to how they could specifically contribute to environmental protection. Close ties between NGOs and the media have enabled ordinary citizens to learn how they can contribute to fixing environmental problems, and that their personal efforts can have an impact.

As NGOs push the media to cover their environmental activities, the media itself pushes the general public to take action on environmental issues. This occurs because there are some journalists who are themselves dedicated environmentalists. These journalists end up using their newspapers to organize environmental activities or campaigns, as would an NGO. A good example is Liu De Tian, the senior editor of the *Panjin Daily* located in Liaoning Province. Through his reporting on the Shuangtaizihekou Nature Reserve, he raised awareness about the significance of the reserve as a protector of rare birds and the importance of citizen involvement in saving these birds' habitat. In 1995, Liu created the Society to Protect Saunder's Gulls and successfully encouraged the Panjin city government to adopt the Saunder's Gull as its official bird.

Though NGOs have been successful in raising environmental awareness, they are not yet ready to challenge the government on its policies. The media, however, can be more critical of the government on environmental issues: journalists, unlike NGOs, have the benefit of being able to dilute their views and opinions within the general voice of their newspaper or magazine.

Media and the Government

The Chinese government has attached great importance to the role of mass media in environmental protection. According to Qu Geping, Chairman of the Environmental Protection and Natural Resources Conservation Committee of the National People's Congress, environmental protection in China will only be successful with the assistance of the mass media.[6] Due to China's large population and limited governmental resources, the government relies on mass media to publicize its environmental protection campaigns. Environmental laws and regulations, such as the three synchronizations principle and the pollution levy system, are published in newspapers to reach a larger audience. For example, due to its affiliation with NEPA, *CEN* announces every new national environmental law and regulation that is passed.

An example of the government utilizing media resources can be seen through the use of publicity funds to broadcast environmental messages from government environment departments. NEPA has used these funds to support its press conferences, sponsor environmental columns in national newspapers, and support television programs on Beijing TV, such as "Going to Nature."

Local environmental departments utilize this publicity fund in a variety of ways. Dalian Environmental Protection Bureau sponsors a daily half-hour radio program on Radio Dalian entitled "Voice of Green," which aims to raise public environmental awareness in the province. Many provincial departments use this fund to start their own local environmental newspapers or magazines.

While increasingly more serious environmental problems and greater public and media awareness have been important factors in increasing media's coverage of environmental issues, the government's influence and coverage requirements have had the most direct and immediate impact on increasing coverage. In 1996, after the Fourth National Environmental Protection Conference, environmental reporting had remarkably increased in all major forms of the Chinese media, clearly displaying the government's support for such issues.

Media Coverage and the Promotion of Environmental Action

Media coverage has not only promoted governmental and NGO activities, it has also helped promote environmental action. Two successful examples follow.

China Century Tour on Environmental Protection

A survey conducted by the China Environmental Protection Foundation in 1995 found that 60 percent of 4,000 people interviewed thought that China was rich in natural resources and had no need to worry about environmental protection. In addition, over 80 percent admitted that they knew little about environmental problems.[7] This report showed a discouraging disparity between the gravity of the country's environmental problems and the public's understanding of these issues.

The Foundation recommended a strategy of increased publicity to raise public awareness and education. More importantly, it was hoped that these efforts would harness the attention of government officials and policymakers. In 1993, the Environmental Protection and Natural Resources Conservation Committee (EPNRC) of the National People's Congress launched the China Century Tour on Environmental Protection—a wide reaching, fact-finding investigation to raise awareness against environmental pollution. Each year, a single theme is chosen as the Tour's focus topic. EPNRC then convenes and develops media activities at the central level on this topic while twenty-seven provinces, cities, and autonomous regions simultaneously carry out their own local Century Tours on Environmental Protection.

Top officials and over 100 journalists trek to these provinces, engaging over 800 million people in the cause via newspaper stories and television broadcasts.

The coverage generated by the Century Tour has been extremely influential: the Century Tour's exposé on polluting industries along the Huai River, which supplies water to over 150 million people, alerted State Counselor Song Jian to the severity of this river's pollution problem and served as the impetus for the eventual decision to close hundreds of polluting enterprises along the Huai. The Century Tour's campaign has also maintained its popularity with the media. Since 1993, over 1,500 journalists have joined the campaign in order to publicize the country's environmental situation.[8]

Yunnan Snub-nosed Monkeys

In late 1995, Xi Zhinong, a wildlife photographer at the Yunnan Provincial Department of Forestry, raised an alarm regarding the fate of Yunnan Snub-nosed monkeys. Spurred by a local Deqin County decision to log over 100 square miles of primitive forest, which comprised over one-fifth of the endangered monkey's habitat, Xi distributed information about the situation and secured the support of Beijing-based Friends of Nature (FON). FON immediately issued a statement in support of Xi's efforts, which was distributed throughout Beijing and caught the attention of various media groups.

On 26 December 1995, student-run environmental groups held a candlelight vigil on the Beijing Forestry University campus. The event attracted wide media attention, and the following day *China Environment News* published two stories on its front page revealing Deqin's logging scheme.

With Xi's campaign underway, journalists were able to write newsworthy stories that were widely published and televised. Extensive coverage of the Yunnan Snub-nosed monkey campaign and the Deqin County's logging plan raised the profile of this little known endangered species, and helped convince the Chinese central authority to intervene, halting Deqin's logging scheme.

Constraints on the Media

While Chinese journalists have been successful in covering general environmental issues and some NGO activities, there are still many areas that fail to receive adequate coverage. A majority of Chinese environmental reporting concentrates on meetings, tree-plantings, and environmental sanitation efforts. There continues to be a lack of in-depth environmental reporting that can have a resounding impact on the public and decision makers.

There are also many misleading reports in the Chinese media that cause confusion among the public and provide an incorrect impression of China's environmental situation. For example, there has been widespread reporting on China's increased forest coverage as a result of reforestation efforts using monoculture trees. However, these reports fail to mention that the initial logging of old-growth forests creates habitat loss, which cannot be replaced by monoculture forests and consequently poses a threat to China's biodiversity.

The Chinese media has also failed to raise awareness on the following important environmental issues:

1. *Overseas Polluters*: China views foreign enterprises as essential to its economic growth and, therefore, the impact of these firms' operations on China's environment is largely ignored. Foreign enterprises can produce as much pollution as Chinese enterprises, yet they tend to have a more positive environmental image within China. There are two main reasons why there is little media coverage in China about pollution from foreign enterprises: (1) journalists have little understanding of these firms' global activities and their potential global notoriety as polluters; and (2) language barriers limit opportunities for journalists to interact with representatives from these firms. Foreign firms also organize public relations campaigns on the environment, making it difficult for journalists to publish stories that would tarnish their image. For example, DuPont and the China Forum of Environmental Journalists created the DuPont Environmental News Award in 1997, Shell Oil supported a 1996 expedition and survey for Wild Bactrian Camels in Xinjiang, and British Petroleum supports World Wide Fund for Nature's (WWF) environmental education seminar. In part due to these efforts, there is little mention in the media about the volume of pesticides or waste materials produced by DuPont in Shanghai or Guangzhou, or the potential environmental impact of oil exploration or eventual oil production by Chevron and the China Offshore Oil Corporation in the Bohai Sea.

2. *Nuclear Power*: There is virtually no reporting of nuclear power issues in China and, consequently,

there is a complete lack of awareness among the Chinese public about the environmental impacts of nuclear testing and nuclear power production, the generation of radioactive waste, and the potential for devastating nuclear accidents. Though many Chinese have heard about the Chernobyl disaster, few believe that such an event could happen in their own country. In this regard, the Chinese media has failed to inform citizens about nuclear safety issues and the hazards associated with potential problems at nuclear sites.

3. *Hydroelectric Dams*: The impact of dam construction on the environment is another issue on which the media has failed to inform the public. Because China's problems with floods have historically been so severe, every hydroelectric project is hailed as a means to conquer nature and halt flooding. Increased energy production to assist economic progress is touted as a side benefit to these flood protection measures. In addition, after the Three Gorges Project was approved by Chinese authorities, articles opposed to hydroelectric projects, or their negative environmental impacts, have seldom been allowed to be published in China.

4. *Marine Conservation*: When discussing China's natural resources, many Chinese forget that their country's vast marine territory covers approximately 3 million square kilometers. For centuries, Chinese marine awareness has been low, creating a lack of action regarding China's marine pollution and the destruction of China's marine resources. Although a few publications, such as *China Ocean News* and *Ocean World*, focus on marine issues, their circulation is too low to impact public perception of marine issues, or to influence governmental action.

Conclusion

In order to encourage the media to provide more coverage of environmental issues, awareness about the importance and urgency of China's environmental problems must be raised within the media itself. Friends of the Earth-Hong Kong (FoE-HK), WWF-China, and Friends of Nature have recently undertaken efforts to address precisely this problem.

FoE-HK has been especially vigorous in its promotion of environmental reporting in the Chinese media. FoE-HK not only distributes its environmental publications to Chinese media groups, it also provides timely environmental information for them to cover. In addition, FoE-HK founded an annual Earth Award in September 1996 to acknowledge the contribution of China's journalists and educators to the environment. Through the nomination process, FoE-HK has created a network of lesser known activists whom the group supports.

After opening its Beijing office in 1996, WWF-China has worked more closely with Chinese reporters. WWF-China recognizes the important role that the media plays in promoting its "solution-oriented" approach to environmental issues, and has created seminars to provide training on environmental reporting for Chinese journalists. WWF-China also distributes environmental information to Chinese journalists, much of which originates from its international network, making international environmental messages easily accessible to Chinese reporters. Additionally, WWF-China supports the Environmental Education Television Project, through which China's television stations can order a vast catalog of environmental videos and television programs.

Friends of Nature has contributed by conducting surveys of Chinese newspapers in 1995 and 1996 that examined environmental reporting. These surveys were the first institutional research on environmental reporting and have stimulated Chinese newspapers to offer more coverage of environmental issues.

The seriousness and urgency of environmental issues in China will continue to make the environment a hot topic among the press and public for years to come. Although environmental reporting has made great progress in recent years, coverage is relatively minimal considering that environmental protection is one of only two basic national policies.[9] At this point, it is more important for Chinese reporters to focus on the quality, rather than the quantity, of their articles. Influential reports with profound social impact are still rare: reporters urgently need to increase in-depth reporting and investigative coverage of environmental issues for their stories to have the greatest impact on increasing public awareness and influencing government policy.

Wen Bo, a journalist with the Beijing-based China Environment News, *organized China's first student environmental conference in 1995, and is co-founder of Green Students' Forum, a student environmental network in China.*

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