SECTION 4: U.S.-CHINA CLEAN ENERGY COOPERATION

Introduction

The United States and China have a long history of bilateral clean energy cooperation, both through official channels and among private and nongovernmental actors. Both nations have seen some benefits from the technology-sharing relationship as have neighboring nations whose skies and waterways have been subject to increasing levels of pollution from the rapidly industrializing China. After a slow start, the benefits of some of the cooperative energy programs are only now being recognized. Future efforts, particularly in joint research and development, will require more assessment and measurement of progress if the many programs are to retain public and industry support.

This section, which draws from the April 25 Commission hearing on U.S.-China clean energy cooperation and other sources, continues the Commission's examination of China's rapidly growing domestic energy needs, its attempts to implement clean energy policies, and the opportunities and challenges that exist for bilateral cooperation in these areas. This section will focus on the facilitation by the governments of the United States and China of cooperative activities aimed at improving the efficiencies of conventional energy sources such as coal, natural gas, and nuclear.* Through several case studies, this section explores the role of U.S. government agencies, universities, and businesses in this cooperation. The section concludes by assessing the implications of such cooperation for U.S. national interest.

U.S.-China Clean Energy Cooperation Policy

In a briefing to the Commission, Jonathan Elkind, acting assistant secretary for International Affairs at the U.S. Department of Energy (DOE), said the United States cooperates with China on clean energy both "because we need to and because we want to," pointing to shared interest in protecting the environment and creating business opportunities.[1] Indeed, the two countries share many energy and climate challenges. The United States and China lead in global energy consumption and rely on the abundant domestic coal resources to provide energy, which results in carbon dioxide (CO_2) emissions. China is the world's largest emitter of CO_2 (26 percent of world emissions in 2010), followed by the United States (17 percent),[2] and their joint efforts are necessary for suc-

*For a discussion of wind and solar industries see U.S. Economic and Security Review Commission, *2010 Annual Report to Congress*, November 2010, pp. 183–210. *http://origin.www.uscc.gov/sites/default/files/annual_reports/2010-Report-to-Congress.pdf*.

cessful global reduction. Both countries are investing in renewable resources, such as wind and solar, while also working on increasing efficiencies and reducing pollution by making conventional energy sources, such as natural gas and coal, cleaner.

China's environmental problems pose some of the most pressing challenges for Chinese leaders. The combination of its large population, rapid economic growth, and lax environmental enforcement has led China to consume more energy with each year and emit ever more toxins into the air and water. A major international study found that air pollution contributed to 1.2 million premature deaths in China in 2010.[3]

China's heavy reliance on coal for energy generation, industrial production, and heating is a major contributor to its environmental woes. While use of nuclear and renewable energy is growing rapidly, they remain minor energy sources, and are not expected to soon replace coal in a substantial way.[4] According to latest data from the U.S. Energy Information Administration, coal supplied 69 percent of China's total energy consumption in 2011 (see Figure 1).[5] The corresponding figure for the United States was far lower, at 20 percent.*

The Chinese leadership, through consecutive Five-Year Plans, has placed increasing emphasis on reducing pollution and energy consumption through regulation and promotion of clean energy and technologies.† China has stated it plans to cap coal use below 65 percent by 2017 and to raise non-fossil fuel energy consumption to 15 percent of the energy mix by 2020 (though consumption of coal will continue to rise in absolute terms).[6] In addition, the 12th Five-Year Plan sets targets for increasing energy efficiency and carbon efficiency of the economy by 16 percent and 17 percent, respectively.[7] The government reemphasized its commitment to promote an "ecological" civilization during the 2014 National People's Congress, promising to "declare war" on pollution and providing some concrete targets for reducing energy inefficiency.‡

Coal and peat also dominate China's electricity generation, accounting for almost 80 percent of China's electrical capacity in 2011. Although coal and peat are the largest fuel source for the U.S. electricity market, the energy mix is much more diversified (see Figure 2). Coal and peat account for only 43 percent of U.S. electricity generation.

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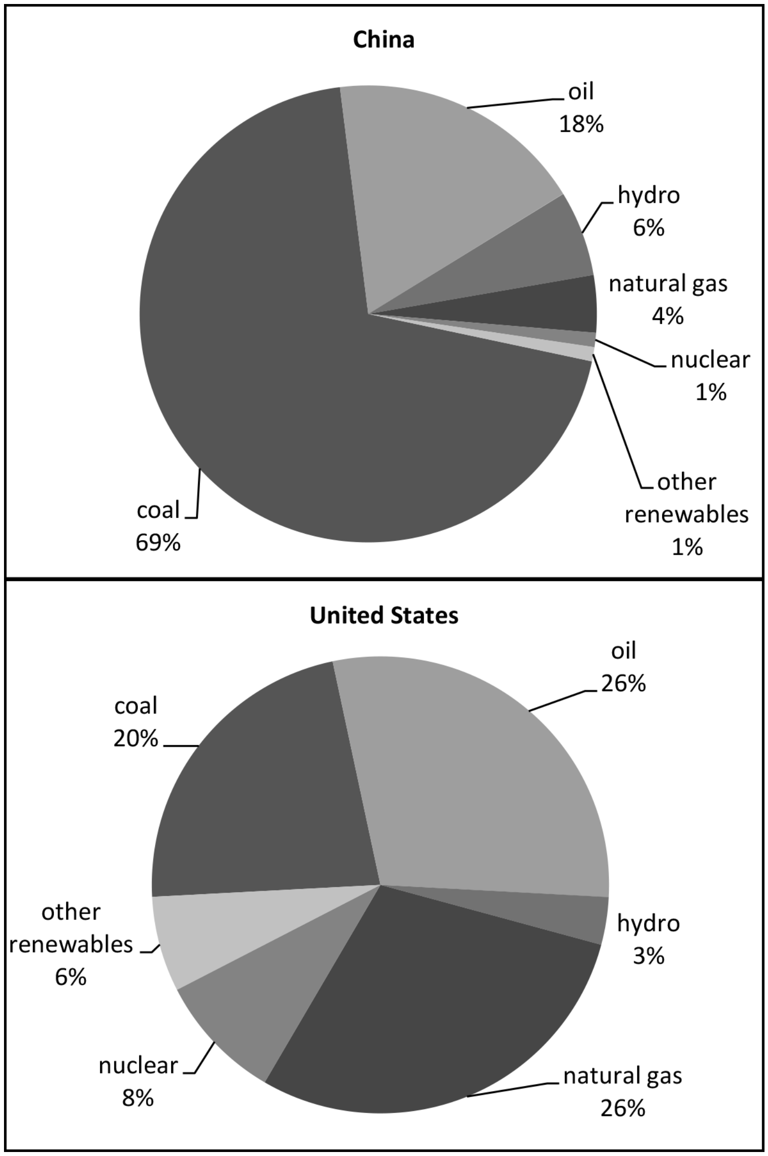
*The United States holds the world's largest estimated recoverable reserves of coal and is a net exporter of coal. In 2012 U.S. coal mines produced more than a billion short tons of coal and more than 81 percent of this coal was used by U.S. power plants to generate electricity. *http://www.eia.gov/coal/*. According to EIA, in 2012 China was the third biggest market for U.S. coal (9 percent of the total) behind the Netherlands (12 percent) and UK (11 percent). In 2012, the U.S. was the eighth largest source of Chinese coal imports behind Indonesia, Australia, Mongolia, Russia, Vietnam, South Africa, and North Korea.

†For an in-depth analysis of Chinese government's policies supporting the clean energy sector, see U.S. Economic and Security Review Commission, *2010 Annual Report to Congress*, November 2010, pp. 183–210. *http://origin.www.uscc.gov/sites/default/files/annual_reports/2010-Report-to-Congress.pdf*.

‡For more details on the *2014 National People's Congress and the Government Work Report*, see Nargiza Salidjanova and Iacob Koch-Weser, *China's 2014 Government Work Report: Taking Stock of Reforms* (U.S.-China Economic and Security Review Commission, April 1, 2014). *http://origin.www.uscc.gov/sites/default/files/Research/USCC%20Backgrounder_NPC%20scorecard.pdf*.

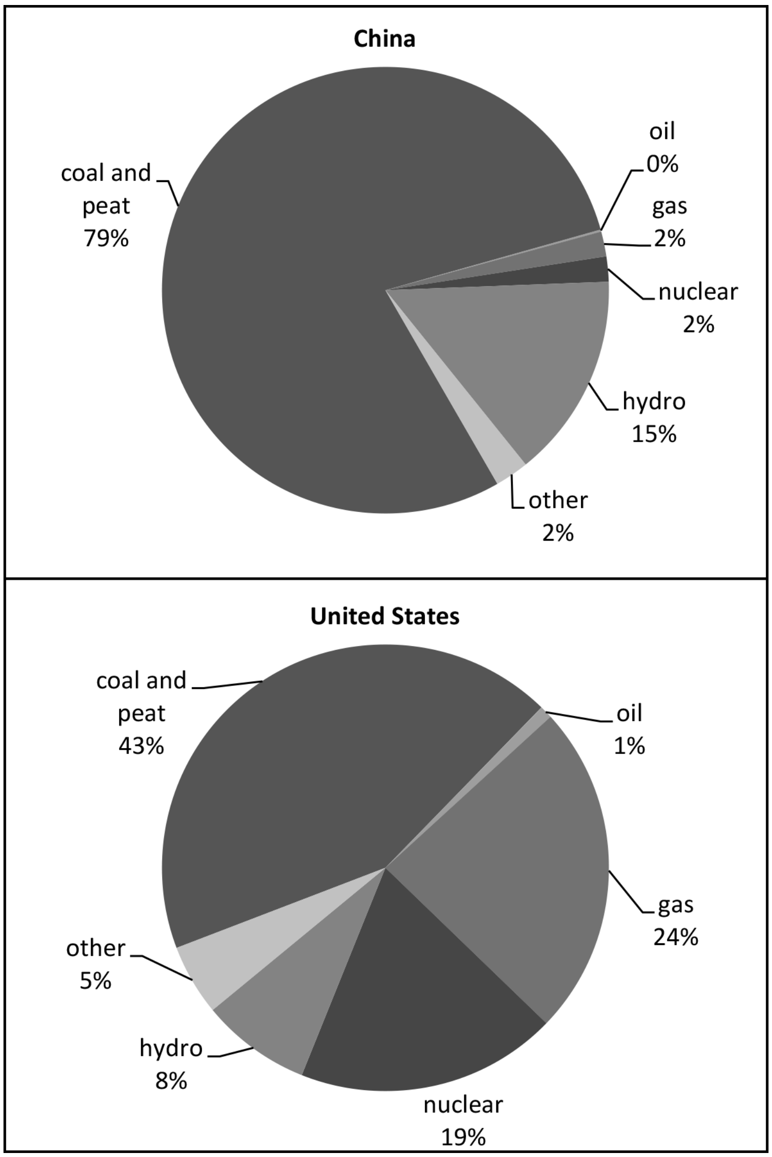
Figure 1: Total Energy Consumption by Type, 2011



Source: U.S. Energy Information Administration, *International Energy Statistics*.

China is the world's largest investor in clean energy (it surpassed the United States in 2012). In 2013 alone, China's combined public and private investment in that sector reached $61.3 billion, or about one quarter of the $254 billion world total.[8] But even as China's spending on clean energy development surpasses all other nations, its consumption of fossil fuels is still growing much faster than its consumption of clean energy. For every gigawatt (GW) of new solar capacity that China added in 2013, for example, China added 27 GW of new coal capacity.[9]

Figure 2: Total Electricity Generation by Source, 2011



Source: International Energy Agency. *http://www.iea.org/statistics/statisticssearch/*.

In 2013, U.S. public and private investment in clean energy totaled $48.4 billion, the second largest national investment globally.[10] The Obama Administration has set a goal for the United States to generate 80 percent of its electricity from clean sources by 2035,[11] and has sought to fund and incentivize an array of activities to help the country reach this milestone (U.S. Energy Information Administration estimates that coal-fired power plants will continue to be the largest source of electricity generation in the United States, though coal's share of total U.S. power generation will decline from 42 percent in 2011 to 38 percent in 2025 and 35 percent in 2040).[12] As clean energy alternatives have become more viable, the U.S. private sector has also deepened its investments, resulting in dynamic market growth and technological advancement.

With so much combined investment focused on clean energy, the potential opportunities for both countries are immense, and U.S. and Chinese governments have endorsed cooperation. Many experts argue that U.S.-China cooperative initiatives "could increase the capacity and reduce the cost of new energy technologies, which over the long term will produce economic, energy, and environmental security benefits on both sides of the Pacific." [13]

At a 2011 Brookings Institution seminar, Zhou Dadi, vice chairman of the China Institute for Innovation and Development Strategy, urged cooperation because it "provides each side with access to the specialized expertise of the other . . . increases the diversity of approaches that can be investigated . . . and speeds up progress on both sides." [14] U.S. businesses are also interested in cooperation, given the substantial economic opportunities that exist in the clean energy field.[15] At an energy cooperation event in Beijing in April 2013, Secretary of State John Kerry summed up the opportunities:

> *The energy market that we are talking about here today, the energy market of the future, is a $6 trillion market with five billion users today and growing to perhaps nine billion users over the next 40 years. This is the largest of all markets ever imagined on the face of this planet.*[16]

However, the tremendous opportunities of U.S.-China clean energy cooperation are tempered by significant obstacles, stemming primarily from China's lax protection of intellectual property rights and China's use of allegedly WTO-illegal subsidies to promote its clean energy sector.* The Chinese government's deployment of massive resources toward developing clean energy technologies—such as tax breaks, preferential financing, access to government contracts and other incentives—is a major challenge confronting proponents of U.S.-China clean energy cooperation, and may have damaging consequences for the U.S. energy sector and economy.[17] As a result of the anticompetitive aspects of Chinese policies, U.S.-China trade disputes involving clean energy industries have proliferated.

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* For an in-depth analysis of Chinese government's policies supporting the clean energy sector, see U.S. Economic and Security Review Commission, *2010 Annual Report to Congress*, November 2010, pp. 183–210. *http://origin.www.uscc.gov/sites/default/files/annual_reports/2010-Report-to-Congress.pdf*.

In 2010, the United States challenged China's Special Fund for Wind Power Manufacturing at the World Trade Organization (WTO). China's program gave domestic wind turbine manufacturers special subsidies, in violation of its WTO commitments.[18] Following consultations with the United States, China agreed to end the subsidies program.[19] In 2012, the U.S. International Trade Commission (ITC) found that cheap wind tower imports from China were having detrimental effects on U.S. manufacturers because Chinese wind tower companies were receiving countervailable subsidies and dumping (i.e., selling below cost of production) their products in the U.S. market.[20]

The Chinese government's heavy subsidization of the domestic solar industry—which allowed Chinese solar manufacturers to sell their products below market value—has also led to U.S. trade action.[21] In June and July 2014, the U.S. Department of Commerce announced preliminary countervailing (CVD) and antidumping (AD) duty investigations of imports of Chinese solar panels. U.S. Customs will begin collecting duties based on the preliminary rates of 18.56 to 35.21 percent in the CVD investigation and 26.33 percent to 165.04 percent in the AD investigation.[22] The final determination is expected in December 2014.

This marks the latest step in a fight over low-cost solar panels from China. In 2012, Commerce imposed AD and CVD duties on imports of Chinese solar panels, in response to a petition by SolarWorld Americas, a U.S. subsidiary of a German solar company, and a coalition of other solar manufacturers, alleging WTO-illegal subsidies from the Chinese government to Chinese producers.[23]

China asked the U.S. Department of Commerce for a suspension of the duties, and for a chance to negotiate a settlement. But while the U.S. government has not yet responded to China's request, SolarWorld Americas asked the U.S. Department of Commerce to increase the duties applied to Chinese solar products in response to Chinese military personnel hacking the company's computers.[24] The request follows the U.S. Justice Department's indictment of five members of the Chinese military for allegedly stealing documents and files from U.S. companies, including SolarWorld (for additional information on China's use of state-sponsored cyber-theft to promote domestic companies, see Chapter 1, Section 1 of this Report.)

Public-Private Partnerships

The two countries have been cooperating for over 30 years on environmental and energy efficiency initiatives, with much of the early agreements focusing more on establishing the basic frameworks for cooperation and on energy policy discussions (see Addendum I for a timeline of U.S.-China cooperation on clean energy and climate change). In the 2000s, clean energy and climate change mitigation emerged as leading topics of cooperation between China and the United States, culminating with a series of agreements signed in 2008–2009, which moved beyond discussion and into the realm of technical cooperation.

At the June 2008 Strategic Economic Dialogue, the United States and China signed the Ten Year Framework on Energy and Environmental Cooperation, establishing goals for cooperation on clean electricity, clean water, clean air, efficient transportation, and forest conservation. During President Obama's November 2009 trip to Beijing, he used this framework as the basis for establishing a number of initiatives to enhance U.S.-China cooperation on clean energy (see Table 1).

Table 1: Government-Sponsored U.S.-China Cooperation Initiatives Signed in 2009

Initiative	Chinese Body	U.S. Body	Description
U.S.-China Clean Energy Research Center (CERC)	Ministry of Science and Technology; National Energy Agency	Department of Energy	Establishes research center focused on developing energy efficiency, clean coal, and clean vehicle technologies, including carbon capture and storage.
U.S.-China Electric Vehicles Initiative	Various public and private entities	Various public and private entities	Includes joint standards development for electric vehicles, demonstration projects in China, creation of a research and development (R&D) and manufacturing roadmap, and public education projects.
U.S.-China Energy Cooperation Program (ECP)	Various public and private entities	Various public and private entities	Provides private sector money for work in China on renewables, smart grid, clean transportation, green building, clean coal, combined heat and power, and energy efficiency.
U.S.-China Renewable Energy Partnership	Various public and private entities	Various public and private entities	Fosters collaboration on advanced wind, biofuels, solar, and grid technologies, while expanding trade in these sectors through an annual U.S.-China Renewable Energy Forum.
21st Century Coal	Various public and private entities	Various public and private entities	Creates joint ventures and other public-private partnerships on clean coal, including carbon capture and near-zero emissions coal plants.
U.S.-China Energy Efficiency Action Plan	Various public and private entities	Various public and private entities	Develops energy efficient building codes and rating systems, benchmarks industrial energy efficiency, trains building inspectors and energy efficiency auditors for industrial facilities, and convenes a new annual U.S.-China Energy Efficiency Forum.

Table 1: Government-Sponsored U.S.-China Cooperation Initiatives Signed in 2009—*Continued*

Initiative	Chinese Body	U.S. Body	Description
Shale Gas Initiative	Various public and private entities	Various public and private entities	Enables both nations to use experience gained in the United States to assess China's shale gas* potential, conduct joint technical studies, and promote shale gas investment in China through the U.S.-China Oil and Gas Industry Forum, study tours, and workshops.

*Shale gas is natural gas trapped within shale formations. Although the complex geology of shale gas formations makes it more difficult to extract than conventional natural gas, recent advances in hydraulic fracturing (commonly called "fracking") have enabled gas producers to extract shale gas economically. U.S. Energy Administration, "What is Shale Gas and Why is it Important?" December 5, 2012. *http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm.*

Source: The White House, U.S. Office of the Press Secretary, "U.S.-China Clean Energy Announcements," November 17, 2009. *http://www.whitehouse.gov/the-press-office/us-china-clean-energy-announcements.*

U.S.-China government-facilitated collaboration takes many forms—from sponsoring workshops where U.S. and Chinese businesses and academics meet to discuss shared challenges to providing funding for projects. Most often, the collaboration is conducted through public-private partnerships, with the U.S. government providing resources or capacity building while academic institutions, nongovernmental organizations (NGOs), foundations, and the private sector join government-established frameworks. U.S.-based environmental NGOs have sizeable China programs and engage in cooperative activities with Chinese partners. These NGOs include the Natural Resources Defense Council, the Environmental Defense Fund, and the World Resources Institute.

One example of such public-private partnerships is work done by the U.S. Trade and Development Agency (USTDA), which focuses on trade capacity building initiatives, technical assistance, and pilot projects in the transportation, energy, information technology, and healthcare sectors. In 2013, USTDA completed 6 study tours and 16 workshops, conferences, and training programs for over 1,200 Chinese participants in the areas of transportation, energy, water and environment, healthcare and emergency response, and antimonopoly law. According to USTDA, its China projects have facilitated over $8.1 billion in exports since 2001, including over $960 million in new exports in 2013.[25] USTDA reports that in 2013, 21 percent of its total China portfolio was invested in the clean energy sector.

In her testimony before the Commission, USTDA Director Leocadia Zak highlighted the Energy Cooperation Program (ECP), which USTDA supports through grants for feasibility studies, technical assistance, and workshops.[26] ECP is a nongovernmental organization that includes over 45 U.S. companies across ten industry subsector working groups.[27] Several U.S. government agencies "support the ECP's efforts to connect Chinese decision-makers to U.S. technical expertise in clean energy," including the Department of Commerce and the Department of Energy, which joined USTDA in signing the Memorandum of Understanding (MOU) that created ECP in 2009.[28]

Building on the work done by USTDA to enhance cooperation with Chinese government counterparts, ECP leverages private sector resources for project development work in China, encompassing renewable energy, smart grid, clean transportation, clean coal, and energy efficiency. To support ECP and promote clean energy development in China, USTDA has funded eight Chinese trade missions to the United States, seven pilot projects in China, and six workshops for Chinese public and private leaders.[29]

U.S.-China Clean Energy Research Center (CERC)

CERC is the most ambitious U.S.-China program for joint research and clean energy development to come out of the November 2009 meeting between President Obama and President Hu. CERC is governed by a steering committee which includes ministerial or secretary level oversight from DOE and three ministries—the Ministry of Science and Technology (MOST), the National Energy Administration (NEA), the Ministry of Housing and Urban and Rural Development (MOHURD)—from the Chinese side. According to its steering committee, CERC's goal is to

> *accelerate the development and deployment of clean energy technologies for the benefit of both countries ... by providing a supportive platform for collaborative research, protecting intellectual property, and encouraging top scientists and engineers in both countries to join forces, learn from each other, and capitalize on unique assets and complementary strengths.*[30]

CERC's work was launched in January 2011, with the signing of joint work plans by the participants. Its three research priorities (the consortia) are advanced clean coal technologies, including carbon capture and storage (CCS),* clean vehicles (including advanced biofuels), and building energy efficiency (for a list of CERC projects, see Addendum II). As part of the program, DOE awarded grants to research teams led by West Virginia University on clean coal, the University of Michigan on clean vehicles, and Lawrence Berkeley National Laboratory on building energy efficiency. These U.S. teams conduct joint research with Chinese teams led by Huazhong University of Science and Technology on clean coal, Tsinghua University on clean vehicles, and the Ministry of Housing and Urban-Rural Development on building energy efficiency. CERC is funded in equal parts by the United States and China, with each consortium allocating a budget of $50 million for the first five years ($25 million provided by the national governments matched by $25 million from industry, universities, research institutions, and other stakeholders).[31] U.S. funds support only U.S. researchers and Chinese funds support only Chinese researchers.

On the U.S. side, each consortium is allocated $2.5 million per year from DOE; this is matched equally by the academic and industrial participants. On the Chinese side, there is no matching requirement. According to Huei Peng, the U.S. director of the CERC

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*Carbon capture and storage (CCS) (or carbon capture and sequestration) is the process of capturing waste CO2 from large sources, such as fossil fuel used in power generation and other industries, transporting it to a storage site, and depositing it where it will not enter the atmosphere.

clean vehicles consortium, Chinese industrial partners only provide guidance and in-kind contributions.[32] In its 2012–2013 Annual Report, CERC reported its funding plan for the duration of the first five-year phase (see Table 2).

Table 2: Multi-Year Bilateral CERC Funding Plan

Funding Fiscal Year	United States		China	Totals
	DOE	Partners	MOST & Partners	
2010	$7.5	$3.8	$0	$11.3
2011	$7.5	$8.7	$12.5	$28.7
2012	$5	$9.4	$22.3	$36.7
2013	$8.4	$9.7	$15	$33.1
2014	$7.5	$8.2	$15	$30.7
2015	$1.6	$2.5	$15	$19.1
Totals	$37.5	>$37.5	>$75	>$150

Note: Shaded areas indicate planned spending.
Source: U.S.-China Clean Energy Research Center, *Annual Report 2012–2013*, p. C1.

Management of Intellectual Property under CERC

The nature of CERC's work is collaborative, with several participants (academic, industry, or a combination) working on each project at the same time. As of July 2014, the CERC consisted of 75 individual projects within its three consortia, of which 58 were joint. For example, the Clean Vehicles Consortium's work on advanced batteries is conducted by representatives from University of Michigan, the Ohio State University, Beijing Institute of Technology, and Tsinghua University. Managing intellectual property (IP) resulting from such cross-national joint work is a key challenge to overcome. One of CERC's unique features is its Technology Management Plan (TMP), which was created to address IP concerns associated with joint research and development (R&D) activities. While the TMP does not add any new IP protections that the law does not otherwise provide, TMP establishes a framework to manage any IP developed under the CERC umbrella. The TMP states that the owners of background IP retain "all right [sic], title, and interest in their background IP" and they are not required to "license, assign or otherwise transfer" it, though using it may require an appropriate license.[33] For IP created by signatories from one country only, the TMP mandates that participants agree to negotiate in good faith terms of a nonexclusive license to the other participants.

Although common elements are shared in the plan framework, each consortium has a TMP to address the unique characteristics of its individual research.[34] To help researchers understand the TMPs and other IP laws and practices in each country, the U.S. DOE and China's Ministry of Science and Technology carry out a continuing program of IP education and training. The program includes legal education, technical assistance, and a series of IP workshops for CERC participants.[35]

While the TMP was designed to manage the joint ownership of IP resulting from CERC research activities, its utility is yet to be tested in practice, because CERC is not yet producing inventions that were jointly developed by U.S. and Chinese participants.[36] Protection of IP is a crucial component of promoting collaborative innovation, yet lack of joint IP from CERC research projects points to a longstanding mistrust of China's lax IP protections. Joanna Lewis, an expert on China's energy policy at Georgetown University, noted that the TMP "does not seem to have sufficiently changed" behavior of CERC participants with regards to their willingness to share IP or co-develop IP with Chinese participants. U.S. participants are reluctant to share IP likely because "although the TMP provides IP protection on paper, in practice there is still much skepticism about its enforceability." [37]

CERC Cooperation Case Study: Advanced Coal Technology Consortium (ACTC)

The Advanced Coal Technology Consortium (ACTC) is led jointly by James Wood, West Virginia University (WVU) and Zheng Chuguang, Huazhong University of Science and Technology. The U.S. side of the ACTC is headquartered in the WVU National Research Center for Coal and Energy, located in Morgantown, WV. The consortium consists of U.S. universities, national laboratories, and energy companies (see Table 3).

Table 3: CERC Advanced Coal Technology Consortium Current Members

U.S. Members	Chinese Members
West Virginia University (lead)	Huazhong University of Science and Technology (lead)
University of Wyoming	China Huaneng Group Clean Energy Research Institute
University of Kentucky	China University of Mining and Technology
Wyoming State Geological Survey	Harbin Institute of Technology
Indiana Geological Survey	Institute for Rock & Soil Mechanics, Chinese Academy of Science
Lawrence Livermore National Laboratory	Northwest University
Los Alamos National Laboratory	Research Center for Energy & Power, Chinese Academy of Sciences
National Energy Technology Laboratory	Shanghai JiaoTong University
U.S.-China Clean Energy Fund	Tsinghua University
World Resources Institute	Zhejiang University
American Electric Power	China Huaneng Group Power International, Inc.
Babcock and Wilcox *	China Power Engineering Consulting Group Corporation
Duke Energy, Inc.	China Power Investment Corporation

Table 3: CERC Advanced Coal Technology Consortium Current Members—*Continued*

U.S. Members	Chinese Members
General Electric (GE)	ENN
LP Amina	Shaanxi Yanchang Petroleum Group Co., Ltd.
	Shenhua Group

* *Note:* Participation ended June 30, 2014, with further participation subject to corporate review.[38]

Source: U.S.-China Clean Energy Research Center. *http://www.us-china-cerc.org/Advanced_Coal_Technology.html*.

The ACTC was the first CERC consortium to launch joint demonstration projects, several of which expanded upon existing private sector partnerships that had been in the early stages of development as CERC was being established and were folded into the CERC portfolio.[39] For example, Huaneng and Duke Energy had begun cooperation related to advanced coal technology and CCS demonstration in 2009 as the CERC agreement was being negotiated.[40]

In its most basic form, CCS is the process by which CO2 emissions from power plants and other industrial facilities are captured and stored underground. CCS can be applied to electricity generating plants that burn fossil fuels, such as coal- or gas-fired power stations, and can also significantly reduce emissions from industry, such as the cement, steel, and chemical industries. Although the United States has championed CCS research in the 2000s,* interest in coal emission mediation (and related funding) has been on the decline as a result of the influx of cheap natural gas derived from advancements in "fracking."[41] As greater attention and financing has focused on natural gas for its cheap generation cost and low emissions relative to alternatives, utilities are reducing their demand for coal, and are unwilling to pay a premium for CCS.[42] China's reliance on coal, however, will remain quite strong for the near future: Even if the Chinese government is successful in reducing the share of coal in the energy mix, as envisioned in the 12th Five-Year Plan, consumption of coal will rise in absolute terms, as total energy demand is set to grow 4.3 percent a year over the 2011–2015 period. In 2013 alone, China approved the construction of more than 100 million tons of new coal production capacity, six times more than a year earlier.[43] Therefore, involvement

* Several CCS demonstration projects are currently underway in the United States, most with DOE support. For some examples of DOE's programs, see U.S. Department of Energy, "Carbon Capture and Storage Research." *http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research*. An electrical generating station currently under construction in Kemper County, Mississippi, when completed, will be the first U.S. power plant with integrated CCS technology (the plant is expected to go into operation in 2015). The project, however, has been behind schedule and over budget, leading to criticism of its viability and broader applicability to U.S. coal power plants. See Steven Mufson, "Intended Showcase of Clean-Coal Hits Snags," *Washington Post*, May 17, 2014. *http://www.washingtonpost.com/business/economy/intended-showcase-of-clean-coal-future-hits-snags/2014/05/16/fc03e326-cfd2-11e3-b812-0c92213941f4_story.html*. Another project partially funded by DOE, the Petra Nova Carbon Capture Project (under construction in Thompsons, Texas), will be the largest CCS coal power plant in the world. The project is expected to be completed in 2016. Ucilia Wang, "NRG's $1B Bet To Show How Carbon Capture Could Be Feasible For Coal Power Plants," *Forbes*, July 15, 2014. *http://www.forbes.com/sites/uciliawang/2014/07/15/nrgs-1b-bet-to-show-how-carbon-capture-could-be-feasible-for-coal-power-plants/*.

in the ACTC presents a unique opportunity for U.S. companies specializing in CCS and related clean coal research.[44]

The ACTC's current research agenda is divided into seven themes to match the research interests and efforts of both the United States and China. These can be loosely categorized into three general areas: CCS; power generation; and coal conversion.[45] Jerald Fletcher, founding director of the ACTC noted in his testimony before the Commission that although both countries are engaged in all aspects of the research, "it has been clear from the beginning that the [United States] perceived the carbon management issues to be of the highest interest while China was most interested in the increasing efficiency and technical advances in power generation and coal utilization."[46]

This mismatch in research interests is reflected in IP creation. Although several of the ACTC's projects have led to IP creation, none of the IP is jointly held by Chinese and U.S. partners. As of January 2013, ACTC participants had filed 15 patents (12 filed in China by Chinese ACTC members, and three filed in the United States by U.S. members).[47]

According to CERC's U.S. Director Robert Marlay, as of July 2014, the ACTC had 39 research projects, 30 of which are joint research activities; some of which are highlighted here.[48]

- *Clean Coal Conversion Technology Project* involves joint research, led by WVU and Zhejiang University, into developing new technology to convert conventional power plants into power plants that use waste heat and fuel combustion to produce chemicals and further byproducts from coal, making the overall coal power production process more efficient, reducing emissions, and increasing economic benefits. To date, researchers have successfully validated the theoretical modeling on a 1-megawatt pilot plant. Upon completion of the project, the newly developed technology is expected to reduce maintenance costs and greenhouse gas emissions by more than 25 percent, compared to conventional energy. Future plans include ACTC participant LP Amina building a demonstration project at a power plant in Shanxi, China.[49]
- *CO2 Utilization Project* involves research, by the University of Kentucky and Duke Energy on the U.S. side and ENN Group and Zhejiang University on the Chinese, into developing an economically feasible technology to use CO2 to make biofuels. In a demonstration facility installed at Duke Energy's East Bend power plant in Rabbit Hash, Kentucky, CERC researchers feed to algae the CO2 captured after combustion. Eventually, the algae, which absorb the CO2, as do all plants, can be harvested for biogas fuels and animal feed. The research involves finding the optimum methods for growing and harvesting the oil from the algae, picking the best varieties of algae, and selecting the best types of growing media, such as ponds or closed-loop photobioreactors.[50]
- *Advanced Power Generation Project* is led by LP Amina on the U.S. side and Tsinghua University on the Chinese side. Researchers designed and constructed a unique experimental sys-

tem to research pulverized coal combustion and developed a toolbox of energy conservation and emission reduction technologies for coal-fired power plants. Researchers investigated combustion characteristics of Xinjiang Houxun coal in advanced ultra supercritical (A–USC) boilers. Power plants equipped with A–USC boilers have the potential to dramatically improve efficiency and reduce emissions compared to existing coal-fired power plants. The development of improved A–USC boiler technologies was adopted as a national program in China.[51]

- *Post-combustion CO2 Capture Project* is focused on developing new technologies to capture and dissolve captured CO2, which will be used to lower energy costs related to the post-combustion capture process. The research is led by University of Kentucky and China Huaneng Group. Researchers completed the simulation of a 1 million ton/year post-combustion CO2 capture system at Duke Energy's Gibson station, which revealed advantages over other methods. A two-phase solvent and a new catalyst family with record activity levels were also developed for the project.[52]
- *CO2 Sequestration and Storage Project* resulted in the publication of 11 peer-reviewed papers and conference papers on the storage and use of CO2 in the Ordos Basin in China. Led by West Virginia University, University of Wyoming, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Shenhua Group, and the Institute of Rock and Soil Mechanics (Chinese Academy of Sciences), the researchers initiated design, construction, and injection of CO2 at a pilot project in China. They also assembled a large data set regarding the geologic structural framework of the Ordos Basin in China, as well as for the Wyoming and Illinois Basins in the United States. The significant opportunity for storage and use of CO2 in the Ordos Basin complements opportunities that are being explored in the Wyoming and Illinois Basins.[53]

Another U.S.-based ACTC participant, LP Amina, had begun cooperation with Gemeng International Energy Co. of Shanxi province, following a successful demonstration of an LP Amina technology process in China with the Zhejiang Energy Group. LP Amina's new technology, a coal classifier, prevented larger coal particles from entering the boiler, reducing nitrogen oxide emissions by up to approximately 15 percent, and reduced coal consumption and emissions. Despite the benefits, customers in the United States would not buy the new classifier because it was an unproven technology that demanded a substantial upfront investment.[54] After engagement in joint R&D and workshops convened by the CERC–ACTC, LP Amina partnered with Zhejiang Energy Group, which installed the converter at one of its power plants in Fengtai in the Anhui Province in eastern China. David Piejak, president of LP Anima in the United States, said that following the successful demonstration in China, LP Amina started marketing this technology to global companies, including plants in the United States.[55]

CERC Cooperation Case Study: Clean Vehicles Consortium (CVC)

Huei Peng from the University of Michigan (Ann Arbor) leads the U.S. consortium, and Minggao Ouyang from Tsinghua University leads the Chinese consortium. Current CVC participants are listed in Table 4.

Table 4: CERC Clean Vehicles Consortium Current Members

U.S. Members	Chinese Members
University of Michigan (lead)	Tsinghua University (lead)
The Ohio State University	Beihang University
Massachusetts Institute of Technology (MIT)	Beijing Institute of Technology
Sandia National Laboratories	Chinese Academy of Sciences
Joint BioEnergy Institute	Hunan University
Oak Ridge National Laboratory	North China Electric Power University
Argonne National Laboratory	Shanghai Jiao Tong University
Aramco Services	Tianjin University
Delphi	Tongji University
Denso	Wuhan University of Technology
Eaton	Changzhou ECTEK Automotive Electronics Limited
Ford Motor Company	China Automotive Engineering Research Institute Co., Ltd.
Honda R&D Americas, Inc.	China Automotive Technology & Research Center
Huntsman International	China Potevio
PJM	Geely Group
TE Connectivity	JAC Motors
Toyota Motor Company, North America	Jing-jin Electric Co., Ltd.
	Keypower
	SAIC Motor.
	Shanghai General Motor Muling
	Tianjin Lishen Battery Joint-stock Co., Ltd.
	Wanxiang

Source: U.S.-China Clean Energy Research Center. *http://www.us-china-cerc.org/Clean_Vehicles.html*.

According to the testimony from Dr. Peng, the CVC's research projects officially started in 2011. Since then, joint research has been conducted in the following areas: advanced batteries and energy conversion, advanced biofuels and clean combustion, vehicle electrification, advanced lightweight materials and structures, vehicle-grid integration, and energy systems analysis. The CVC has been one of the most active consortia in terms of inventions. According to CERC U.S. Director Robert Marlay, as of July 2014, the CVC had 24 research activities, of which 16 were joint, some of which are highlighted here.[56]

- *Degradation in Li-ion Batteries* is a project led by the Ohio State University, Tsinghua University, and Beijing Institute of Technology. The researchers explored ways to extend life and improve performance of lithium-ion (Li-ion) batteries, commonly used in hybrid and electric vehicles. The CVC researchers demonstrated a new design that minimizes this degradation in performance by applying a special polymer coating. The final outcome of this research is expected to be a development of a new battery cell for further studies.[57]
- *Research into Materials Sourcing and Driving Behavior* is led by University of Michigan and Tsinghua University, in partnership with General Motors and Ford. CERC researchers used GPS tracking software on 1,000 vehicles to reveal that 60 percent of Beijing drivers travel fewer than 25 miles per day. By contrast, U.S. drivers log an average of 40 miles daily, which guided U.S. design criteria for battery-sizing of the Chevrolet Volt. Based on this new information, General Motors could downsize the Volt's battery in the Beijing market and still provide a level of service similar to that provided in the United States. Researchers simulated a Plug-in Hybrid Electric Vehicle similar to the Chevrolet Volt and examined the impact of vehicle component materials on lifecycle energy and emissions.[58]
- *Vehicle Body Design Optimization*, a project led by University of Michigan, Tsinghua University, and Tongji University, explores a methodology for using lightweight materials in vehicle design. Further research is expected to explore the safety of newly designed vehicles, the effects of battery layouts on crashworthiness, and optimization of the vehicle's aerodynamic performance.[59]
- *Electric Vehicle Charging Station Simulations* conducted by researchers at the Ohio State University and Tsinghua University was aimed at improving coordination between road networks and electricity systems. Researchers found that current strategies for determining the location of vehicle charging stations will result in significant inefficiencies, and proposed alternative solutions.[60]

As of January 2013, participants in the CERC CVC had filed 12 patents in China and 11 in the United States, as well as 20 disclosures* in the United States. Although all of the patents filed in China were filed by Chinese participants, the 11 patents filed in the United States were also filed by Chinese participants. These fil-

*An invention disclosure is a document describing the invention, prepared by the scientist, investor, or a third party, which usually serves as a first step in the patenting process.

ings were related to patents that had first been filed in China. In contrast, U.S. participants filed no patents in China.[61] Furthermore, none of the patents were filed jointly by U.S. and Chinese CERC participants. The lack of jointly-created IP and of U.S. inventions patented in China—features shared by all CERC consortia—point to the continued sensitivity over the capacity of Chinese law to protect IP and address violations.

The automotive industry is highly competitive and, although foreign brands or joint ventures have dominated the Chinese automotive market to date, Beijing is heavily invested in making China a world leader in the production and deployment of electric and hybrid vehicles.* This poses a significant competitive challenge to U.S. industrial partners in CERC—how to advance their own presence in China while maintaining an edge over Chinese competitors. According to Dr. Peng, the funding model for U.S. CERC ensures that all work supported by U.S. industrial membership fees is U.S.-only and does not have Chinese collaborators.[62]

Unlike the CERC ACTC, where several industry partners joined to seek help with demonstrating a ready technology, the work done by CERC CVC participants is in the early stages of research, with commercialization years away.[63] Still, Dr. Peng noted in a 2013 CERC CVC progress report that U.S. industrial partners have requested a review of the implementation for all U.S. based tasks, with the goal of setting clear pathways towards commercialization.[64]

U.S.-China Cooperation on Natural Gas

Although natural gas accounted for only 4 percent of China's energy consumption in 2011 (the most recent data available), the government has invested heavily in resource development and infrastructure. The 12th Five-Year Plan set a target to boost the share of natural gas to 8 percent of total consumption by the end of 2015 and to 10 percent by 2020. According to a 2014 report by the U.S. Energy Information Administration, China's technically recoverable shale gas reserves are 1,115 trillion cubic feet, the largest shale gas reserves in the world.[65]

The government agenda for natural gas in China is ambitious, but it faces significant obstacles. China lacks technical experience and adequate infrastructure which, coupled with the difficult geology of Chinese reserves, makes recovery challenging. The Chinese shale gas revolution cannot progress without U.S. cooperation. [66]

The United States and China are working together in both a governmental and private sector capacity. In 2009, Presidents Barack Obama and Hu Jintao announced the launch of the U.S.-China Shale Gas Resource Initiative with the goal of sharing information about shale gas exploration and technology to reduce greenhouse gas emissions, promote energy security, and create commercial op-

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*The government established targets for pure electric and hybrid electric vehicles of 500,000 by 2015 and 5 million by 2020. Its "ten cities, thousand vehicles" program, launched the same, planned for ten cities to develop 1,000 electric vehicles each; by 2011, the list of cities had expanded to 25. Subsidies of 50,000–60,000 RMB ($8,000–$9,600) were offered to consumers who purchased the cars. Elizabeth Economy, "China's Round Two on Electric Cars: Will It Work?" *Asia Unbound* (Council on Foreign Relations), April 17, 2014. *http://blogs.cfr.org/asia/2014/04/17/chinas-round-two-on-electric-cars-will-it-work-2/*.

portunities. The U.S.-China Shale Gas Resource Initiative promotes information sharing and joint studies to provide U.S. commercial opportunities and increase the pace of development of shale gas in China.[67] Tours, workshops, and the U.S.-China Oil and Gas Industry Forum are functions of the Initiative used to increase investment in China's shale market. The U.S.-China Oil and Gas Industry Forum sponsors an annual meeting designed to bring industry players together to share information via technical presentations.[68] In September 2012, the forum sponsored a meeting focused on shale gas. DOE also has relevant work underway that focuses on issues under Annex III of the bilateral Fossil Energy Protocol.[69]

Other examples of government-to-government collaboration include the U.S. Geological Survey and DOE's work with Chinese counterparts to develop estimates for China's shale gas resources.[70] USTDA has also contributed by partnering with China's NEA on a training program that included four short courses led by the Gas Technologies Institute and targeted attendees from the Chinese government and industry.[71]

These government-led activities notwithstanding, commercial activities have been the main avenue for information sharing and technology transfer in the shale gas sector. The U.S. technological edge makes U.S. companies valuable sources of fracking know-how for Chinese oil companies, and Chinese investment in the U.S. shale gas sector has been on the rise. Rhodium Group, a consultancy, shows that from 2000 to the first quarter of 2014, Chinese investors made over 100 deals, both greenfield and acquisition, in the U.S. energy sector, valued at nearly $12 billion.[72] In 2013 alone, China invested $3.2 billion in the U.S. energy sector. Sinopec invested $1 billion in Chesapeake Energy's oil and gas assets in Oklahoma; Sinochem bought the Wolfcamp shale field for $1.7 billion from Pioneer Natural Resources, and CNOOC acquired Nexen's U.S. operations in the Gulf of Mexico.[73]

The success of Chinese investors in the United States points to a troubling lack of reciprocity. As Sarah Forbes, senior associate at World Resources Institute, has pointed out, China prohibits foreign companies from fully entering this sector on their own, forcing them instead to form partnerships with Chinese entities.[74] Chinese companies face no such obstacles when they acquire assets in U.S. gas and oil companies working on shale projects. While Chinese capital helps U.S. companies to pursue the domestic energy projects driving the United States' move toward energy independence, they raise concerns about the long-term effects of technology transfer on U.S. economic competitiveness.

U.S.-China Cooperation on Civil Nuclear Energy

As a reliable non-fossil energy source, nuclear power plays a central role in China's plan to reduce its reliance on coal.[75] Although nuclear sources accounted for only 1 percent of China's total energy consumption in 2011 (the most recent data available), Chinese nuclear expansion plans are by far the most ambitious in the world. While China has 20 reactors online (accounting for about 2 percent of total generation capacity),[76] it has 28 reactors under construction (representing roughly 40 percent of reactor construction around the world),[77] and an additional 58 reactors are being planned.[78] China's installed nuclear capacity was 14.7 GW in 2013; the 12th Five-Year plan set a goal of 40 GW by the end of 2015 and 58 GW by 2020. In contrast, the United States has 62 commercial nuclear power plants with 100 nuclear reactors (with combined capacity of 101 GW) generating 19 percent of the country's electricity, behind coal and natural gas.

The Chinese government's plans for nuclear energy development emphasize self-reliance. Technology development, however, presents a major challenge for the Chinese nuclear sector, where a select number of state-owned nuclear companies have long struggled to develop advanced reactor technology based on older reactor imports.[79] As it has done in other industrial sectors, the government started obtaining foreign technology to rectify gaps in indigenous capability.

The United States and China have cooperated on nuclear energy for nearly 30 years, although for most of its history, the cooperation has focused primarily on strengthening safety. Under the U.S.-China Peaceful Uses of Nuclear Technology Agreement of 1998, DOE has provided nuclear safety, safeguards, and security training to Chinese regulators and technicians to ensure China meets the highest nuclear safety and nonproliferation standards. DOE's National Nuclear Security Administration has been collaborating with Chinese authorities on radioactive source security, nuclear safeguards, export controls, materials and waste management, emergency management, and the establishment of a center of excellence for nuclear security training.

The United States and China also participate in cooperative research in nuclear energy technology under the auspices of the U.S.-China Bilateral Civil Nuclear Energy Cooperative Action Plan, signed in 2007. Designed to "explore advanced nuclear fuel cycle approaches in a safe, secure and proliferation-resistant manner," the two countries cooperate in the areas of advanced fuel cycle technology, fast reactor technology, and small and medium reactors.[80]

As with shale gas development, however, transfer of technology through commercial engagement dominates U.S.-China nuclear cooperation. In 2007, U.S.-based Westinghouse (owned by Toshiba Corp.) won the contract to build four AP1000 nuclear reactors in China. The deal included a technology transfer agreement that allowed China's State Nuclear Power Technology Corp., directly under China's State Council, to receive over 75,000 documents that relate to the construction of the AP1000 reactors.[81] The first reactor built under this arrangement was expected to go on line in 2013, but construction delays and tougher safety checks pushed the start back several times—first to December 2014 and later to the end of 2015.[82]

According to Jane Nakano, Energy and National Security Program fellow at CSIS, the construction of AP1000 reactors has been providing U.S. regulators and engineers with valuable first-hand observations that contribute to the overall improvement of work on nuclear safety.[83] China decided to begin construction on the AP1000 reactors before they were approved by the U.S. Nuclear

Regulatory Commission, essentially becoming a "pilot" for U.S.-designed reactors.

China has drawn technology from foreign partners (notably Russia and France) prior to the Westinghouse deal. In fact, the most common reactor type currently under construction is the CPR–1000, a Chinese development of French design. The intellectual property rights were retained by the French company Areva, however, which limited the overseas sales potential for the CPR–1000.[84] Because the sale of the AP1000 entailed a substantial IP transfer, it created a situation where Westinghouse bolstered the competitiveness of Chinese vendors. As Ms. Nakano notes in her testimony, the Chinese government has dedicated significant resources to "indigenize" most advanced nuclear technology, making development of a Chinese reactor based on the AP1000 one of the 16 "national projects" under China's Medium- and Long-Term National Science and Technology Development Plan (covering 2006–2020).[85] According to various statements from Chinese nuclear regulators and operators, the intellectual property rights on "indigenous" reactor, CAP1400, reside with the Chinese entities, referring to their agreement with Westinghouse that reportedly "gave the Chinese domestic rights to much of the core AP1000 derivatives."[86]

As a consequence of using, adapting, and improving foreign technology, China is now self-sufficient in reactor design and construction, and is pursuing a policy of exporting nuclear technology.[87] China National Nuclear Corporation (CNNC) and China General Nuclear Power Group (CGN), China's main nuclear operators, are working to find an international market for their reactors, mostly developed based on the CAP1400 reactor. In 2013, CNNC was contracted to build two reactors for a nuclear power project in Pakistan,* with the Chinese government committing to finance $6.5 billion of the $9.95 billion for the project.[88]

United States and China also collaborate on the next generation of nuclear technologies. Under an MOU on Cooperation in Nuclear Energy Sciences and Technologies, which includes cooperation on nuclear fuel resources and nuclear hybrid energy systems,[89] DOE and the Chinese Academy of Sciences (CAS) are collaborating on a molten salt reactor † that could run on thorium. Thorium, a naturally-occurring radioactive metal, is an alternative to uranium, and is abundant in nature.[90]

The first thorium reactor was designed and built at DOE's Oak Ridge National Laboratory in the 1960s (the program was ultimately cancelled due to a preference for uranium-fueled reactors). The Chinese government made research into thorium-based reactors a priority and budgeted $350 million to a project at the Shanghai Institute of Applied Physics, with the intention to "obtain full intellectual property rights on the technology."[91] The Chinese pro-

* Although the Nuclear Suppliers Group (NSG), of which China is a member, forbids the supply of nuclear power plants to non-members like Pakistan without approval, China has argued that its agreement with Pakistan for cooperation in civil nuclear technology was signed before China joined the NSG. NSG has not censured China for the deal. See Saurav Jha, "With Reactor Deal, China and Pakistan Seek to Reshape Global Nuclear Governance," *World Politics Review*, November 5, 2013. *http://www.worldpoliticsreview.com/articles/13349/with-reactor-deal-china-and-pakistan-seek-to-reshape-global-nuclear-governance*.

† Unlike the pressurized water cooling system most often used in traditional uranium-fueled reactors, molten salt reactors are an experimental class of nuclear fission reactors in which the primary coolant is a molten salt mixture, which reduces the risk of meltdowns.

gram is headed by Jiang Mianheng, son of the former Chinese president Jiang Zemin, who in 2010 brokered a cooperative agreement between DOE (primarily Oak Ridge National Laboratory) and CAS.[92] In 2011, DOE gave a $7.5 million grant for related research led by MIT in collaboration with the University of California at Berkeley and the University of Wisconsin at Madison. Westinghouse has been tapped as a commercial partner,[93] but no U.S. government program currently exists to develop thorium reactors.

Implications for the United States

To the extent that China's investment in clean energy leads to reduced emissions of CO2 and other pollutants of water, air, and soil, U.S. public and private cooperation with China on development of clean energy has positive outcomes for all nations. China is a global leader in clean energy investment, and Chinese funding could be used to boost technologies that are not cost effective in the short run. Moreover, the combined work of U.S. and Chinese researchers can magnify progress made individually. Intangible benefits, such as building trust and mutual understanding, are also valuable and will likely lead to future collaboration.

China's lack of strong IP standards and potential for future competition with U.S. renewable energy companies remain primary challenges to closer cooperation. Analysts and policymakers continue to fear that China could reap the benefits of cooperation at the expense of U.S. industry and workers.[94] Although much of the current friction has been concentrated in the renewable energy sector, the Chinese government has deployed massive resources to promote the clean energy sector as well, which may result in additional anticompetitive or illegal practices. In 2012, the U.S. Department of Commerce applied antidumping and countervailing duties on Chinese solar panels after U.S. solar companies successfully argued that Chinese manufacturers were unfairly subsidized by the Chinese government.[95] In a separate case, American Superconductor Corp. (AMSC) sued Sinovel, a Chinese wind turbine manufacturer, through the Chinese courts for up to $1.2 billion of damages for theft of IP.[96] The U.S. Department of Justice charged Sinovel (along with two of its employees and a former employee of an AMSC subsidiary) with stealing trade secrets from AMSC, causing an alleged loss of more than $800 million to the company. The case is still pending.[97]

CERC's efforts are still too new to comprehensively assess. Under CERC, the policy dialogue, capacity building, and technology transfer are supplemented with joint R&D and new technologies. The Technology Management Plan set up by CERC is one example of an attempt to alleviate concerns over protection of IP. However, to date, most CERC participants still tend to design collaborative projects only around less sensitive research topics and little of the new IP generated through CERC activities has come from collaborative efforts—an indication that China's history of poor IP protection continues to have a chilling effect on cooperation.

Dr. Lewis noted that many of the truly collaborative and international projects under CERC do not deal in true R&D activities, but rather less sensitive research areas, such as technology modeling and policy analysis.[98] Experts working on other collaborative efforts have reached the same conclusion. For example, Valerie Karplus, project director of the China Energy and Climate Project at MIT, echoed Dr. Lewis's assessment. The China Energy and Climate Project collaborative team studies energy and environmental policy decision making in China, in most cases employing open-source modeling tools, which eliminates common IP- or competition-related concerns associated with U.S.-China cooperation on clean energy.[99] Focusing on building trust might be a good option in the short term, but work needs to be truly collaborative in the long run to ensure that benefits accrue equally to all participants.

For U.S. energy companies, lack of consistent U.S. government policy and secure funding for new technologies means that they have to seek research or implementation opportunities elsewhere. According to Dr. Lewis, for almost all of the U.S. business participants in CERC "one of the biggest advantages of participating . . . was to gain leverage for technology demonstration projects."[100] Many industry CERC participants have invested their own money in the collaborations "far in excess of government support because government involvement provided leverage for project approvals, and many CERC collaborations were perceived to have current or future commercial value."[101]

Despite some positive trends, all too often, U.S.-China collaboration continues to default to the transfer of U.S. technology to China. Collaboration on shale gas and nuclear power exemplify this trend. Investment by Chinese companies in U.S. shale points to the unequal access U.S. energy companies have in China, even as their Chinese counterparts do not have similar restrictions in the United States. In civil nuclear energy, too, the collaboration seems to have consisted solely of a transfer of U.S. intellectual property to China, which is now building its own reactors.

So many collaborative initiatives with overlapping priorities exist in the government-sponsored arena alone (see Addendum I) that it becomes difficult to track spending, mark progress, and identify redundancies. When various academic and industry initiatives (many receiving public money) are added to the mix, the task of separating successful and useful initiatives from the wasteful ones becomes even more challenging.

Another challenge to productive collaboration is getting participants to move from discussion to action. In her assessment of U.S.-China cooperation on clean coal and CCS, Kelly Sims Gallagher, director of the Center for International Environment and Resource Policy at Tufts University, said that although bilateral work on technical research continues to become more robust, "the problem remains of too many meetings and not enough concrete projects."[102] Still, CERC is only halfway through its first five years, and will likely be renewed for a second five-year phase (2016–2020).

Conclusions

- The United States and China share similar challenges in their quest for clean energy. Both countries are leading global emitters of greenhouse gasses and could benefit from cooperation on issues related to climate change and environmental protection.

- The United States and China have been cooperating for over 30 years on environmental and clean energy initiatives, with much of the early agreements focusing more on establishing the basic frameworks for cooperation and on energy policy discussions. In the 2000s, clean energy and climate change mitigation emerged as leading topics of cooperation between China and the United States, culminating in 2009 with the establishment of the Clean Energy Research Center (CERC), a joint research initiative.

- The CERC facilitates joint research and development on clean energy technology by teams of scientists and engineers from the United States and China. Funded in equal parts by the United States and China, CERC has participation from universities, research institutions and industry. CERC's three research priorities (the consortia) are advanced clean coal technologies, clean vehicles, and building energy efficiency.

- While Chinese CERC participants have been filing patents in China and in the United States, to date, there have been no jointly-created intellectual property (IP) and no U.S. inventions patented in China, suggesting that China's history of lax protection of IP dampens enthusiasm for collaboration.

- While collaboration under CERC is research-driven, U.S.-China cooperation on shale gas development is more commercial, largely involving investment by Chinese companies in U.S. shale assets in order to acquire technology and know-how.

- Similar to shale gas, U.S.-China cooperation on civil nuclear energy involves a sale of technology to China, supplemented by nuclear safety, safeguards, and security training to Chinese regulators and technicians to ensure China meets the highest nuclear safety and nonproliferation standards.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014

Year	Initiative	Participants	Purpose/Description
1979	Scientific and Technology Cooperative Agreement	Official bilateral governmental agreement established by President Carter and Vice Premier Deng Xiaoping	Began with a focus on high-energy physics and then served as an umbrella for 30 subsequent bilateral environment and energy protocols. Extended for 5 years.
1979	MOU for Bilateral Energy Agreements	U.S. DOE and the China State Development Planning Commission (SDPC)	Led to 19 cooperative agreements on energy, including fossil energy, climate change, fusion energy, energy efficiency, renewable energy, peaceful nuclear technologies, and energy information exchange.
1979	Atmosphere and Science and Technology Protocol	NOAA and Chinese Meteorological Administration	Promotes bilateral exchange on climate and oceans data, research, and joint projects.
1983	Protocol on Nuclear Physics and Magnetic Fusion	DOE and State Science and Technology Commission (SSTC)	Pursues the long-term objective to use fusion as an energy source.
1987	Annex III to the Fossil Energy Protocol Cooperation in the Field of Atmospheric Trade Gases	DOE and State Science and Technology Commission (SSTC)	Cooperative research program on the possible effects of CO2 on climate change.
1988	Sino-American Conference on energy demand, markets and policy in Nanjing	Lawrence Berkeley National Laboratory (LBNL)/ DOE and State Planning Commission (SPC)/ Energy Research Institute (ERI)	Informal bilateral conference on energy efficiency that led to an exchange program between ERI and LBNL, and the first assessment of China's energy conservation published by LBNL in 1989.
1992	U.S. Joint Commission on Commerce and Trade	U.S. Department of Commerce (DOC)	Facilitates the development of commercial relations and related economic matters between the U.S. and China. The JCCT's Environment subgroup supports technology demonstrations, training workshops, trade missions, exhibitions and conferences to foster environmental and commercial cooperation.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
1993	U.S. Commercial Mission to China	DOE and DOC	For U.S. companies to promote their electric power technology services in China. Industry representatives identified a potential for $13.5 billion in U.S. electric power exports between 1994–2003 (not including nuclear power), equating to 270,000 high-salary U.S. jobs and an opportunity for introducing cost-effective, environmental sound U.S. technologies into China's electric power industry.
1993	Establishment of the Beijing Energy Efficiency Center (BECon)	ERI, LBNL, Pacific Northwest National Laboratory (PNNL), WWF, EPA, SPC, SETC, SSTC	The first nongovernmental, nonprofit organization in China focusing on promoting 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.
1994	Annexes to the fossil energy protocol	DOE and SSTC	(1) To make positive contributions towards 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. (2) Cooperation in coal-fired magnetohydrodynamic (MHD) power generation.
1994	China's Agenda 21 Document Released	SSTC and China's National Climate Committee	Lays out China's request for international assistance on environmental issues. The U.S. agreed to support China through DOE's Climate Change Country Studies and Support for National Actions Plans programs.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

<table>
<tr><th>Year</th><th>Initiative</th><th>Participants</th><th>Purpose/Description</th></tr>
<tr><td>1995</td><td>Series of DOE bilateral agreements signed by Secretary of Energy Hazel O'Leary</td><td colspan="2">Bilateral agreements on energy between DOE and ministries as noted below:
(1) MOU on bilateral energy consultations (with SPC)
(2) Research on reactor fuel (with China Atomic Energy Authority)
(3) Renewable energy (with Ministry of Agriculture)
(4) Energy efficiency development (with SSTC)
(5) Renewable energy technology development (with SSTC)
(6) Coal bed methane recovery and use (with Ministry of the Coal Industry)
(7) Regional climate research (with the China Meteorological Administration)
Also established
• Plan for mapping China's renewable energy resources (with SPC)
• Strategies for facilitating financing of U.S. renewable energy projects in China (with SPC, Chinese and U.S. Ex-Im Banks)
• Discussions for reducing and phasing out lead gasoline in China (DOE & EPA with China's EPA & SINOPEC)</td></tr>
<tr><td>1995 (some annexes in 1996)</td><td>Protocol for Cooperation in the Fields of Energy Efficiency and Renewable Energy Technology Development and Utilization</td><td>DOE and various ministries</td><td>This Protocol has seven annexes that address policy; rural energy (Ministry of Agriculture); large-scale wind systems (with SEPA); renewable energy business development (with SETC) and geothermal energy; energy efficiency (with SPC); and hybrid-electric vehicle development. Ten teams of Chinese and U.S. government and industry representatives work under this protocol focusing on: energy policy, information exchange and business outreach, district heating, cogeneration, buildings, motor systems, industrial process controls, lighting, amorphous core transformers, and finance.</td></tr>
<tr><td>1995–2000</td><td>Statement of Intent for Statistical information exchange (later became a Protocol)</td><td>DOE and China's National</td><td>Consisted of five meetings to discuss energy supply and demand and exchange information on methods of data collection and processing of energy information.</td></tr>
</table>

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	**Initiative**	**Participants**	**Purpose/Description**
1997	U.S.-China Forum on Environment & Development	Established by Vice President Al Gore and Premier Li Peng	Venue for high-level bilateral discussion on sustainable development. Established four working groups: energy policy, commercial cooperation, science for sustainable development, and environmental policy. Three priority areas for cooperative work: urban air quality; rural electrification; and clean energy and energy efficiency.
1998-ongoing	Agreement of Intent on Cooperation Concerning Peaceful Uses of Nuclear Technology	DOE and SPC	Paved the way for the exchange of information and personnel, training and participation in research and development in the field of nuclear and nuclear nonproliferation technologies.
1997	Energy and Environment Cooperation Initiative (EECI)	DOE and SPC	Targeted urban air quality, rural electrification and energy sources, and clean energy sources and energy efficiency. Involved multiple agencies and participants from business sectors, and linked energy development and environmental protection.
1997	U.S.-China Energy and Environmental Center	Tsinghua University and Tulane University, with DOE and SSTC/MOST	An initiative centered at Tsinghua and Tulane Universities co-funded by DOE and MOST to: (1) provide training programs in environmental policies, legislation and technology; (2) develop markets for U.S. clean coal technologies; and (3) help minimize the local, regional and global environmental impact of China's energy consumption.
1998	Joint Statement on Military Environmental Protection	U.S. Secretary of Defense and Vice-Chairman of Chinese Central Military Commission	MOU provides for the exchange of visits by high-level defense officials and the opening of a dialogue on how to address common environmental problems.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
1999	U.S.-China Forum on Environment & Development	The U.S. Ex-Im Bank, DOE, the China Development Bank, and the SDPC	The second meeting of the Forum in Washington, co-chaired by Vice President Al Gore and Premier Zhu Rongji. Two key agreements that came out of the meeting related to renewable energy included a MOU for the establishment of a $100 Million Clean Energy Program to accelerate the deployment of clean U.S. technologies to China in the area of energy efficiency, renewable energy, and pollution reduction, and a Statement of Intent on Cleaner Air and Cleaner Energy Technology Cooperation that focused on energy efficiency improvements in industrial coal-fired boilers; clean coal technology; high-efficiency electric motors; and grid-connected wind electric power.
1999–2000	Fusion Program of Cooperation	DOE and CAS	Plasma physics, fusion technology, advanced design studies and materials research.
2002–2003	U.S.-China Fusion Bilateral Program	DOE and CAS	Plasma physics, fusion technology and power plant studies.
2003	FutureGEN	DOE with many international partners	Initially planned as a demonstration project for an Integrated Gasification Combined Cycle (IGCC) Coal plant with carbon capture and storage (CCS), the project was significantly restructured in January 2008 and now may provide federal funding to support CCS on a privately funded IGCC or PC plant, though the timeframe is highly uncertain.
2004	U.S.-China Energy Policy Dialogue	DOE and NDRC	Resumed the former Energy Policy Consultations under the 1995 DOE–SPC MOU. Led to a MOU between DOE and NDRC on Industrial Energy Efficiency Cooperation and includes energy audits of up to 12 of China's most energy-intensive enterprises, as well as training and site visits in the U.S. to train auditors.
2004	U.S.-China Green Olympic Cooperation Working Group	DOE, Beijing Government	Included opportunities for DOE to assist China with physical protection of nuclear and radiological materials and facilities for the Beijing Olympics as done in Athens, Greece.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2006	Asia-Pacific Partnership on Clean	U.S., China + India, Japan, Korea, Australia (later Canada)	Created public-private task forces around specific sectors: Aluminum, Buildings and Appliances, Cement, Cleaner Use of Fossil Energy, Coal Mining, Power Generation and Transmission, Renewable Energy and Distributed Generation, and Steel.
2006	U.S.-China Strategic Economic Dialogue (SED)	U.S. Treasury Secretary Henry Paulson and Vice Premier Wu Yi. Includes DOE, EPA, NDRC, MOST	Bi-annual, cabinet level dialogue that includes an energy and environment track.
2007	MOU on Cooperation on the Development of Biofuels	USDA and NDRC	Encourages cooperation in biomass and feedstock production and sustainability; conversion technology and engineering; biobased product development and utilization standards; and rural and agricultural development strategies.
2007	U.S.-China Bilateral Civil Nuclear Energy Cooperative Action Plan	DOE and NDRC	To compliment discussions under the Global Nuclear Energy Partnership (GNDP) towards the expansion of peaceful, proliferation-resistant nuclear energy for greenhouse gas emissions-free, sustainable electricity production. Bilateral discussions include separations technology, fuels and materials development, fast reactor technology and safeguards planning.
2007	U.S.-China Westinghouse Nuclear Reactor Agreement	DOE, State Nuclear Power Technology Corporation (SNPTC)	DOE approved the sale of four 1,100-megawatt AP1000 nuclear power plants which use a recently improved version of existing Westinghouse pressurized water reactor technology. The contract was valued at $8 billion and included technology transfer to China. The four reactors are to be built between 2009 and 2015.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2008	Ten Year Energy & Environment Cooperation Framework (SED IV)	DOE, Treasury, State, Commerce, EPA, NDRC, State Forestry Administration, National Energy Administration (NEA), Ministry of Finance, Ministry of Environmental Protection (MEP), MOST, and MFA	Establishes five joint task forces on the five functional areas of the framework: (1) clean efficiency and secure electricity production and transmission; (2) clean water; (3) clean air; (4) clean and efficient transportation; and (5) conservation of forest and wetland ecosystems.
2009	U.S.-China Strategic & Economic Dialogue	U.S. Department of State and Department of Treasury, China Ministry of Foreign Affairs	In April 2009 the SED was rebranded as the Strategic and Economic Dialogue (S&ED), with the State and Treasury Departments now co-chairing the dialogue for the United States. Treasury Secretary Timothy F. Geithner and Secretary of State Hillary Rodham Clinton were joined for the first Dialogue in July 2009 by their respective Chinese Co-Chairs, State Councilor Dai Bingguo and Vice Premier Wang Qishan, to cover a range of strategic and economic issues. The S&ED was convened again in Beijing in May 2010.
2009	Memorandum of Understanding to Enhance Cooperation on Climate Change, Energy and the Environment This MOU is to be implemented via the existing Ten-Year Energy and Environment Cooperation Framework, and a newly established Climate Change Policy Dialogue, as well as new agreements forthcoming.	Signed between DOE, State and NDRC. To strengthen and coordinate respective efforts to combat global climate change, promote clean and efficient energy, protect the environment and natural resources, and support environmentally sustainable and low-carbon economic growth. Both countries resolve to pursue areas of cooperation where joint expertise, resources, research capacity and combined market size can accelerate progress towards mutual goals. These include, but are not limited to: • Energy conservation and energy efficiency • Renewable energy • Cleaner uses of coal, and carbon capture and storage • Sustainable transportation, including electric vehicles • Modernization of the electrical grid • Joint research and development of clean energy technologies • Clean air • Clean water • Natural resource conservation, e.g., protection of wetlands and nature reserves • Combating climate change and promoting low-carbon economic growth	

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2009	Climate Change Policy Dialogue	Representatives of the two countries' leaders	The United States and China will work together to further promote the full, effective and sustained implementation of the United Nations Framework Convention on Climate Change. The dialogue will promote: (1) discussion and exchange of views on domestic strategies and policies for addressing climate change; (2) practical solutions for promoting the transition to low-carbon economies; (3) successful international negotiations on climate change; (4) joint research, development, deployment, and transfer, as mutually agreed, of climate-friendly technologies; (5) cooperation on specific projects; (6) adaptation to climate change; (7) capacity building and the raising of public awareness; and (8) pragmatic cooperation on climate change between cities, universities, provinces and states of the two countries.
2009	Memorandum of Cooperation to Build Capacity to Address Climate Change	EPA and NDRC	In support of the MOU to Enhance Cooperation on Climate Change, Energy and the Environment, this five-year agreement includes: (1) capacity building for developing greenhouse gas inventories; (2) education and public awareness of climate change; (3) the impacts of climate change to economic development, human health and ecological system, as well as research on corresponding countermeasures; and (4) other areas as determined by the participants.
2009	U.S.-China Joint Commission on Commerce and Trade	Co-chaired by U.S. Dept. of Commerce Secretary Gary Locke, U.S. Trade Representative Ron Kirk, Chinese Vice Premier Wang Qishan, with participation from many ministries/agencies from both countries	The Commission met in October 2009 in Hangzhou, China, and reached multiple agreements in many sectors, including, in the clean energy sector for China to remove its local content requirements on wind turbines.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2009	U.S.-China Clean Energy Research Center (CERC)	DOE, MOST, NEA	First announced in July 2009 during U.S. Department of Energy Secretary Steven Chu's visit to Beijing and finalized during the November 2009 Presidential Summit, the Center will facilitate joint research and development of clean energy technologies by teams of scientists and engineers from the United States and China, as well as serve as a clearinghouse to help researchers in each country. The Center will be supported by public and private funding of at least $150 million over five years, split evenly between the two countries. Initial research priorities will be building energy efficiency, clean coal including carbon capture and storage, and clean vehicles.
2009	U.S.-China Electric Vehicles Initiative	DOE, MOST, NEA	Announced during the November 2009 Presidential Summit and building on the first-ever U.S.-China Electric Vehicle Forum in September 2009, the initiative will include joint standards development, demonstration projects in more than a dozen cities, technical roadmapping, and public education projects.
2009	U.S.-China Renewable Energy Partnership	DOE, MOST, NEA	Announced during the November 2009 Presidential Summit, the Partnership calls for the two countries to develop roadmaps for widespread renewable energy deployment in both countries. The Partnership will also provide technical and analytical resources to states and regions in both countries to support renewable energy deployment and will facilitate state-to-state and region-to-region partnerships to share experience and best practices. A new Advanced Grid Working Group will bring together U.S. and Chinese policymakers, regulators, industry leaders, and civil society to develop strategies for grid modernization in both countries. A new U.S.-China Renewable Energy Forum will be held annually, rotating between the two countries. The first was held in China late May 2010.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2009	21st Century Coal	DOE, MOST, NEA	Announced during the November 2009 Presidential Summit, the two Presidents pledged to promote cooperation on cleaner uses of coal, including large-scale carbon capture and storage (CCS) demonstration projects. Through the new U.S.-China Clean Energy Research Center, the two countries are launching a program of technical cooperation to bring teams of U.S. and Chinese scientists and engineers together in developing clean coal and CCS technologies. The two governments are also actively engaging industry, academia, and civil society in advancing clean coal and CCS solutions.
2009	Shale Gas Resource Initiative	DOE, MOST, NEA	Announced during the November 2009 Presidential Summit, this shale gas initiative will use experience gained in the United States to assess China's shale gas potential, promote environmentally sustainable development of shale gas resources, conduct joint technical studies to accelerate development of shale gas resources in China, and promote shale gas investment in China through the U.S.-China Oil and Gas Industry Forum, study tours, and workshops.
2009	U.S.-China Energy Cooperation Program	A public-private partnership, including 22 companies as founding members, including Peabody Energy, Boeing, Intel and GE.	Announced during the November 2009 Presidential Summit, the U.S.-China Energy Cooperation Program (ECP) will leverage private sector resources for project development work in China across a broad array of clean energy projects on renewable energy, smart grid, clean transportation, green building, clean coal, combined heat and power, and energy efficiency.
2010	U.S.-China Strategic & Economic Dialogue	U.S. Department of State and NDRC/NEA	26 specific outcomes were produced by the second round of the S&ED under the Strategic track alone. Key outcomes addressing energy and climate issues specifically included MOUs on nuclear safety cooperation, EcoPartnerships, and Shale Gas; a joint statement on energy security; and three clean energy forums held each year.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2010	U.S.-China Energy Efficiency Forum	NEA/NDRC, MIIT, DOE/ LBNL/ORNL/ FERC, private sector participants	This first meeting of this Forum (established in the 2009 U.S.-China Energy Efficiency Action Plan) included the signing of an MOU on industrial energy efficiency between Lawrence Berkley National Laboratory, Oak Ridge National Laboratory and the University of Science and Technology, Beijing.
2010	U.S.-China Renewable Energy Forum	NEA/NDRC, DOE/NREL/ FERC, private sector participants	The first meeting of this forum that was established in the 2009 U.S.-China Renewable Energy Partnership included a significant focus on potential cooperation opportunities between U.S. and Chinese renewable energy companies. The forum was followed by technical discussions that established three working groups on renewable energy, including: (1) planning, analysis and coordination; (2) wind technology; and (3) solar technology.
2010	U.S.-China Advanced Biofuels Forum	NEA/NDRC, DOE/NREL, private sector participants	The eight MOUs signed under this forum focus on private sector partnerships in advanced biofuels research and deployment. Private sector partnerships include: Boeing and PetroChina jointly developing a sustainable aviation biofuels industry in China; an expanded research collaboration between Boeing Research & Technology and the Qingdao Institute of Bioenergy and Bioprocess Technology on algae-based aviation biofuel development; and an inaugural flight using biofuel derived from biomass grown and processed in China conducted by Air China, PetroChina, Boeing and Honeywell.
2011	MOU for Protocol for Cooperation in Energy Sciences	U.S. Department of Energy and the Chinese Academy of Sciences	This Protocol will facilitate and promote cooperation in energy sciences such as nuclear energy sciences, biological science and environmental science.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2011	U.S.-China Strategic & Economic Dialogue	U.S. Department of State and Department of Treasury, China Ministry of Foreign Affairs,	Decided to share information about regulatory experiences and practices of the Federal Energy Regulatory Commission and the National Energy Administration related to energy issues in both the United States and China. Also decided to enhance cooperation and analysis of the planning and deployment of large-scale wind projects research, and connecting wind projects to the electric transmission grid.
2011	MOU on Support of the Energy Cooperation Program	U.S. Trade & Development Agency (USTDA), NEA	Provides support for a wide range of clean energy activities in 2012. These include activities on clean fuels, energy efficiency, power generation, renewable energy, smart grid, and clean transportation.
2011	MOU for the advancement of Eco-Cities	DOE and the China Ministry of Housing and Urban Rural Development	Advance Eco-Cities Initiative in the United States and China, under which both sides will develop guidelines and policies to support the integration of energy efficiency and renewable energy into city design and operation.
2013	MOU for the creation of a Joint U.S.-China Green Data Center Industrial Initiative	U.S.-China Energy Cooperation Program (ECP) and Chinese Institute of Electronics (CIE)	Creation of a Joint U.S.-China Green Data Center Industrial Initiative aims to provide valuable reference and living best practices for green data center development in China through deep cooperation between both U.S. and China industries.
2013	MOU on U.S.-China Clean Energy Cooperation	China Industrial Overseas Development and Planning Association (CIODPA) and ECP's Energy Financing and Investment Working Group (EFI WG)	This MOU establishes the agreement for jointly cooperate initiatives that expand opportunities for U.S.-China collaboration in clean energy investment in the U.S. and other international markets. It also establishes a communication channel with ECP members and other key stakeholders to improve cooperation on Chinese investment in the energy sectors.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	**Initiative**	**Participants**	**Purpose/Description**
2013	MOU in Support of U.S.-China Energy Cooperation Program	U.S. Trade and Development Agency (USTDA) and China's National Energy Administration (NEA)	This MOU will establish a work plan between USTDA and NEA that will cover a broad range of energy activities over the next year in support of ECP. Subjects include, but are not limited to: clean transportation (clean fuels), decentralized energy and combined cooling, heat and power, industrial energy efficiency, shale gas, renewable energy, smart grid and microgrid, and other fields as mutually determined. USTDA intends to continue contributing funding for feasibility studies, consultancies, study tours, workshops and related project development work on clean and efficient energy best practices, as identified in continued consultation with ECP, the NEA, and other Chinese government agencies.
2013	U.S.-China Strategic & Economic Dialogue	U.S. Department of State and Department of Treasury, China Ministry of Foreign Affairs	Established the U.S.-China Climate Change Working Group to develop and implement significant proposals for bilateral cooperation on climate change between the two. Also decided to enhance cooperation on energy security and transparency. Also signed an MOU on Enhancing Energy Regulation Cooperation between the Federal Energy Regulatory Commission and the National Energy Administration to expand cooperation on electricity, oil, and gas issues.
2013	MOU to lower carbon dioxide emissions	Xie Zhenhua, vice-minister of the National Development and Reform Commission of China, and California Governor Jerry Brown	A two-year agreement to share expertise and resources to reduce CO2. It includes sharing of information and experiences regarding policies and programs to strengthen low carbon development across economic sectors. The MOU also includes exchanges and temporary assignments of personnel from one of the parties to the other; cooperative research on clean and efficient energy technologies, including developing shared research, development and deployment projects.

Addendum I: U.S.-China Cooperation on Clean Energy and Climate Change, 1979–2014—*Continued*

Year	Initiative	Participants	Purpose/Description
2013	U.S.-China Energy Efficiency Forum	DOE and NDRC	MOUs were signed between Chinese partners and the University of Colorado-Boulder to initiate the International Center for Urban and Building Engineering Sustainability, the Digital Energy and Sustainability Solutions Campaign on comprehensive exchanges to improve the efficiency of the IT sector, and LBNL to harmonize standards and foster pre-competitive R&D collaboration on high performance data center.
2014	U.S.-China Strategic & Economic Dialogue	U.S. Department of State and Department of Treasury, China Ministry of Foreign Affairs	Launched eight demonstration projects—four on carbon capture, utilization, and storage, and four on smart grids. Agreed to adopt stronger heavy and light duty vehicle fuel efficiency and greenhouse gas emissions standards, conduct a study on the efficiency and use of gas in industrial boilers, and launched a new initiative on climate change and forests.
2014	MOU for cooperation on strategic petroleum reserves	U.S. Secretary of Energy Ernest Moniz and Administrator Wu Xinxiong of China's National Energy Administration, DOE, NEA	The MOU enables the DOE's Office of Petroleum Reserves and NEA's National Oil Reserve Office to share information on technical, management, and policy issues related to oil stockpiles. DOE and NEA will conduct annual technical meetings to be held alternately in the United States and China.
2014	MOU for cooperation on electric vehicles and industrial energy efficiency	U.S. Secretary of Energy Ernest Moniz and Minister Miao Wei of the Chinese Ministry of Industry and Information Technology	The MOU facilitates cooperation in the fields of electric vehicles and related technologies, as well as energy efficiency improvement for end use products.

Source: Agreements for the 1979–2010 period adapted from Joanna Lewis, "The State of U.S.-China Relations on Climate Change: Examining the Bilateral and Multilateral Relationship," *China Environment Series*, no. 11 (December 2010): 26–34. *http://www.wilsoncenter.org/sites/default/files/Feature%20Article%20The%20State%20of%20U.S.-China%20Relations%20on%20Climate%20Change.pdf*. Agreements for the 2011–2014 period compiled by Commission staff.

Addendum II: CERC Research Topics [103]

Advanced Coal Technology Consortium (ACTC)

ACTC focuses on the most critical research needs, categorized by the following eight research areas:

1. Advanced Power Generation: Develop breakthrough technologies in advanced coal power generation and the application of advanced technology.
2. Clean Coal Conversion Technology: Conduct research, development, and demonstration of new coal co-generation systems with CO2 capture, including new coal-to-chemical co-generation; new CO2 capture processes; and co-generation systems with combined pyrolysis, gasification, and combustion. Projects in this area will pursue high-efficiency conversion.
3. Pre-Combustion CO2 Capture: Conduct major industrial-scale demonstrations of integrated gasification combined cycle (IGCC) power generation with carbon capture and sequestration.
4. Post-Combustion CO2 Capture: Investigate various technologies for post-combustion capture and conduct demonstrations of CO2 capture, utilization, and storage in cooperation with large power generation companies.
5. Oxy-Combustion Research, Development, and Demonstration: Study the fundamental and pilot-scale combustion and emission characteristics of indigenous Chinese and U.S. coals of different ranks under oxyfuel conditions, create a model for oxy-fired burner design, evaluate and optimize pilot-scale oxy-combustion, and conduct a commercial-scale engineering feasibility study for an oxyfuel–combustion reference plant, with the goal of achieving cost and performance breakthroughs in the laboratory and the field that help overcome the challenges to oxyfiring with both U.S. and Chinese coals.
6. Sequestration Capacity and Near-Term CCUS Opportunities: Develop research work focused on CO2 geological sequestration (CGS) in China's Ordos Basin to better understand and verify key technologies for CO2 storage in saline formations, to provide the scientific evidence to implement large-scale carbon capture and storage (CCS) in China and to provide support for CCS development in the United States.
7. CO2 Algae BioFixation and Use: Support the industrial demonstration of carbon biofixation using microalgae to absorb CO2 and turn the biomass produced into a rich source of renewable energy, including biodiesel.
8. Integrated Industrial Process Modeling and Additional Topics: Apply modeling techniques to a wide variety of issues associated with pre- and post-combustion CO2 capture and oxy-combustion to assess the economic and operability potential of existing capture technologies in conjunction with removal of criteria pollutants, assess the technical feasibility and potential economic benefit and operability of new carbon capture technologies, and optimize the economics of different carbon capture technologies.

Clean Vehicles Consortium (CVC)

CVC research is organized into six areas:

1. Advanced Batteries and Energy Conversion: Increase application of novel battery designs that promise much higher energy densities, such as lithium-air and lithium-sulfur batteries; develop high efficiency thermoelectric materials to recover waste heat.
2. Advanced Biofuels, Clean Combustion, and Auxiliary Power Unit (APU): Accelerate development and deployment of advanced biofuels with molecular models that can be used to predict the behavior of novel fuels in various combustion environments; system controls for clean vehicles; and development, integration, and control of APU systems.
3. Vehicle Electrification: Develop electric motors and power electronics with higher conversion efficiencies and power/energy densities than are currently possible.
4. Advanced Lightweight Materials and Structures: Develop low-cost, energy-efficient, high-quality processes for producing, forming, and joining of lightweight materials to increase integration of aluminum alloys, magnesium alloys, and carbon-polymer composites into vehicle structures while maintaining structural rigidity and crash safety.
5. Vehicle-Grid Integration: Develop advanced control strategies and protocols to coordinate plug-in electric vehicle (PEV) charging and develop interfaces to accelerate the deployment of PEVs and minimize impact to grid quality and battery aging.

6. Energy Systems Analysis, Technology Roadmaps, and Policies*:* Integrate vehicle and energy infrastructure systems to address temporal and spatial variation of energy sources, petroleum demand, and CO2 emissions impacts; diversity in consumer drive cycles and trip patterns; producer and consumer economic factors; global vehicle and fuel market factors; and future fuel efficiency and carbon policy regimes.

Building Energy Efficiency Consortium (BEE)

BEE has developed a collaborative research agenda organized into six research topics:

1. Integrated Building Design & Operation of Very Low Energy, Low Cost Buildings: Provide a rich foundation to support prioritization of energy savings opportunities from buildings. Research in this topic area is focusing on new scientific methods for collecting data and modeling energy consumption that will guide development of high-impact energy efficiency technologies.
2. Building Envelope: Develop new building materials and related control and integration systems. Research in this area improves understanding and strategies for ventilation, comfort systems, and cool roofs.
3. Building Equipment: Research and demonstrate the adaptability of advanced building equipment technologies. Research in this area includes new lighting system design and control and improvements to the performance and market penetration of climate control (heating, ventilation, and cooling) technologies. Research includes integrating building equipment with control systems and metering equipment and optimizing management software.
4. Renewable Energy Utilization: Research and demonstrate technological adaptability in applying new and renewable energy to buildings. This research area includes integration of geothermal, solar, and wind energy systems, among others, to convert buildings from energy consumers to net energy suppliers.
5. Whole Building: Research and demonstrate integrated building energy technologies. Research in this area includes analyzing building energy use in the United States and China to improve building integration and optimize the use of energy-efficient and low-carbon energy supply technologies.
6. Operation, Management, Market Promotion and Research: Evaluate standards, certification, codes and labels, and other policy mechanisms to establish a knowledge base from which to make effective decisions.

ENDNOTES FOR SECTION 4

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