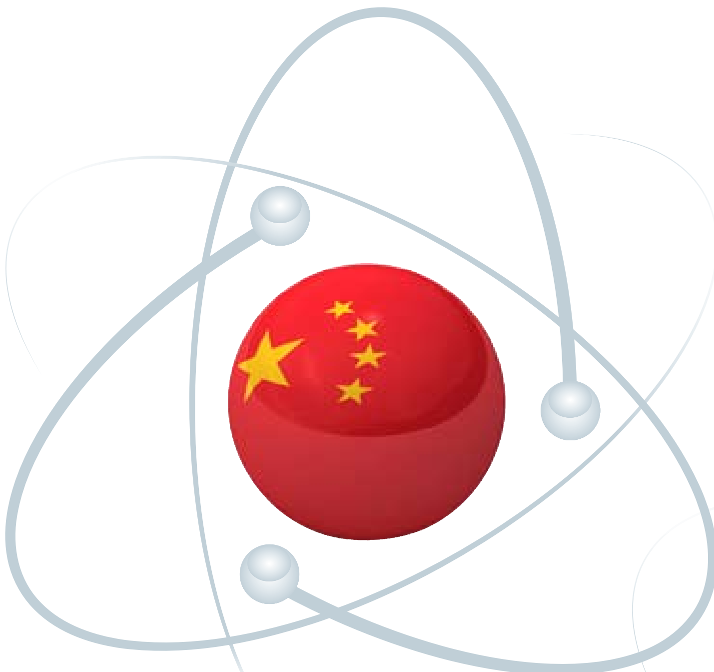
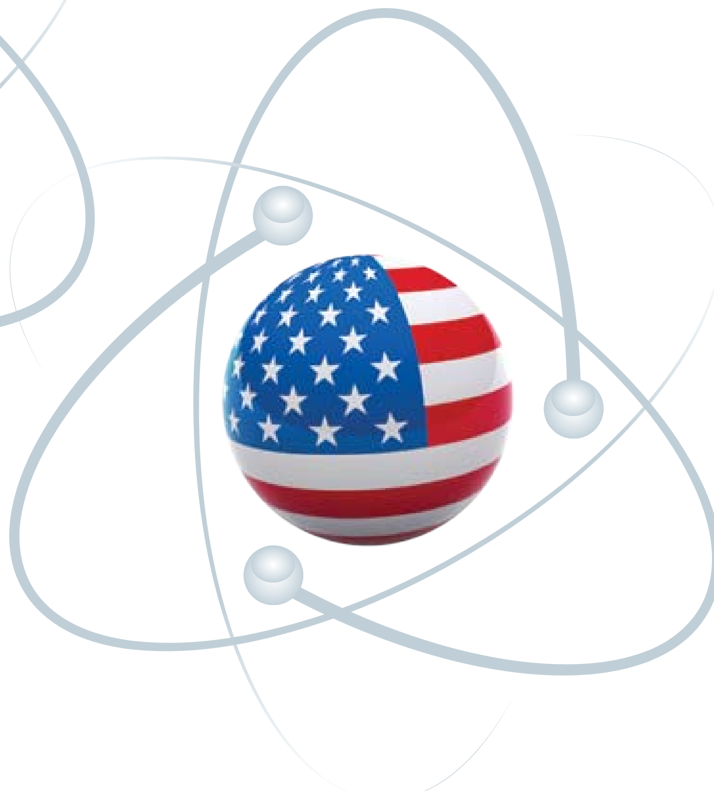
Atlantic Council

UNITED STATES-CHINA COOPERATION On Nuclear Power:

An Opportunity for Fostering Sustainable Energy Security





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Under the Chairmanship of
Gen. Richard L. Lawson, USAF (Ret.)

Washington DC • March 4–6, 2009

Based on the Dialogue Sponsored by the Atlantic Council and the U.S./China Energy and Environment Technology Center

The Atlantic Council promotes constructive U.S. leadership and engagement in international affairs based on the central role of the Atlantic community in meeting the international challenges of the 21st century. The Council embodies a non-partisan network of leaders who aim to bring ideas to power and to give power to ideas by stimulating dialogue and discussion about critical international issues with a view to enriching public debate and promoting consensus on appropriate responses in the Administration, the Congress, the corporate and nonprofit sectors, and the media in the United States and among leaders in Europe, Asia, and the Americas. The Council is also among the few forums conducting educational and exchange programs for successor generations of U.S. leaders so that they will come to value U.S. international engagement and have the knowledge and understanding necessary to develop effective policies.

Through its diverse networks, the Council builds broad constituencies to support constructive U.S. leadership and policies. Its program offices publish informational analyses, convene conferences among current and/or future leaders, and contribute to the public debate in order to integrate the views of knowledgeable individuals from a wide variety of backgrounds, interests and experiences.

The Energy and Environment Program at the Atlantic Council explores the economic and political aspects of energy security and supply, as well as international environmental issues. Major shifts in policies, behavior, and expectations are increasingly required throughout the world to meet the challenges of maintaining secure and sustainable energy supplies and protecting the environment while maintaining economic competitiveness. The Energy and Environment Program facilitates international cooperation on developing strategies, policies, and regulations to address the energy security, environmental and economic challenges posed by increasing energy demands and climate change.

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Foreword

The Atlantic Council of the United States, in collaboration with the US/China Energy and Environmental Technology Center (EETC) of Tsinghua University and Tulane University, hosted a Dialogue on U.S.-China Cooperation on Nuclear Power in Washington, DC on March 4 - 6, 2009. This event was the third in a series of U.S.-China Strategic dialogues on energy security which aim to contribute to the development of active cooperation and coordination between the United States and China on vital energy issues.

An important step in this dialogue process is the development of a common understanding of each country's energy outlook and energy-related challenges, and each country's national and foreign policies related to energy. Over the past several years, the Council and EETC have invited key organizations, experts from industry and government, and representatives from relevant United States (U.S.) and Chinese government agencies to become directly involved in several meetings designed to identify concrete recommendations for increasing official governmental and industry cooperation.

This Dialogue produced an overview of the Chinese nuclear power program and how it fits into China's overall energy development program. This latest conference discussed issues such as regulations, financing, and construction and life-cycle costs. The Chinese participants were frank in their ideas concerning how to build on the cooperative efforts already underway. Likewise, the U.S. speakers discussed ongoing cooperative programs at the government level, and provided an update on the Westinghouse and Shaw AP 1000 Consortium commercial nuclear power plant construction program underway in China. Particularly noteworthy is the extent to which Westinghouse technology has been transferred to China. The report provides a particularly useful overview of dynamic and interdependent relationships that have already been formed between the U.S. and Chinese civilian nuclear program. In addition the report provides a helpful discussion of the complexity of the institutions that are directing China's commercial nuclear industry. Despite a number of challenges which are discussed in the report, between 2005 and 2030, China will add at least 45 GWe of nuclear capacity and over the next 20 years, China's nuclear program is expected to become the second largest in the world.

The Council would like to thank all those who have participated in the project to date: our energy program chairman and board member Richard L. Lawson for his vision and invaluable guidance; program director John Lyman for his leadership, and Blythe Lyons for her skill in distilling the major points of the discussions and to all the meeting participants and experts (listed in Annex 1) for their gift of time and knowledge.

Special thanks also go to the experts representing the Institute of Nuclear and New Energy Technology at Tsinghua University: Prof. WU Zongxin and Prof. CHANG Huajian; the Embassy of the People's Republic of China: REN Hongtao, LI Haiyan and HUA Zhong; the State Nuclear Power Technology Company (SNPTC): Mr. LU Huaxiang, Deputy General Manager, SHEN Wenquan, WANG Bin, YE Chen, WU Luping, and Huang Lei; and the Shanghai Nuclear Engineering Research and Design Institute : Mr. MIAO Hongxing; who attended the meeting either as

speakers or as participants. There were also speakers and/or participants from the nuclear industry including Areva, Babcock and Wilcox, General Electric Hitachi Nuclear Energy, Hyperion Power Generation, and the Westinghouse Electric Corporation and The Shaw Group Inc. (partners in the Westinghouse and Shaw AP 1000 Consortium [the Consortium]); consulting firms including M.S. Chu and Associates, Gee Strategies, Energy Resources International Inc., and Fraser Energy; U.S. government agencies such as the U.S. Nuclear Regulatory Agency (NRC), the White House Council on Environmental Quality and the Departments of Energy, Commerce, and Treasury, and Sandia National Laboratory; and non-governmental organizations including the World Association of Nuclear Operators (WANO), the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI), and the Edison Electric Institute (EEI). In short, there was a wide range of U.S. and Chinese participants closely involved in commercial nuclear commerce and bilateral government programs. The list of speakers and participants is included in Annex I. The Dialogue agenda can be found in Annex II. The Council also thanks the generous donors who supported this work: the Office of Fossil Fuels at the U.S. Department of Energy and the Luce Foundation.

Frederick Kempe
President and CEO, Atlantic Council

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Executive Summary

In 2007, the Atlantic Council of the United States (the Council) partnered with the U.S./China Energy and Environment Technology Center (EETC) at Tsinghua and Tulane Universities to hold a series of dialogues to foster cooperation between the United States and China on developing secure and sustainable energy supplies. Over the past several years, the Council and EETC have invited key organizations, experts from industry and government, and representatives from relevant United States (U.S.) and Chinese government agencies to become directly involved in several meetings designed to identify concrete recommendations for increasing official governmental and industry cooperation.

Between March 4 and 6, 2009, a Dialogue on United States-China Cooperation on Nuclear Power was held in Washington, DC. There was a wide range of U.S. and Chinese participants closely involved in commercial nuclear commerce and bilateral government programs.

Recommendations resulting from this Dialogue will hopefully serve to cement the cooperative relationship between the U.S. and China, who will have the world's two largest nuclear programs within the next 20 years. The recommendations which will help both nations develop secure, sustainable and affordable sources of energy include:

1. As it becomes more clear that nuclear power will be an important part of China's and the U.S.'s energy portfolio throughout this century and well into the next, so too does the need for adequate planning. To make the right decisions, energy policy makers need to expand their horizons to consider the longer term, i.e., past 2050, and what fuel cycle R&D must be initiated now.

2. This dialogue represented a good first step to bring together some of the key players in the U.S. and Chinese nuclear sectors. At a future meeting, the Dialogue could be enhanced by broadening participation. For example, the meetings should include Chinese counterparts to attending U.S. organizations, a diverse range of Chinese utilities, other U.S. reactor design vendors and representatives from U.S. national laboratories.

3. The U.S. government should continue to promote U.S.-Sino cooperation, especially in the nuclear area. Such cooperation would be supportive of the ongoing efforts to expanded cooperation on fossil fuel and climate change efforts that will not only benefit each country, but also developing countries such as India and Indonesia.

4. The U.S. nuclear industry is mature; many lessons have been learned with regard to how to structure a robust commercial program. China could benefit from the U.S.'s experience to create viable utilities, vendors, a world-class regulator as well as supporting universities and institutes.

5. Commercial nuclear power deployment is a truly global endeavor demanding absolute quality assurance without compromise. There were several suggestions as to how it can be fostered:

   - Increased engineering and construction cooperation by sharing best practices, utilizing 3D and 4D design techniques, better information management (taking advantage of communications devices such as "blackberries"), and adopting standardized barcodes.

- Assisting with the cultivation of China's human resources by increasing opportunities for U.S. experts to do on-site training in China as well as for Chinese workers to come to the U.S. for training at the Nuclear Regulatory Commission (NRC) and utility facilities to witness U.S. "best policy and practices".
- Developing a mindset of management and operational excellence by collaboration with organizations such as the World Association of Nuclear Operators (WANO.) The Chinese might best profit from the WANO experience by all Chinese organizations participating in the same WANO center.
- Steps are needed by the Chinese government to raise the profile of the profession and encourage the universities to improve the number and quality of their degree-programs. The industry must continue to coordinate with the universities regarding their needs.
- China should be encouraged to implement establishment of independent testing labs as is now apparently authorized under the auspices of the Institute of New and Nuclear Energy Technology.

6. The U.S. NRC should continue to aid China's National Nuclear Safety Administration (NNSA) in the development of its regulatory system and training of regulators. A follow-on dialogue should focus on obtaining more information as to how China plans to ramp up its regulatory structure to meet the demands of a rapid deployment of commercial nuclear power across the spectrum of reactors it is currently planning.
7. As the Chinese nuclear power industry matures, there will be opportunities for Chinese companies to provide services such as uprating, refueling, maintenance and outage control services. Efforts to establish such cooperation should be initiated in the near term.
8. To improve the commercial nuclear plant supply chain, China should consider establishing a qualified supplier list. In the process, Chinese companies fabricating components need better training with regard to the American Society of Mechanical Engineers (ASME) standards code.
9. Commercial entities in both the U.S. and China can take advantage of their competitive edges for mutual benefit. The U.S. has technical competitive edges and China has geographic edges vis-à-vis the developing market for nuclear power. U.S. and Chinese companies can jointly exploit these competitive edges to develop the South East Asian markets.
10. One of the roadblocks to the development of cooperative opportunities is the U.S. visa issuance system. The Atlantic Council was encouraged to ask the U.S. Department of State to improve its processing of visa applications to significantly shorten the time needed for Chinese nationals involved in nuclear power to obtain a visa for travel to the U.S. Consider, for example, that France provides a dedicated consulate. It is important to recognize that U.S. authorities must take into consideration the security of nuclear facilities but that a better balance can be reached. This is a problem that can be solved.
11. There is an opportunity for international cooperation on the development of a nuclear waste repository based on the experience the U.S. has already gained through 10 years of operation at the Waste Isolation Pilot Project (WIPP) facility and through its Yucca Mountain site characterization and licensing activities.
12. China's 10 MWe High Temperature Gas Reactor (HTGR) scheduled to be in operation by November 2013 in Shandong Province, could serve as an international experimental facility. The currently operating test pebble bed reactor has provided an opportunity for international collaboration.

13. Cooperation on the development of advanced fuel cycle technologies, already underway in U.S.-China working groups, will provide significant opportunities to share rather than duplicate knowledge and funding. Generation IV (Gen IV) international collaboration on R&D is necessary and beneficial for all participants to share costs, facilities and experience. Specific fuel cycle R&D opportunities proposed by the State Nuclear Power Technology corporation (SNPTC) include the following: Advanced fuel, such as mixed oxide (MOX) fuel, and metal fuel;

- Transmutation technology, such as fast reactor and accelerator driven systems;
- Reprocessing technologies, such as MOX spent fuel reprocessing, dry processing, on-site recycle; and,
- Repository design technology.

14. The Generation IV International Forum (GIF) will provide a good framework to deal with intellectual property issues. If prototype or demonstration plants were to be built under the aegis of the GIF, it could also provide experience in dealing with legal and regulatory issues. Issues such as design ownership, who would build the facility, cost sharing would have to be addressed. As countries have vested interests in certain types of technologies, resolution of such issues may be difficult.

15. The Global Nuclear Energy Partnership (GNEP): The U.S., which led the way in establishing the international collaborative effort to develop proliferation-resistant technologies and institutions, should take advantage of its leadership position to nurture and expand GNEP's international activities. As in GIF, there are advantages to sharing technical expertise and pooling financial resources. GNEP is already in place and the Obama Administration can take advantage of the years of effort it took to set up the framework for international collaboration while adapting GNEP goals to current realities and domestic nuclear development policies. Consistency in U.S. nuclear energy policies, especially in relation to international efforts, is crucial to foster global acceptance of a safe, secure and sustainable nuclear power.

The Chinese participants signaled their desire to improve both government-to-government cooperation and commercial sector ties. It appears that the U.S. government is equally interested in working with China to tackle the overarching challenges of developing a safe and secure commercial nuclear fuel cycle. By supporting and participating in this Dialogue, U.S. industry and government participants have demonstrated their commitment to dealing with the challenges to realize the burgeoning nuclear trade between the two countries.

1.0 Introduction

In 2007, the Atlantic Council of the United States (the Council) partnered with the U.S./China Energy and Environment Technology Center (EETC) at Tsinghua and Tulane Universities to hold a series of dialogues to foster cooperation between the United States (U.S.) and China on increasing secure and sustainable energy supplies. Over the past several years, the Council and EETC have invited key organizations, experts from industry and government, and representatives from relevant U.S. and Chinese government agencies to become directly involved in these meetings designed to identify concrete recommendations for increasing official governmental and industry cooperation between the U.S. and China.[1]

Between March 4 and 6, 2009, a Dialogue on U.S.-China Cooperation on Nuclear Power was held in Washington, DC. Approximately one dozen Chinese participants representing the Institute of Nuclear and New Energy Technology at Tsinghua University, the Embassy of the People's Republic of China, the State Nuclear Power Technology Company (SNPTC), and the Shanghai Nuclear Engineering Research and Design Institute attended the meeting either as speakers or as participants. On the U.S. side, there were speakers and/or participants from the nuclear industry including Areva, Babcock and Wilcox, General Electric Hitachi Nuclear Energy, Hyperion Power Generation, and the Westinghouse Electric Corporation and The Shaw Group Inc. (partners in the Westinghouse and Shaw AP 1000 Consortium [the Consortium]); consulting firms including M.S. Chu and Associates, Gee Strategies, Energy Resources International Inc., and Fraser Energy; U.S. government agencies such as the U.S. Nuclear Regulatory Agency (NRC), the White House Council on Environmental Quality and the Departments of Energy, Commerce, and Treasury, and Sandia National Laboratory; and non-governmental organizations including the World Association of Nuclear Operators (WANO), the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI), and the Edison Electric Institute (EEI). In short, there was a wide range of U.S. and Chinese participants closely involved in commercial nuclear commerce and bilateral government programs. The list of speakers and participants is included in Annex I. The Dialogue agenda can be found in Annex II.

This Dialogue produced a snapshot of the Chinese nuclear power program and how it fits into China's overall energy development program. The Chinese participants were frank in their ideas concerning how to build on the cooperative efforts already underway. Likewise, the U.S. speakers discussed ongoing cooperative programs at the government level, provided an update on the Consortium's commercial nuclear power plant construction program underway in China, and offered many ideas regarding the necessity of and how to help China further develop a robust commercial nuclear program.

1 A December 2007 dialogue in Beijing identified eight fundamental areas for cooperation based on a common understanding of global and country specific energy existing and future energy markets initiated the dialogues. This was followed by a set of workshops in May 2008 on US- China Cooperation on Transportation that provided input to the development of an Action Plan being developed by US Department of Treasury's and China's National Development Reform Commission's Strategic Economic Dialogue. In June 2009 there will be dialogue in Beijing devoted to Clean Coal Technologies, another fundamental area for cooperation identified in the December 2007 dialogue. These two dialogues followed a four -year series of dialogues between China, India, Japan and the US on developing energy policies to reduce air pollution in Asia while increasing energy security within the region. The policy papers and Issue Briefs resulting from these dialogues can be found on the Council's web site at www.acus.org.

This report summarizes and expands on the information provided during the Dialogue; makes observations placing both countries' nuclear power program developments in a broader global perspective; and synthesizes recommendations that will hopefully serve to cement the cooperative relationship between the U.S. and China as both nations seek to develop secure, sustainable, and affordable sources of energy. The report can also be found on the Council's Energy and Environment Program page at **www.acus.org/tags/energy-environment.**

2.0 Energy Supply and Nuclear Power Programs in China and the U.S.

2.1 China

2.1.1 Overview

2.1.1.1 Status of the Chinese Economy

China's economic growth during the past decade averaged around 10% per year until the recession. Presently, China has Asia's second largest economy and the world's third largest by GDP.[2] China appears to be committed to maintaining an economic growth rate around 8% in order to ensure the country's ability to simultaneously improve the population's living standards and to absorb rural migration into the cities. (Growth in 2007 had hit a high of 13%.) Most of the world focuses attention on the tremendous increase in Chinese exports, particularly of consumer goods. However, China's economic growth has been and is expected to continue to be primarily driven by increasing domestic demand for industry, infrastructure, and residential and commercial buildings for at least the next decade.

Even though the world recession has dampened China's growth, it is expected to rebound over the coming years. On February 2, 2009 the International Monetary Fund's Managing Director, Dominique Strauss-Kahn, stated in an interview with *Xinhua*: "We expect 6.7 percent growth this year [for China], 8 percent will be very challenging but is possible." China's National Bureau of Statistics reported that 2009 first quarter GDP rose 6.1%, down from the 2008 last quarter growth of 6.8%.

2.1.1.2 Energy Demand in China

Table 1 provides a sampling of "reference case" statistics and data comparisons regarding China's energy demand and electric capacities through 2030, provided by the U.S. Department of Energy's (DOE) Energy Information Administration (EIA) in its 2008 *International Energy Outlook*.[3] This report presents EIA's data (even though with regard to China it often underestimates what the Chinese authorities report), as the EIA also provides data on the same reference points for the U.S. and thus allows the readers to make apple-to-apple comparisons.

Whether China achieves its officially targeted 8% annual GDP growth rate, or a 6.4% annual rate from 2005 through 2030 as projected by the EIA, there will be significant increases in electric demand that will require a further rapid expansion of supply. EIA's "reference case" projections show energy demand more than doubling between 2005 and 2030 and installed capacity increasing more than four-fold over the same period of time.

2 According to the International Monetary Fund, in 2008, GDP in trillion US$, in the US was $14.33, Japan $4.84, and China $4.22.

3 This document was accessed on April 10, 2009 at http://www.eia.doe.gov/oiaf/ieo/world.html.

Table 1: Selected Energy Demand and Electricity Generating Data for China

Reference Case Data:	2005	2010	2015	2020	2025	2030	Average annual % change
Electricity Consumption Quadrillion BTU	67.1	87.3	104.0	120.6	138.0	155.2	3.4
Installed Generating Capacity (GW)	442	692	890	1132	1384	1818	5.3
Installed Nuclear Generating Capacity (GW)	7	9	22	35	45	52	8.5
Hydro and Renewable Generating Capacity (GW)	106	132	132	136	158	179	2.1
Installed Coal Generating Capacity (GW)	299	478	619	757	897	1034	5.1

Source: Tables A1, H1, H5, H6, and H4, International Energy Outlook 2008*, DOE/EIA-0484(2008), released June 2008*

The outlook for nuclear power is discussed in the next section, but to put it into context vis-a-vis other supply options, the outlook for coal and renewables is presented. The EIA reports that after growing at an average rate of 3% per year from 1990 to 2001, China's coal consumption increased by 17% per year on average from 2002 to 2005. As a result, coal use in China has nearly doubled since 2000. Given the country's rapidly expanding economy and large domestic coal deposits, its demand for coal is projected to continue growing strongly.

Over the period 2005 through 2030, annual increases of 2.1% in renewable energy are projected by the EIA. By 2030, they are estimated to provide significantly more—more than three times more—electricity than nuclear power, but only a fraction of that provided by coal-fired power plants. China's National Development and Reform Commission has announced its goal to increase installed wind capacity from the current capacity of 6.0 GWe to 10.0 GWe by 2010. The country is well on the way to meet the goal, having installed 3.4 GWe of new wind capacity in 2007 alone.

The majority of China's renewable energy comes from hydroelectric projects. Large-scale hydroelectric projects under construction or in the planning stage include:

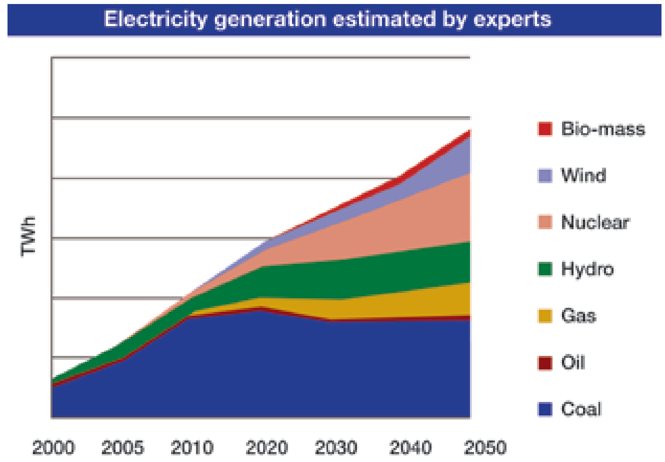
- 18.2 GWe Three Gorges Dam project to be completed shortly with an announced increase to an installed capacity of 22.4 GWe;
- 12.6 GWe Xiluodu project on the Jisha River (scheduled for completion in 2020 as part of a 14-facility hydropower development plan) and the 6.3 GWe Longtan project on the Hongshui River;
- the world's tallest dam (at nearly 985 feet) currently under construction, as part of the 3.6 GWe Jinping I project on the Yalong River, scheduled for completion in 2014 as part of a plan by the Ertan Hydropower Development Company to construct 21 facilities with 34.6 GWe of hydroelectric capacity on the Yalong; and,
- the China Power Investment Corporation has begun construction of a proposed 13-dam hydroelectric power system on the Yellow River with a projected total installed capacity of 8.0 GWe.

Figure 1 takes a longer-range view of the portfolio of energy supply sources from 2000 up to 2050. The key point is that coal still provides around 70% of electricity supplies in 2020, but Chinese authorities predict that coal fueled power will decline slightly before leveling off between 2030 and 2050. By 2020, hydropower levels off. By 2030, China's heavy and chemical industries are expected to reach a peak stage of development, resulting in a reduction in the growth rate of energy demand and lead to a reduced on reliance of coal-fired electricity. If the pace of planned nuclear power growth is maintained, and the utilization of coal can be reduced by 2030, China may also be able to increase its reliance on renewables leading to a considerably cleaner energy portfolio. At present, China's renewable energy policy calls for a 10% contribution by 2030. China is expected to increase its decarbonization targets within the next two years, impacting both the pace and magnitude of nuclear power and renewables deployment in China over the longer term.

2.1.1.3 *Organization of China's Commercial and Government Nuclear Program*

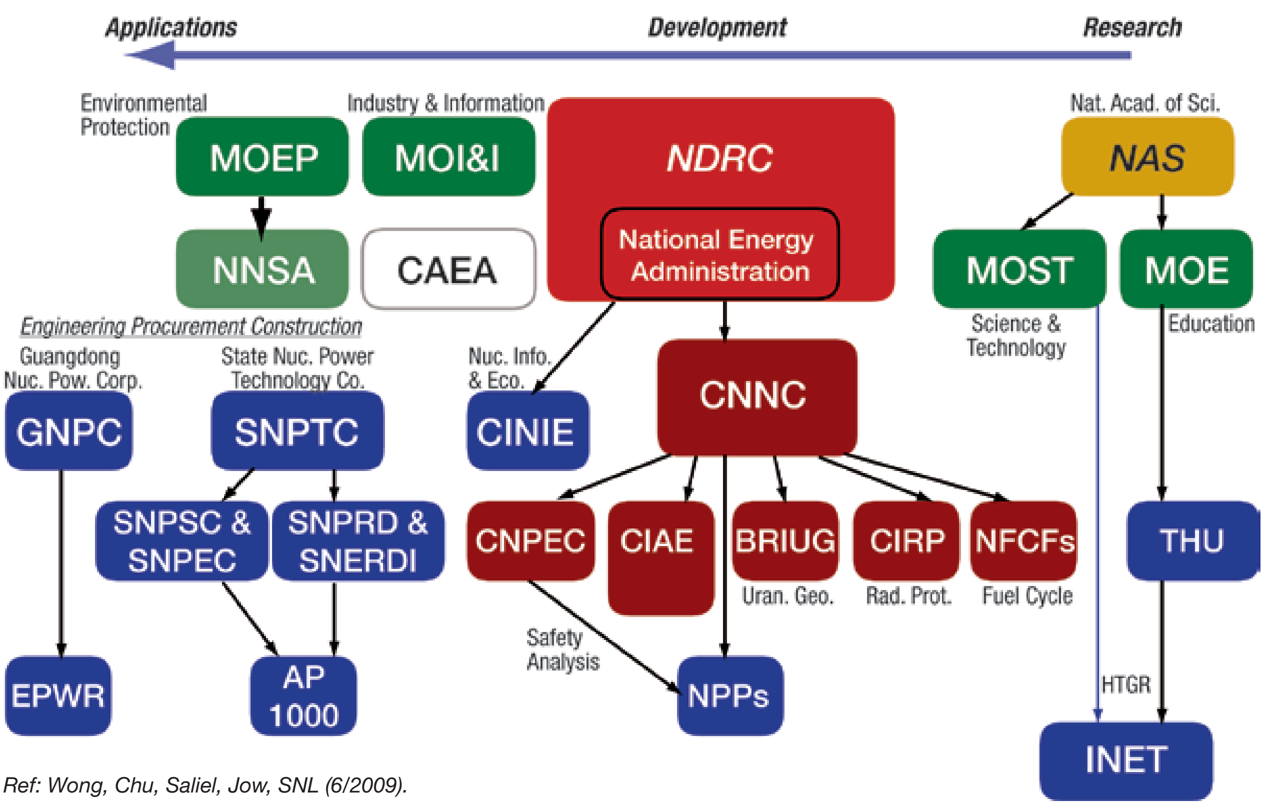
Figure 2 presents a summary of the organizations involved in China's nuclear power program (as of early 2009.) This section summarizes the roles of various Chinese government institutions involved in developing commercial nuclear power policies and facilities[4]:

Figure 1: Electricity Generation by Fuel Type



Source: "Opportunities and Challenges of Generation IV Nuclear Technologies Development", Shen Wenquan, State Nuclear Power Technology Corporation, presentation to the Atlantic Council, March 5, 2009.

Figure 2: Organizations Involved in China's Nuclear Power Program



Ref: Wong, Chu, Saliel, Jow, SNL (6/2009).

4 Information given in this section was based on the organizational chart provided by Messieurs Wong, Chu, Saliel and Jow, Sandia National Laboratory and the testimony before the US-China Economic and Security Review Commission, "China's Energy Policies and their Environmental Impacts," by Dr. Andrew C. Kadak, August 13, 2008, accessed on April 12, 2009 at http://www.uscc.gov/hearings/2008hearings/written_testimonies/08_08_13_wrts/08_08_13_kadak_statement.php. The organizational structure changes frequently so this information is intended to provide a snapshot of the structure at the time of writing this report.

The State Council of Ministers (SCOM) oversees China's nuclear related organizations, including the following:

- Commission for Science Technology and Industry for National Defense controls the China Atomic Energy Agency (CAEA). CAEA is responsible for setting nuclear energy policy and promoting international cooperation. State Assets Supervision and Administration Commission (SASAC) invests state-owned assets on behalf of the central government. SASAC has a major role in nuclear expansion based on its ability to finance new nuclear projects for the benefit of the national government.
- National Development and Reform Commission (NDRC) is the agency responsible for assessment and approval of major projects throughout China and is specifically responsible for deciding which nuclear projects China will pursue. It supervises the China National Nuclear Corporation and the China Guangdong Nuclear Power Corporation.
- National Energy Bureau (NEB) reports to the NDRC and is charged with developing an integrated energy development strategy and monitoring its implementation. It will house a state energy bureau to integrate NDRC's energy management functions and to promote various energy development projects and conservation.
- State Nuclear Power Technology Corporation (SNPTC), reports to the SCOM and is authorized to select foreign reactor systems to be purchased.
- National Nuclear Safety Administration (NNSA) is China's nuclear safety and licensing regulatory authority, which reports directly to the SCOM.
- The Ministry of Environmental Protection (MOEP), which also reports to the SCOM, is responsible for radiological monitoring and waste management. NNSA and MOEP are both required to approve a utility's nuclear plant building plan.
- China National Nuclear Corporation (CNNC) controls most of the nuclear sector business including research and development, engineering design, uranium mining, fuel fabrication and all fuel cycle services. It is a major investor in all nuclear plants in China.
- China Power Investment Corporation (CPI) is a major power generator and is currently the largest state-owned nuclear power holding company.
- China Guangdong Nuclear Power Company (CGNPC), CPI and the CCNC are the only entities permitted to build and operate nuclear power plants.
- Chinergy, a joint venture owned by Tsinghua University, China National Nuclear Construction Company and Huaneng Group, China's largest utility, has an advanced pebble bed reactor project scheduled to begin operation by 2014.
- CNNC, China Nuclear Engineering and Construction Group, China Nuclear Engineering Company, Shanghai Nuclear Energy Research and Design Institute, Beijing Institute of Nuclear Engineering, and China Nuclear Power Engineering Corporation, state-owned enterprises, are involved in the design and construction of nuclear power plants.

2.1.1.4 Outlook for Nuclear Power in China

Table 2 provides a snapshot of the nuclear power plants currently operating in China.

China currently has 9.1 GWe of installed nuclear capacity, representing almost 2% of electric capacity. (Coal and hydropower represent 74% and 24%, respectively.) There are 11 operating nuclear units at three sites, Quinshan, Daya Bay and Tianwan. China reports that the average unit load factor of the nuclear power plant fleet is over 84%.

Over the coming years, according to the EIA, most the world-wide expansion of installed nuclear power capacity is expected in Russia, China, and India, who together account for almost two-thirds of the projected net increment in world nuclear power capacity between 2005 and 2030. In the EIA's reference case, between 2005 and 2030, China will add 45 GWe of nuclear capacity. Over the next 20 years, China's nuclear program is expected to be the second largest in the world, trailing only the U.S.'s.

In October of 2007 the Chinese government adopted the "11th Five-year Plan to Actively Develop Nuclear Power," fast-tracking the development of nuclear power. The plan's official goal is 40 GWe of installed nuclear power capacity by 2020, provided by the current fleet and the addition of

Table 2: Overview Nuclear Power Plants in Commercial Operation

Plant	Type	Unit	Nominal Power	Start of Construction	Date of Comm. Op.
QINSHAN PH. 1	PWR	Unit 1	310MWe	21-03-1985	01-04-1994
DAYA BAY	PWR	Unit 1	984MWe	07-08-1987	01-02-1994
		Unit 2	984MWe	07-04-1988	05-06-1994
QINSHAN PH. 2	PWR	Unit 1	650MWe	02-06-1996	15-04-2002
		Unit 2	650MWe	01-04-1997	03-05-2004
LINGAO	PWR	Unit 1	990MWe	15-06-1997	28-05-2002
		Unit 2	990MWe	28-11-1997	08-01-2003
QINSHAN PH. 3	PHWR (CANDU)	Unit 1	728MWe	08-06-1998	31-12-2002
		Unit 2	728MWe	25-09-1998	24-07-2003
TIANWAN	PWR (WER)	Unit 1	1060MWe	20-10-1999	17-05-2005
		Unit 2	1060MWe	20-09-2000	16-08-2005
TOTAL		**11**	**9134MWe**		

Source: "Ensure Operational Excellence," presentation to the Atlantic Council, Ye Chen, State Nuclear Power Plant Service Company, March 5, 2009

Table 3: Nuclear Power Plants in China under Construction or Firmly Planned

UNDER CONSTRUCTION OR FIRMLY PLANNED					
Plant Name	Plant Type	Owner/ Operator	Net MW(e)	CODT	Percent Complete
Lingao-3	PWR	LNPC	950	2010	40
Qinshan 4-1	PWR	QNP	610	2011	30
Lingao-4	PWR	LNPC	950	2011	30
Qinshan 4-2	PWR	QNP	610	2011	30
Hongyanhe-1	PWR	GNP	1,000	2012	15
Sanmen-1	PWR	SNPC	1,135	2013	10
Sanmen-2	PWR	SNPC	1,135	2014	10
Yangjing-1	PWR	YNPC	1,000	2013	10
Nigde-1	PWR	GNP	1,000	2012	5
Haiyang-1	PWR	SHNPC	1,135	2014	Planned
Hongyanhe-2	PWR	GNP	1,000	2014	Planned
Hongyanhe-3	PWR	GNP	1,000	2014	Planned
Nigde-2	PWR	GNP	1,000	2014	Planned
Taishan-1	PWR	GNP	1,600	2014	Planned
Yangjing-2	PWR	YNPC	1,000	2014	Planned
Haiyang-2	PWR	SHNPC	1,135	2015	Planned
Hongyanhe-4	PWR	GNP	1,000	2015	Planned
Taishan-2	PWR	GNP	1,600	2015	Planned
Yangjing-3	PWR	YNPC	1,000	2015	Planned
Yangjing-4	PWR	YNPC	1,000	2016	Planned
Total			**20,860**	**20 plants**	
Many additional units and sites are planned.					

Source: Energy Resources International, Inc., May 2008.

20 more units under construction or firmly planned. Table 3 present the list of nuclear plants under construction or firmly planned in China.

Some Dialogue participants ventured that China might soon raise its 2020 nuclear target from 40 GWe to 60 GWe, and perhaps even as high as 80 GWe. Recently the Chinese government approved an economic stimulus plan providing a total of 4 trillion RNB ($584 billion), of which 100 million RNB is earmarked for nuclear power support.

In May 2005, China announced the purchase of nuclear power technology from the Consortium.[5] China has decided, at least for the present, to build pressurized water reactors (PWRs) purchased from France, Russia, Canada and the U.S. July 2007, SNPTC and the Consortium signed the contracts to purchase four Advanced Passive (AP) 1000 reactors. The concrete for the first unit at Sanmen has been poured and fuel loading is projected for May 2013. The respective dates for pouring concrete and fuel loading at the Haiyang site is September 2009 and November 2013. Both the Sanmen and Haiyang sites have the capacity for four more AP 1000 units.

The Consortium agreed to a comprehensive transfer of technology to SNTPC, the world's largest commercial nuclear technology transfer between commercial entities to date. The Consortium will supply the key equipment for the initial plants; the Consortium and SNTPC will jointly manage the projects; and SNTPC will supply all the other equipment and take the lead responsibility for reactor construction. The STPTC will collaborate with the Consortium on the engineering work.

Shaw is under contract with SNPTC, Sanmen Nuclear Power Company, Shandong Nuclear Power Company Ltd. and China National Technical Import and Export Corporation to provide engineering, procurement, commissioning, information management and project management services for the two Westinghouse AP 1000 nuclear units at Sanmen and the other 2 units to be built at Haiyang. The Shaw Group and SNPTC have recently formalized a "task-based" strategic cooperation agreement relating to transferring the Consortium's reactor design expertise.

China has committed to develop its domestic manufacturing and service sectors to provide future reactor components. In addition, the Consortium is cooperating with Chinese organizations to assist in their development of a domestically designed, advanced PWR to be constructed throughout China. The long-term goal of China is to have the capability to take over all of these designs through technology transfer agreements so that they can become thoroughly capable of indigenously designing and supplying all reactor components and fuel.

The SNTPC expressed its desire for increased cooperation with the Consortium in order to develop their technical expertise, increase their manpower capabilities, and improve communications between the two entities. There is also interest in increased cooperation with the Consortium in the areas of R&D on nuclear technologies, reactor construction, engineering, operations and maintenance, and marketing the AP 1000. Commercial nuclear cooperation could be mutually beneficial for the U.S. and China. For example, as China masters its ability to manufacture and supply components, it strengthens the Consortium's AP 1000 supply chain worldwide, especially in the Asian market.

Chinese nuclear companies belong to several bilateral, international and owners groups that focus on improving operational issues and technical support. A professional management company was formed in March 2003 to operate four reactors at Daya Bay and Lingao. In addition, the operators of the existing nuclear power plants participate in the World Association of Nuclear Operators (WANO) centers in Paris, Tokyo and Moscow.

5 The Consortium is comprised of the Westinghouse Electric Corporation and The Shaw Energy Group, Inc. In October 2006, Shaw became a 20% owner of Westinghouse for US$1.1 billion. Shaw's and Westinghouse's ties have been strengthened with the appointment of former Westinghouse CEO Steve Tritch to Shaw's board of directors. The remaining ownership of Westinghouse Electric Corporation is held by Toshiba Corporation, 77% and Ishikawajima-Harima Heavy Industries Co., Ltd, 3%. Toshiba acquired Westinghouse from British Nuclear Fuels Limited for US$5.4 billion.

2.1.1.5 Hurdles to Development of Nuclear Power in China

China faces several domestic constraints and issues relating to commercial ties between China and its U.S. partners that may constrain its ability to more rapidly develop commercial nuclear power. They include:

- **Workforce:** While the demand for nuclear professionals continues to rise, neither the number nor quality of trained personnel are currently available to meet a surge in new plant construction. To put this into perspective, it is estimated that the CGNPC, alone, will require 13,500 engineers, technicians and operators for their planned program. Historically, there have been few jobs in China in the nuclear profession, universities have cut back their degree programs, and the pay scale has to date not been sufficient to attract the best and brightest. In addition, there are significant needs for craft labor. Importing labor is not an acceptable option; China must develop programs to provide and train its workers.
- **Public acceptance:** A recent survey of public acceptance of nuclear power showed that the public knows little about the development of nuclear power in China. Out of six forms of energy, nuclear ranks fourth in acceptance behind solar, hydropower and natural gas, but much better than acceptance of coal power. Safety is the number one concern, followed by concerns about its impact on the environment.
- **Supply chain:** Significant ramp up of nuclear power plant construction exposes potential problem areas, particularly in the engineering and large equipment manufacturing sectors. It is expected that the supply chain can be expanded over time as demand grows.
- **Assurance of quality and safety:** Because China plans to indigenously design, manufacture and operate a fleet of nuclear power plants-and eventually export reactor components, ensuring the reliability and performance of Chinese-made plants and components will pose a challenge. China must staff its regulatory and other oversight agencies with a sufficient number of highly trained individuals with the needed authority to assure absolute quality and safety assurance. In addition, China needs to close the gaps in their technical capabilities in design, to better benefit from the U.S.'s skills in computer codes and analyses.
- **Communications:** Relations between the Consortium and SNTPC face challenges any project would due to differences in language, measurement systems, and cultures. The geographic distance between the U.S. and China makes frequent meetings hard to hold. However, the real (but surmountable) challenge is that access to U.S. sites is made difficult as the process to obtain visas often takes 3 or more months. Chinese attendance at meetings is not finalized until the last minute and visas are often rejected. Understandably, U.S. government authorities are sensitive to nuclear security issues in light of unauthorized access at U.S. nuclear labs in the recent past. As a result, the U.S. has increased its scrutiny of Chinese visitors to commercial nuclear facilities, leading to a lengthy visa processing timeframe.
- **Legal:** Differences between Chinese and American legal frameworks can cause delays when negotiating contracts.
- **Compatibility of regulatory systems, codes and standards:** While the nuclear power facility licensing process differences themselves are not particularly problematic (China and the U.S. follow two-step and one-step processes, respectively) issues have arisen because standards are different. The AP 1000 was designed to meet U.S. specifications and regulations. The Chinese regulatory body, NNSA, is requiring adherence to different (not necessarily more rigorous) standards than those Westinghouse had designed around. The AP 1000 was designed to meet a different containment vessel pressure safety margin than that required by the Chinese. During the licensing reviews for the AP 1000 plants, the Chinese authorities have requested safety information that is not required by the U.S. NRC' or that is copyrighted under U.S. laws and so must be acquired independently by the Chinese. The advanced technology used in the AP 1000 design is new to the Chinese regulatory body. U.S. authorities approved the AP 1000 design for a 40-year operating period of time, but the Chinese require data to support an operating license for a 60-year period.

2.2 The United States

2.2.1 U.S. Energy Overview

For comparison purposes, Table 4 provides the same data regarding U.S. energy demand and electricity generation sources as provided for China in Table 1.

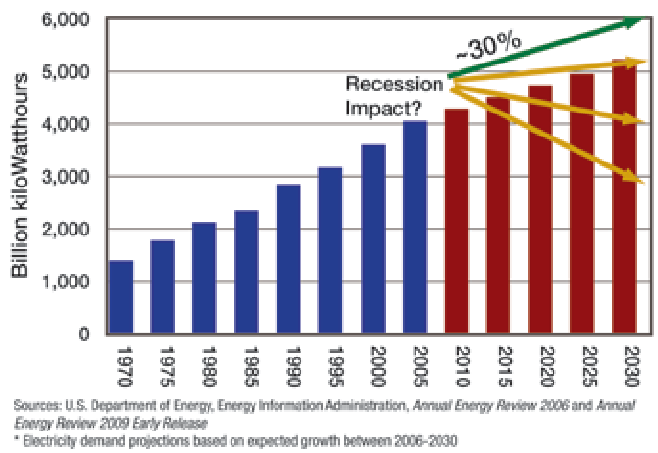
The 2009 *Annual Energy Outlook* produced by the EIA[6], estimates in its reference case that the U.S. economy will grow on average by 2.5% annually through 2030 (in contrast to Chinese authorities' forecasted annual increase in China's economy of 8% annually). U.S. electric demand will grow 26% in absolute terms between 2007 and 2030, an average of 1% per year (contrasted with the EIA's forecasted 3.4% annual electric demand growth in China). This growth will require a significant amount of infrastructure to supply the required capacity.

Electric demand is slowing compared to the period from 2000 to 2007 that saw an annual increase of 1.1%. It should be noted that the EIA forecast is based on current U.S. energy policy and does not reflect reductions in electricity demand that might accompany energy conservation and efficiency measures now under consideration by the U.S. Congress.

In 2007, primary U.S. energy consumption was provided almost 40% by petroleum, around 23.5% by natural gas, almost 23% by coal, almost 7% by renewable energy, and almost 8.5% by nuclear electric power.[7] As in China, in the U.S., coal continues to provide the largest share of energy for electricity generation. In 2007, electricity was generated 49% by coal, 16% by petroleum products, 21.5% by natural gas, 20% by nuclear power, and 8.5% by renewable sources (rounded up). The EIA projects that coal's share of electricity generation will only slightly decline to 47% by 2030 under current policies.

Figure 3 shows the EEI's projections regarding U.S. electricity demand growth. EEI estimates that total electric demand in the U.S. may grow by 30% from 2010 to 2030, which is greater than the EIA forecast. However, in both forecast the full impact of the recession on demand growth is unknown.

Figure 3: Demand Projected to Increase 30% by 2030



Source: "Outlook of the United States Power Sector," presentation to the Atlantic Council, John J. Easton, Jr. Edison Electric Institute, March 5, 2009

Table 4: Selected Energy Demand and Electricity Generating Data for the U.S.

	2005	2010	2015	2020	2025	2030	Average annual % change
Electricity Consumption Quadrillion BTU	100.1	100.3	107.3	110.8	114.5	118.0	0.7
Installed Generating Capacity (GW)	974	1035	1025	1073	1141	1213	0.9
Installed Nuclear Generating Capacity (GW)	100	101	102	111	116	115	0.6
Hydro and Renewable Generating Capacity (GW)	121	149	157	166	175	181	1.6
Installed Coal Generating Capacity (GW)	314	320	329	349	379	414	1.1

Source: Tables A 1, H1, H5, H6, and H4, "International Energy Outlook 2008," U.S. Department of Energy, #DOE/EIA-0484(2008), May 2008

6 The Annual Energy Outlook was accessed on April 11, 2009 at http://www.eia.doe.gov/oiaf/aeo/.

7 "Introduction to Generation IV Nuclear Energy Systems and the International Forum," presentation by Thomas J. O'Connor, Department of Energy, to the Atlantic Council, March 6, 2009.

As mentioned above, factors other than the recession could further impact electric demand in the U.S. The Obama Administration has proposed reductions in carbon emissions of 80% below 1990 levels by 2050, a 25% Renewable Portfolio Standard (RPS)[8] nationwide by 2025, improved energy efficiency measures including a 50% reduction in energy intensity by 2030, and introduction of smart grid technologies. EEI estimates that without aggressive energy efficiency and smart grid technology, 214 GWe of new capacity may be needed. However, new initiatives could reduce generation investment 28%, total capital investment 15%, and new capacity requirements by 38%. Even with efficiency and conservation measures, there would still be an increase in electricity demand and resulting supply capacity.

2.2.2 Outlook for U.S. Nuclear Power

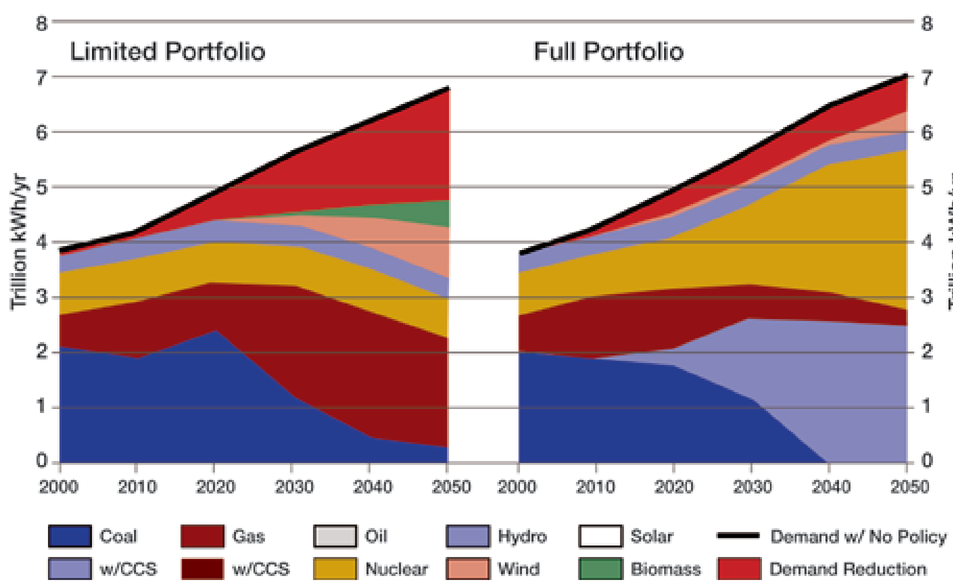
The U.S. is grappling with the question of what technologies will provide a secure, low carbon energy supply and in particular, what role nuclear power will play. There are indications that there is "a renaissance" in nuclear power in the U.S.. The Nuclear Regulatory Commission (NRC) reports that as of March 2009, it has 17 applications for 26 reactors and expects it may get applications for seven more by the end of 2010.

Nuclear's contribution to future U.S. electricity supply will hinge on many factors. EPRI has studied various scenarios that may come into play between 2000 and 2050 assuming that CO_2 emissions would be capped at 2010 levels and then would decline at an annual rate of 3% after 2020. Table 5 outlines demand and supply variables in two possible scenarios and defines the technology portfolios that could come into play in each. Figure 4 shows the variations in the role nuclear power might play under the two different scenarios.

Table 5: Contrasting Electricity Technology Scenarios

	Full Portfolio	Limited Portfolio
Supply - Side		
Carbon Capture and Storage (CCS)	Available	Unavailable
New Nuclear	Production Can Expand	Existing Production Levels - 100 GW
Renewables	Costs Decline	Costs Decline Slower
New Coal and Gas	Improvements	Improvements
Demand – Side		
Plug-in Hybrid Electric Vehicles		
End – Use Efficiency	Accelerated Improvements	Improvements

Figure 4: U.S. Electricity Generation: 2000 to 2050



Source: "The Power to Reduce CO_2 Emissions: the Full Portfolio," Report #1015461, Electric Power Research Institute, August. [2007][RWJ2].

8 RPS refers to the requirement that an electric power provider generate or purchase a specified percentage of the power it supplies/sells from renewable energy resources, and thereby guarantee a market for electricity generated from renewable energy resources.

Additional EPRI analysis ("The Power to Reduce CO_2 Emissions: the Full Portfolio – 2008 Economic Sensitivity Studies", Report #1018431, November 2008) concludes that in an economically optimal technology mix, advanced nuclear and advanced coal with CO2, capture and storage (CCS) technologies play a dominant role in nearly all scenarios. End-use efficiency is also likely to be critical over the next 10–15 years as well as in the long-term. Beyond 2030, wind and biomass play a large role in nearly all scenarios.

The important point is that no one technology will be a silver bullet: a portfolio of technologies will be needed—and much of the needed technology is not even available today. For the long-term, EPRI notes the importance of research, development and deployment (RD&D) for advanced nuclear power, and advanced coal with CCS. EPRI also concludes that RD&D for large-scale energy storage and smart distribution grids are critical to enable widespread deployment of renewables and energy efficiency technologies.

2.2.3 Hurdles Facing U.S. Energy Supply and Nuclear Power

While there are issues constraining the deployment of new nuclear power plants, the coal option faces significant problems as well. Clean coal technologies have yet to be demonstrated on a large-scale, and there are concerns over high costs compared to natural gas and nuclear power plants. In fact, almost all renewable technologies involve higher cost than existing nuclear or coal power plants. The public and politicians are grappling today with higher electricity prices that would be required to meet the challenge of increased demand and lower CO_2.

Compared with China, the U.S. commercial nuclear industry is in a mature stage. However, its role in the U.S. over the longer term faces some hurdles as well. Both the U.S. and China face similar workforce and supply chain constraints. The U.S.'s issues are more of a political and economic nature, and include:

- The imposition of greenhouse gas reductions, a centerpiece of President Obama's energy policies, is speculative until necessary federal legislation is enacted. The passage of the 2005 Energy Policy Act required 2 years of intense debate and this next round of changes to U.S. energy policy may be even more contentious especially given the state of the economy and the economic costs associated with decarbonization. Nuclear power's role could significantly increase if the U.S. enacts carbon restraints and/or taxes.
- Uncertainties, especially the impact of the recession, make it difficult to estimate energy demand and adjust technology portfolios accordingly.
- It is uncertain how much efficiency measures as well as smart grid technology and grid transmission improvements can reduce the EIA's projected capacity requirements of 178 GWe over the next 20 years.[9] Likewise, if there is significant demand for electric vehicles, electricity demand could be higher than projected.
- More RD&D is needed than is now underway in the U.S. to develop affordable green technologies. If renewable energy sources are unable to provide as much power as hoped for, then even more electricity from nuclear power will be needed.
- There is debate over what technologies can be included in the government-mandated portfolio if the U.S. enacts a 25% RPS requirement. Some argue for including nuclear energy in the portfolio mix, as it contributes toward reducing CO2 emissions just as much or even more than renewable energy sources. Including nuclear power in the RPS will have an impact on the number of new nuclear power plants to be built in the next 20 or more years.
- The current financial crisis has resulted in utilities' diminished access to capitol. Credit downgrades make it difficult for utilities to fund needed investments in new nuclear power plants.
- It was also acknowledged that President Obama's opposition to the licensing of the Yucca Mountain repository might present a political hurdle to building new nuclear power plants. Technically, disposal of nuclear waste in a geologic repository has been proven at the 10 year old Waste Isolation Pilot Project (WIPP) in New Mexico.

9 See Table 4.

3.0 Generation IV and Related Fuel Cycle Research and Development

3.1 The Transition to Next Generation Nuclear Technologies

The fleet of nuclear power plants being constructed in the U.S. and China now and for the next 20 years will be in operation potentially until the end of the 21st century. In the previous sections, the plans for assuring that nuclear power remains a viable, safe and secure power option were reviewed and evaluated. Both the U.S. and China are actively seeking to further the nuclear option to provide baseload power for growing economies without adding more carbon to the environment.

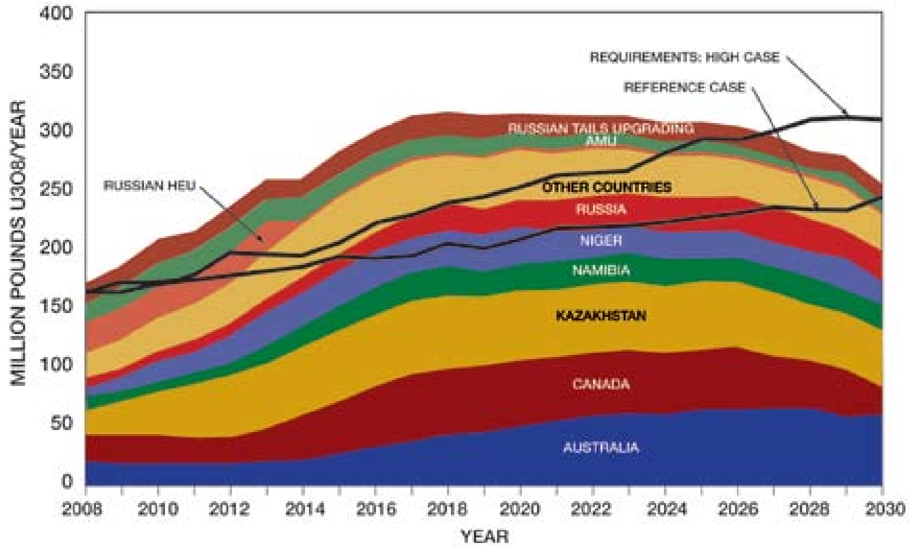
Both countries are naturally developing advanced nuclear power reactor technologies. For example, in the U.S., the Energy Policy Act of 2005 authorized the development of the "next generation nuclear plant" to be built at the Idaho National Laboratory. China is actively working on high temperature reactors.

In addition to the advanced reactors, new fuel cycle technologies are also under investigation. A new generation of technology, named "Generation IV" or "Gen IV", is desired for many reasons, including helping to destroy the wastes from the current plants, conserve potentially dwindling uranium resources, and even harness the power of the atom further with breeder reactors. Government and private sector entities across the spectrum of the nuclear fuel cycle are collaboratively working to develop Gen IV concepts.

An examination of the front-end of the nuclear fuel cycle puts the need for Gen IV technologies, and the supporting R&D on fuel cycle services, into perspective. Figure 5 shows that regardless of whether the nuclear industry grows at a moderate pace (dubbed the reference case) or at a rapid pace (dubbed the high case), world uranium supplies may be insufficient for either of those scenarios as of 2030 and 2027, respectively. However, the resources that are seen to be excess to requirements may provide supply for an additional 5 to 15 years, respectively, at least theoretically. Many argue that the potential inadequacy of uranium supplies leads to the conclusion that the U.S. must undertake today the preparation work to close the fuel cycle in order to conserve uranium resources and to develop breeder reactors for the long term.

There are some who argue that as nuclear power expands, so do uranium resources, and that as the price for uranium increases, as it has in the recent past, uranium exploration will lead to expanded reserves. However, because of the long lead time between grass-roots exploration and completion of project development, it is far from certain that uranium supplies will be adequate in a timely basis for nuclear power plants later in this century.

Figure 5: World Uranium Supply and Requirements: 2008 to 2030



Source: "Cooperation on Fuel Cycle Research: World Status of Fuel Cycle Front-end," presentation to the Atlantic Council, Julian J. Steyn, March 6, 2009

Due to the uncertainty over the long-term supplies, it is prudent to develop technically viable alternatives. "It pays to have options." Given the lead-times needed for RD&D, now is the time for policies and programs to move to advanced nuclear technologies.

3.2 Overview of Fuel Cycle Policies and R&D Programs in China

China has adopted a closed nuclear fuel cycle policy with national coordination of reactor technology and fuel cycle R&D. As waste minimization is a key goal, China intends to pursue both fast reactor and accelerator driven reactor options for waste transmutation. China plans to complete an underground waste disposal lab by 2020 with a commercial repository to be operational in the 2040 to 2050 timeframe. Sites in the northwest region of China have been determined to be suitable candidates for deep geologic disposal. Two 500 and 700 meter exploratory boreholes have already been drilled. In the interim, spent fuel is trucked to a 550 tHM centralized wet storage facility at the Lanzhou Nuclear Fuel Complex (LNFC). (The facility received its first shipment from Daya Bay, which is over 4000 km in distance.) The fuel will then be reprocessed. A pilot reprocessing plant, using a modified PUREX process, is under construction at the LNFC. The pilot facility will have a continuous production capacity of 100 tHM per year. China is also pursuing R&D on waste vitrification using German technology and has undertaken lab tests.

China attaches great importance to nuclear fuel cycle R&D in order to improve the utilization of uranium fuel resources as well as to burn nuclear waste with fast reactors. China also intends to broaden the application of nuclear technologies to hydrogen production, saltwater desalination, and district heating. It supports projects in four major areas including an advanced, domestic version of the AP 1000, a high temperature gas cooled reactor (HTGR), an experimental fast reactor, and a fusion project. These projects are briefly described below.

Under the leadership of the SNPTC, China is doing the engineering and conceptual design of a domestic large advanced power water reactor (LAPWR), piggybacking on the technology provided by the consortium. It plans to have a domestically designed and constructed LAPWR in operation by 2017 that will have a capacity of 1,400 MWe.

Starting in 1987, Tsinghua University, located in a Beijing suburb, began the development of a research high temperature gas test reactor (HTGTR.) A 10 MWe test reactor is now in operation, the only pebble bed modular HTGR in the world.[10] There are approved plans for a 200 MWe model in Shandong Province, with construction slated to begin in September 2009 and startup expected by November 2013. Further R&D on this reactor is needed to prove applicability for uses such as desalination, hydrogen production and heavy oil extraction.

Under the direction of the China Institute for Atomic Energy, China has been developing a liquid metal sodium cooled fast breeder reactor with some Russian assistance (on reactor safety systems, heat exchangers, re-loaders and control devices). The thermal power of the reactor is 65 MW and features a 25 MWe turbine generator. The reactor will be filled with sodium in May 2009 and its fuel will be loaded into the reactor during the summer. China plans to commission the reactor by the end of 2009. Next, China plans to develop a 600 MWe prototype fast reactor by 2020 and a 1500 MWe version by 2030. The Russian-Chinese Nuclear Cooperation Commission has announced plans for the construction of an 800 MWe demonstration fast reactor similar to the Russian Beloyarsk 4 reactor, the world's only commercial fast breeder reactor in operation at present.

Many university research organizations have undertaken fusion research activities. In November 2006, China became a member of the International Thermonuclear Experimental Reactor (ITER) Program, China's largest cooperative science-oriented effort undertaken internationally to date.[11]

3.3 Overview of U.S. Fuel Cycle Policies and R&D Programs

The U.S. DOE Advanced Fuel Cycle Initiative (AFCI) program is examining several options for the nuclear fuel cycle. Its focus shifted from accelerated deployment of recycling facilities, to a long-term science-based R&D program on open (thermal) and closed (using mixed oxide [MOX] fuel and fast reactors) fuel cycle options. DOE believes that there is no urgency to make the decision on following an open or closed fuel cycle today. DOE's current view is that there is the time to do the appropriate R&D, but that prudence demands the U.S. investigate options to close the fuel cycle.

The AFCI program has several components. It is evaluating advanced separation techniques, sodium cooled fast reactors, improved fuel performance and fabrication techniques, and advanced waste management strategies, including transmutation. Part and parcel of the R&D program is to examine ways to enhance U.S. nonproliferation goals through diversion prevention, enhanced safeguards, plutonium stockpile reductions and limits to the spread of sensitive fuel cycle technologies such as enrichment and reprocessing.

The challenge is to develop affordable, advanced fuel cycle options. Reprocessing plants may cost as much as $15 billion, and fast reactors may be a factor of 2 times more expensive than conventional reactors. Today, U.S. consumers pay an average of ten cents per KWh for electricity. The potential cost of 1 to 3 mills per kilowatt hour[12] to close the fuel cycle, as estimated by U.S. industry, would only increase the cost by 0.3 cents. The current Administration is committed to long-term fuel cycle research and development and is expected to continue to pursue international and bilateral cooperative efforts with fuel cycle nations such as China to leverage expertise and resources.

The U.S.'s domestic advanced reactor R&D program has been focused on the Very High Temperature Reactor (VHTR)[13] and to a limited degree, a sodium fueled reactor. During the Dialogue, DOE stated that the goal is to have a demonstration gas reactor by 2021 but achieving this goal depends on funding as well as progress in the research, especially regarding fuel materials. To date, fuels have been tested but they have not been taken out of the reactor for testing. The demonstration facility at Idaho is planned to

10 Pebble bed reactor technology is currently under development by MIT, the South African company PBMR, General Atomics , a Dutch company Romawa B.V., Adams Atomic Engines, Idaho National Laboratory, and the Chinese company, Huaneng. In June 2004, it was announced that a new PBMR would be built at Koeberg, South Africa by Eskom, the government-owned electrical utility. However, because of the world-wide economic crisis, plans have since been put on hold.

11 ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power. The partners in the project are the European Union (represented by EURATOM), Japan, the People's Republic of China, India, South Korea, Russia, and the US. The facility will be constructed at Cadarache in the south of France.

12 A mill is a common method of pricing electricity and equals a tenth of one cent.

13 Very high-temperature gas reactors are graphite-moderated, helium-cooled reactors. The core can be built of prismatic blocks such as in the HTTR built by the Japanese and in the GTMHR under development by General Atomics and others in Russia, or it may be pebble bed such as the Chinese HTR-10 and the PBMR under development in South Africa, with international partners. Outlet temperature of 1000°C enables thermo-chemical hydrogen production via an intermediate heat exchanger, with electricity cogeneration, or direct high-efficiency driving of a gas turbine (Brayton cycle). There is some flexibility in fuels, but no recycle.

have a hydrogen component. However, it should be noted that DOE is re-examining all major nuclear energy projects, and there may be a shift in emphasis to revisit all technology options under Generation IV.

3.4 U.S.-China Bilateral and International Cooperative Initiatives on Gen IV Technologies

3.4.1 Bilateral Cooperation Activities

The U.S. and China signed a Bilateral Civil Nuclear Energy Cooperative Action Plan on September 15, 2007. DOE has similar agreements with Russia, Japan, Australia, and pending signature, France. The organizational structure of the U.S.-China Bilateral activity is shown in Figure 6.

This bilateral activity is up and running with a structure approved by both governments and a plan for future progress. The first meeting under the auspices of the U.S./China Civil Nuclear Energy Cooperation Action Plan focused on advanced fuel cycle technologies, namely fast reactor technology, fuels and separations technologies, and advanced safeguards and physical protection This meeting was held at was held at Argonne National Laboratory (ANL) in), Chicago, Illinois on April 23, 2008. Another meeting of the fuel cycle technology-working group is scheduled to take place the week of May 18th in Beijing, China. Assuming significant progress is made at the May working group, then a formal U.S./China, a Steering Committee meeting could take place either in the summer or fall of 2009. The purpose of this meeting would be to approve of the R&D plan developed in the May meeting, and thereby initiate Phase II of the Action Plan. While it is a somewhat formal process, DOE reports that it is working very well as all parties know what to expect and what the process will produce.

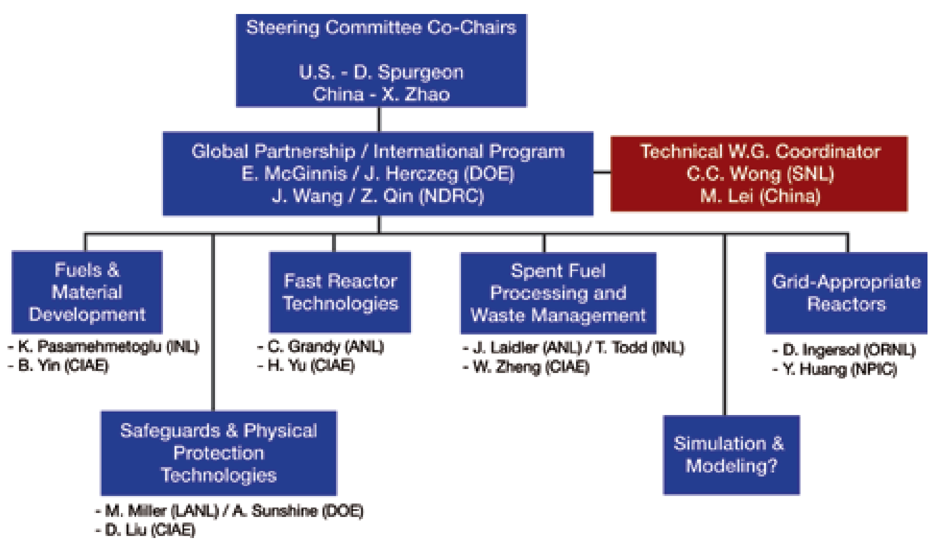
3.4.2 International Cooperation Activities

The U.S. spearheaded the establishment of the Generation IV International Forum (GIF) in July 2001 with nine charter countries, Argentina, Brazil, Canada, France, Japan, South Korea, South Africa, the United Kingdom, and the U.S. Switzerland joined in 2002, EURATOM in 2003, and China and Russia in 2006.

The GIF aims to introduce the Gen IV technologies on a wide scale by 2030. The broad program goals feature:

- Sustainability, promoted by increasing the availability of nuclear fuel and minimizing the waste stream;
- Safety and reliability, with a system that would have a low likelihood and degree of reactor core damage, and a facility that would not need offsite emergency response;

Figure 6: U.S./China Civil Nuclear Energy Cooperation Action Plan-Organizational Structure



Source: "Governmental Nuclear Energy Research & Development-Bilateral and Multilateral Engagement," presentation to the Atlantic Council, John W. Herczeg, U.S. Department of Energy, March 5, 2009.

- Economical system, with life cycle cost advantages over other energy sources and an acceptable level of financial risk; and,
- Proliferation resistance, with little attractiveness as a route for weapons-useable materials and improved physical protection attributes to guard against potential terrorist acts.

Table 6 outlines the six major technologies currently being investigated by the GIF, a summary of their attributes, and the status of their development. Over 100 international experts participated in selecting these technologies.

A Framework Agreement, signed by the GIF partner governments, among other things, specifies R&D projects to be undertaken, assigns the responsible government entities responsible for work, affords intellectual property protection, and allows for multilateral contracts to be given for the R&D work. The focus is on R&D but demonstration plants could conceivably be built under the framework.

China is working on the VHTR projects in the areas of materials testing and components and high performance turbines. China's fast reactor R&D program compliments the DOE's AFCI activities, and those of the GIF, and will provide fertile ground for further cooperation.

The U.S. and China also participate in the U.S.-sponsored Global Nuclear Energy Partnership (GNEP). This international collaboration between 25 countries[14] focuses on how to foster the creation of civilian nuclear power programs in developing countries and to devise an international nuclear fuel supply framework. The GNEP Working Group, under the GNEP Steering Group, charged with developing "Reliable Fuel Services" met in France in March 2009. According to a statement by DOE deputy press secretary Jen Stutsman to *Nuclear Engineering*, "The Department [DOE] has already decided not to continue the domestic GNEP program of the last Administration. The long-term fuel cycle research and development program will continue, but not the near-term

Table 6: Overview of Reactor Systems under Consideration by the Generation IV International Forum

System	Neutron Spectrum	Fuel Cycle	Size (MWe)	Temp. (C)	Applications	R&D Needed
Very-High-Temperature (VHTR)	Thermal	Open (Closed)	250	>900	Electricity, Hydrogen, Process Heat	Fuels, Materials, H2 production
Supercritical- Water Reactor (SCWR)	Thermal, Fast	Open, Closed	1500	510-625	Electricity	Materials, Thermal-hydraulics
Gas-Cooled Fast Reactor (GFR)	Fast	Closed	200-1200	850	Electricity, Hydrogen, Actinide Management	Fuels, Materials, Thermal-hydraulics
Lead-Cooled Fast Reactor (LFR)	Fast	Closed	50-150 300-600 1200	550-800	Electricity, Hydrogen	Fuels, Materials
Sodium Cooled Fast Reactor (SFR)	Fast	Closed	300-1500	550	Electricity, Actinide Management	Advanced recycle options, Fuels
Molten Salt Reactor (MSR)	Epithermal	Closed	1000	700-800	Electricity, Hydrogen, Actinide Management	Fuel treatment, Materials, Reliability

Source: "Introduction to Generation IV Nuclear Energy Systems and the International Forum," presentation to the Atlantic Council, Thomas J. O'Connor, Department of Energy, March 6, 2009

14 In May 2007, the US, China, France, Japan and Russia formally became the founding members of GNEP. The full compliment of members now stands at 25, including: Armenia, Australia, Bulgaria, Canada, China, Estonia, France, Ghana, Hungary, Italy, Japan, Jordan, Kazakhstan, Republic of Korea, Lithuania, Morocco, Oman, Poland, Romania, Russia, Senegal, Slovenia, Ukraine, United Kingdom, the United States.

deployment of recycling facilities or fast reactors."[15] DOE's fuel cycle research and development program will continue under the name "Advanced Fuel Cycle Initiative" (AFCI).

Both the U.S. and China participate in the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), which was established in 2001 by the IAEA General Conference. Its objectives are to ensure that nuclear energy is available to contribute, in a sustainable manner, to meeting the energy needs of the 21st century and bring together technology holders and users so that they can consider jointly the international and national actions required for achieving desired innovations in nuclear reactors and fuel cycles. It is basically a forum for discussion for experts and policy makers from industrialized and developing countries on all aspects of nuclear energy planning as well as on the development and deployment of innovative nuclear energy systems.

In March 2009 China joined the Global Actinide Cycle International Demonstration (GACID)[16] which was formed by France, Japan, South Korea and the U.S. This project, a major GIF activity, is investigating the use of actinide-laden fuel assemblies in fast reactors as part of the sodium-cooled fast reactor program. The work is being undertaken by France's Atomic Energy Commission, Japan's Atomic Energy Agency, and the U.S. DOE. The first stage will lead to demonstration fuel containing minor actinides being used in Japan's Monju reactor.

15 Statement accessed on April 15, 2009 at http://chronicle.augusta.com/cgi-bin/print_story.pl

16 The GACID aims to demonstrate on a significant scale that fast neutron reactors can manage the whole actinide inventory and that the associated technologies can satisfy the GIF criteria of safety, economy, sustainability and proliferation resistance and physical protection.

4.0 Observations

4.1 Regarding Energy Supply and the Role of Nuclear Power

Development of U.S. energy policy is being integrated into the formulation of U.S. policy at the highest level in the national government, with energy issue considerations taking their place beside economic, military and national security imperatives. For the first time since the Carter Administration, major changes to U.S. energy policy are underway and President Obama has made addressing climate change a key goal in establishing his energy policy. However, efforts to curtail the Yucca Mountain repository program may have an adverse impact on the U.S. nuclear renaissance. The Obama Administration's overall nuclear policy has not be fully articulated, and is therefore, at a minimum, causing some concern as to whether nuclear power will play a significant role in de-carbonizing the supply of electricity in the U.S.

The Obama Administration places a high priority on developing renewable energy sources. The most likely renewable technology to be deployed in the short-to-mid term will be wind power due to its abundant availability in the U.S., and the technology and efficiency improvements that are bringing wind power costs down. Concentrated solar and geothermal power will most likely be deployed in the Western part of the U.S. in the mid-term. For any of these technologies to make a significant contribution, improvements to the transmission grid will be necessary, and costly.

In order for the U.S. to meet its energy security and carbon reduction commitments, it will require the inclusion of nuclear power in the portfolio of clean technologies. The U.S. will also need advanced coal and CCS technologies. However, as these technologies, as well as those for more affordable renewable energy technologies are not yet available, significant RD&D is necessary to meet U.S. energy policy goals.

Regarding the role of nuclear power in China, China's continuous improvement in performance factors and in reducing plant construction time is impressive. The construction time for the first Qinshan plant was six years, declining to five years for the Qinshan 3 plant. While renewable energy sources are important to the supply mix in China, they are currently not estimated to provide more than 10% of electricity by 2050. China places greater importance on nuclear power to provide baseload electric capacity, and may even raise its target from 40 to 60 GWe (or even higher) by 2020. The expansion of coal-fired electricity will not taper off until approximately 2030.

4.2 Regarding Issues Facing Development of Nuclear Power

For the next several decades, the nuclear industry and government authorities alike in both China and the U.S. will be focused on overcoming the challenges associated with maintaining nuclear power as a viable, safe and acceptable source of electricity through the 21st Century.

In both China and the U.S., government-sponsored research on Generation IV and related fuel cycles must be expanded to meet their resource and waste management needs by the middle of the 21st Century. Both China and the U.S. are pursuing such research with the goals of creating a fuel cycle that will be proliferation-resistant, resource conserving, and waste minimizing.

Both the U.S. and China face workforce issues, which will continue to grow with rapid deployment of new nuclear power plants. There is a lot that China can learn from initiatives undertaken in the U.S. to solve workforce issues. In the U.S., EPRI member organizations promote local educational development and some target partnerships with universities. The NEI keeps close tabs on workforce concerns through its “workforce surveys” which it undertakes every five years. These surveys enable targeted solutions through the development of proper curriculum and college training programs. INPO supports cooperative ventures between members and both two-year and four-year colleges. The most important goals for China will be training mid- and senior-level management in the rigors of running a nuclear power plant and ensuring excellence across the board, at every level of the workforce.

Quality assurance in construction and operation is key to the ability of nuclear power to meet future energy demands. An accident in one country will have repercussions worldwide, so it is vital that the highest standards of management and operation and safety are maintained. The Consortium has a large role to play in helping its Chinese partners learn how to maintain the highest quality assurance standards. It has a program in place to measure quality and safety, and plans to apply “lessons learned” throughout the building of the four AP 1000 reactors. Chinese nuclear industry participation in WANO programs is beneficial in establishing a safety culture. The Chinese organizations are involved in different WANO centers based on the reactor design affiliations. It was suggested that China could achieve even more by focusing its participation in one rather than three different Centers.

Development of a domestic design, engineering and construction capabilities is intrinsic to the deal between the Consortium and SNPTC. In the long run, China can become a key supplier backing up the Consortium’s supply chain as it expands its sales worldwide.

There is a high level of multilateral and bilateral cooperation programs going on in the regulatory and licensing arena, but efforts can always be enhanced. NRC appears to be taking a lead in establishing cooperative programs, places a priority on such programs and expects to have sufficient funding and technical expertise for such activities even in the current economic downturn. For example, the NRC established the Multinational Design Evaluation Program (MDEP), of which China is a member, to create multinational working groups to review designs for the AP 1000, vendor inspection, and reviews of codes and standards. The NRC is also spearheading development of a framework for multinational construction and vendor inspection knowledge exchange.

At the bilateral level, the NRC established an AP 1000 design centered working group, held a U.S.-Sino Symposium on Nuclear Equipment Qualification, and sponsors training at NRC. Regarding concerns about quality assurance in component manufacturing that will increasingly take place in China, NRC appears to place the onus on the facility owner/operator to maintain a robust quality control program and to do its own vendor inspections. It will observe aspects of component manufacturing and construction of the AP 1000 in China and will widely disseminate their inspections reports to the public. On the issue of codes and standards, it would be ideal to move toward global uniformity, but such a development may be a generation away. However, differences in the U.S. and Chinese licensing processes do not prove to be insurmountable.

4.3 Regarding Next Generation Nuclear Power and Fuel Cycle Technology R&D

Both the U.S. and China are pursuing activities to develop advanced nuclear power reactor technology. The 2005 Energy Policy Act created a program for the U.S. at the Idaho National Laboratory to demonstrate a next generation light water reactors. China intends to develop an indigenous advanced nuclear reactor based on the technology being transferred by the Consortium. Both the U.S. and China are pursuing R&D on high temperature gas reactors that can be used for both electricity production as well as hydrogen production due to its high temperatures. The latter program offers a significant opportunity for collaboration between the U.S. and China.

Looking to the future, advanced fuel cycle technologies will be needed. Given the difficulty of establishing waste repositories, fuel cycle technologies that can minimize the volume and heat load of the waste forms will be at a premium. Increasing proliferation resistance and maximizing the energy from uranium will also drive their development. GIF and GNEP programs specifically address these concerns. Specifically, the Chinese dialogue participants commented that there is a significant need for R&D on advanced fuels that can be remotely fabricated (regardless whether China chooses between an open or closed fuel cycle). It also calls for the development of advanced recycling technologies (through the GIF program activities) with cost effectiveness in mind.

There are a number of major challenges facing Gen IV R&D programs and opportunities for international cooperation, including:

- Complexity of the technologies: As the complexity of the technology increases, the difficulty of achieving success increases. Innovative R&D is very time-consuming, requires huge amounts of capital, as well as demonstration facilities.
- Fuel cycle and resource requirements: Several Gen IV reactor systems will require a closed fuel cycle foundation, which is not uniformly supported by all key policy makers in the U.S. system. While each country will choose its preferred fuel cycle option on the basis of many factors, economics will be particularly important. (Many Dialogue participants discussed the need to factor ways to make advanced technologies more affordable into the R&D decision-making process.) The economics of reprocessing, a key element of an advanced closed fuel cycle technology, is sensitive to high plant throughput. Regional or international centers that provide either sensitive services, or cradle to grave services, could take advantage of the economies of scale that will be needed for the advanced fuel cycles to be competitive.
- Intellectual property: International, as well as national, laws and practices are needed to protect intellectual property. This becoming an even more important issue as a result of multinational collaboration on RD&D.

4.4 Regarding Commercial Deployment of Small-Scale Nuclear Reactors

While most of the Dialogue was devoted to issues related to the deployment of large-scale nuclear power plants, recent advancements towards the commercialization of small-scale nuclear power plants was also reviewed. There are several potential opportunities for advanced, small, modular reactor technologies to be used in both distributed and grid-connected applications.

Such facilities are seen as increasing the flexibility and security of electricity grids. Some note that the smaller-scale designs might provide terrorists with less attractive targets than large-scale nuclear facilities. Small sized reactors also have several uses in addition to base load electric supply, for example, in providing site power for remote oil and gas production or high demand applications like desalination. In addition, they could provide emergency backup to critical facilities in the event of an attack on the electric grid, such as secure/on-site power plant at military sites or for critical industrial complexes.

Additional factors driving the small-sized reactor market include potential bottlenecks in the supply chain for large reactors and the difficulties obtaining a large qualified workforce to build and operate a large reactor. Another intriguing possibility is to utilize self-contained, easily moved small nuclear power plants in less developed countries. In many developing countries, 1000 MWe plus size reactors are simply not compatible with countries' transmission grids. Billions of people currently live without access to electricity and without adequate water supplies. The utilization of distributed nuclear power could provide a major new power option in many less developed countries.

There are various proposals for various types of small-sized reactors that have potential applications in developed and developing countries alike. As noted in section 3.2, the Chinese are interested in commercial application of small modular pebble bed reactors.

The Hyperion Power Module, based on reactor technology developed at Los Alamos National Laboratory in New Mexico, is a sealed, 27 MWe reactor using uranium hydride fuel, which can be delivered on the back of a flat-bed truck at a cost currently estimated (by the reactor developer) at $25 million per unit beginning in 2014.

The Babcock & Wilcox Company reports that it has provided nuclear power plants for U.S. government applications and maintains the industrial capability to offer modular reactors in the 100 MWe range to commercial entities. It was noted that since China and the U.S. have an Agreement for Cooperation and as required by U.S. law, the DOE 810 technology transfer approvals[17], B&W and China could cooperate on further commercial development and marketing of such reactors. Some liability issues would, however, have to be resolved first.

NuScale Power is also interested in commercializing this type of technology. It is in the process of commercializing a modular, scalable 40 MWe light water reactor plant. It features a combined containment vessel and reactor system, and an integrated turbine-generator set. It is scalable in that as many as one to 24 units could be tied together within a single facility, with the ability to take out one unit at a time for servicing. NuScale make use of testing facilities at the Oregon State University to benchmark vendor and NRC safety evaluation models and is seeking certification by the NRC.

17 Part 810 of the US Code of Federal Regulations, "Assistance to Foreign Atomic Energy Activities," contains the regulations to implement section 57b of the Atomic Energy Act which empowers the Secretary of Energy to authorize US persons to engage directly or indirectly in the production of special nuclear material outside the United States.

5.0 Recommendations for U.S.–China Cooperation

Throughout the dialogue, participants called for ways to accelerate commercial nuclear power cooperation between the U.S. and China on a government-to-government level and throughout the commercial sector. Given the importance of developing nuclear trade between the two countries, and the necessity of ensuring safe and reliable plant operations, pragmatic and integrated cooperation is needed. In addition, global acceptance of nuclear power over the long term will depend upon viable solutions to nuclear waste and the creation of (even more) proliferation resistant technologies. Both China and the U.S. have the capability of leading in the creation of solutions to these issues.

Specific recommendations coming from the dialogue include:

1. As it becomes more clear that nuclear power will be an important part of China's and the U.S.'s energy portfolio throughout this century and well into the next, so too does the need for adequate planning. To make the right decisions, energy policy makers need to expand their horizons to consider the longer term, i.e., past 2050, and what fuel cycle R&D must be initiated now.

2. This dialogue represented a good first step to bring together some of the key players in the U.S. and Chinese nuclear sectors. At a future meeting, the Dialogue could be enhanced by broadening participation. For example, the meetings should include Chinese counterparts to attending U.S. organizations, a diverse range of Chinese utilities, other U.S. reactor design vendors and representatives from U.S. national laboratories.

3. The U.S. government should continue to promote U.S.-Sino cooperation, especially in the nuclear area. Such cooperation would be supportive of the ongoing efforts to expanded cooperation on fossil fuel and climate change efforts that will not only benefit each country, but also developing countries such as India and Indonesia.

4. The U.S. nuclear industry is mature; many lessons have been learned with regard to how to structure a robust commercial program. China could benefit from the U.S.'s experience to create viable utilities, vendors, a world-class regulator as well as supporting universities and institutes.

5. Commercial nuclear power deployment is a truly global endeavor demanding absolute quality assurance without compromise. There were several suggestions as to how it can be fostered:

   - Increased engineering and construction cooperation by sharing best practices, utilizing 3D and 4D design techniques, better information management (taking advantage of communications devices such as "blackberries"), and adopting standardized barcodes.

   - Assisting with the cultivation of China's human resources by increasing opportunities for U.S. experts to do on-site training in China as well as for Chinese workers to come to the U.S. for training at the Nuclear Regulatory Commission (NRC) and utility facilities to witness U.S. "best policy and practices".

   - Developing a mindset of management and operational excellence by collaboration with organizations such as the World Association of

Nuclear Operators (WANO.) The Chinese might best profit from the WANO experience by all Chinese organizations participating in the same WANO center.

- Steps are needed by the Chinese government to raise the profile of the profession and encourage the universities to improve the number and quality of their degree-programs. The industry must continue to coordinate with the universities regarding their needs.
- China should be encouraged to implement establishment of independent testing labs as is now apparently authorized under the auspices of the Institute of New and Nuclear Energy Technology.

6. The U.S. NRC should continue to aid China's National Nuclear Safety Administration (NNSA) in the development of its regulatory system and training of regulators. A follow-on dialogue should focus on obtaining more information to how China plans to ramp up its regulatory structure to meet the demands of a rapid deployment of commercial nuclear power across the spectrum of reactors it is currently planning.

7. As the Chinese nuclear power industry matures, there will be opportunities for Chinese companies to provide services such as uprating, refueling, maintenance and outage control services. Efforts to establish such cooperation should be initiated in the near term.

8. To improve the commercial nuclear plant supply chain, China should consider establishing a qualified supplier list. In the process, Chinese companies fabricating components need better training with regard to the American Society of Mechanical Engineers (ASME) standards code.

9. Commercial entities in both the U.S. and China can take advantage of their competitive edges for mutual benefit. The U.S. has technical competitive edges and China has geographic edges vis-à-vis the developing market for nuclear power. U.S. and Chinese companies can jointly exploit these competitive edges to develop the South East Asian markets.

10. One of the roadblocks to the development of cooperative opportunities is the U.S. visa issuance system. The Atlantic Council was encouraged to ask the U.S. Department of State to improve its processing of visa applications to significantly shorten the time needed for Chinese nationals involved in nuclear power to obtain a visa for travel to the U.S. Consider, for example, that France provides a dedicated consulate. It is important to recognize that U.S. authorities must take into consideration the security of nuclear facilities but that a better balance can be reached. This is a problem that can be solved.

11. There is an opportunity for international cooperation on the development of a nuclear waste repository based on the experience the U.S. has already gained through 10 years of operation at the Waste Isolation Pilot Project (WIPP) facility and through its Yucca Mountain site characterization and licensing activities.

12. China's 10 MWe High Temperature Gas Reactor (HTGR) scheduled to be in operation by November 2013 in Shandong Province, could serve as an international experimental facility. The currently operating test pebble bed reactor has provided an opportunity for international collaboration.

13. Cooperation on the development of advanced fuel cycle technologies, already underway in U.S.-China working groups, will provide significant opportunities to share rather than duplicate knowledge and funding. Generation IV (Gen IV) international collaboration on R&D is necessary and beneficial for all participants to share costs, facilities and experience. Specific fuel cycle R&D opportunities proposed by the State Nuclear Power Technology corporation (SNPTC) include the following: Advanced fuel, such as mixed oxide (MOX) fuel, and metal fuel;

    - Transmutation technology, such as fast reactor and accelerator driven systems;
    - Reprocessing technologies, such as MOX spent fuel reprocessing, dry processing, on-site recycle; and,
    - Repository design technology.

14. The Generation IV International Forum (GIF) will provide a good framework to deal with intellectual property issues. If prototype or demonstration plants were to be built under the aegis of the GIF, it could also provide experience in dealing with legal and regulatory issues. Issues such as design ownership, who would build

the facility, cost sharing would have to be addressed. As countries have vested interests in certain types of technologies, resolution of such issues may be difficult.

15. The Global Nuclear Energy Partnership (GNEP): The U.S., which led the way in establishing the international collaborative effort to develop proliferation-resistant technologies and institutions, should take advantage of its leadership position to nurture and expand GNEP's international activities. As in GIF, there are advantages to sharing technical expertise and pooling financial resources. GNEP is already in place and the Obama Administration can take advantage of the years of effort it took to set up the framework for international collaboration while adapting GNEP goals to current realities and domestic nuclear development policies. Consistency in U.S. nuclear energy policies, especially in relation to international efforts, is crucial to foster global acceptance of a safe, secure and sustainable nuclear power.

6.0 Conclusion

The time for debate about the winners and losers in the supply of energy is over. Nuclear energy is needed more than ever as a non-carbon emitting source of electric supply and it can play a role in providing a secure, sustainable, affordable energy supply. The bottom line is that both the U.S. and China need a diversified energy production platform and technology portfolio, including a vibrant nuclear industry. Given the necessity of using all the forms of energy at our disposal while transitioning to a de-carbonized portfolio relying increasingly on renewables, integrated solutions are needed.

Recognizing that this is not an either-or world, cooperation on nuclear energy can lead to expanded cooperation on other energy programs such as clean coal technology and renewable energy R&D. As the scientists and engineers begin to work together on nuclear programs, both will find ways to start other joint efforts. Together the U.S. and China have the ability to set the standards for world's upcoming climate negotiations.

With 2 billion people in the world suffering from a lack of energy and facing increasing shortages of adequate water supplies, developed countries are in a position to spread the benefits of electricity around the globe. To do this, every available source of electric supply must be deployed, and the U.S. and China, who will have the world's two largest nuclear power programs in approximately 20 years, and who may also be the world's top two economies, will be able to lead the way.

This Dialogue provided a very good information base and an excellent platform to help the U.S. and China to work together to bring the benefits of nuclear energy to our nations and to the others in this world suffering from a lack of the basics for life. The U.S. and China are the world's largest energy consumers—and the world's two largest emitters of greenhouse gasses. Both countries must increase their use of nuclear power to help meet energy demands in a carbon-constrained environment. Relevant government agencies and key stakeholders must educate their publics about the parameters involved in producing a diverse energy supply in order to understand the worth of sacrifices that will be needed.

Cooperation between the U.S. and China will be mutually beneficial. It is to the U.S.'s benefit that China designs and operates a safe nuclear power program. China is a significant market for the U.S. nuclear industry and provides an opportunity to maintain its manufacturing capabilities until its first new U.S. orders get underway. U.S. industry presence in China also increases relationships and communications thus improving U.S. security. The unprecedented transfer of nuclear technology to the Chinese will, in turn, help them develop clean sources of electricity sorely needed to address the fast growing needs of its economy and public. As Chinese capabilities grow, the nuclear supply chain is reinforced, supporting further opportunities for U.S. companies to expand reactor sales abroad. American and Chinese companies together can take advantage of their mutual competitive edges in technology and geography to expand into new markets.

Cooperation and leadership are key and complimentary components in the U.S.'s and China's efforts to ensure nuclear power's contribution to meeting energy demand. Cooperation on technology development, human resources, security and safety will form the basis for their leadership on the world stage. Their combined actions will matter greatly in providing a quality environment with adequate energy supplies. The world is watching!

The Chinese participants signaled their desire to improve both government-to-government cooperation and commercial sector ties. It appears that the U.S. government is equally interested in working with China to tackle the overarching challenges of developing a safe and secure commercial nuclear fuel cycle. By supporting and participating in this Dialogue, U.S. industry and government participants have demonstrated their commitment to dealing with the challenges to realize the burgeoning nuclear trade between the two countries.

List of Participants
U.S.–China Cooperation on Nuclear Power

March 4-6, 2009

Sofitel Hotel
806 15th Street NW, Washington DC

Co-sponsored by the **Atlantic Council of the United States** and
The **US/China Energy & Environment Technology Center** at Tsinghua and Tulane Universities

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Agenda
U.S.–China Cooperation on Nuclear Power

March 4-6, 2009

Sofitel Hotel
806 15th Street NW, Washington DC

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MARCH 4

Co-Chairmen:
Prof. WU Zongxin, Institute of Nuclear and New Energy Technology, Tsinghua University
Gen. Richard Lawson, Vice Chair, Board of Directors, Atlantic Council of the United States

6:00pm — **Welcome Dinner**
Hosted by the Atlantic Council with comments by U.S. and Tsinghua representatives at **The University Club** of Washington, DC, located at
1135 Sixteenth Street, N.W.
Washington, D.C. 20036

MARCH 5

Co-Chairman:
Gen. Richard Lawson

8:30–9:00am — **Opening Comments and Introductions**

9:00–10:00am — **Session I: Overview**
Review of current outlook for electric power, and the capacity to be met by nuclear and coal, with discussion of existing bottlenecks

China Presentation (20 minutes)
LU Huaxiang, Deputy General Manager, State Nuclear Power Technology Co.

U.S. Presentation (20 minutes)
John Easton, Vice President, International Programs, Edison Electric Institute

Open Discussion (20 minutes)

MARCH 5 (continued)

10:00–11:00am

Session II: Major Issues and Hurdles
A review of major financing, regulatory, siting and public acceptance issues impacting the deployment and construction of large-scale base load nuclear and coal fired power plants

U.S. Presentation (20 minutes)
Revis James, Electric Power Research Institute

China Presentations (20 minutes)
Chang Huajian, Institute of Nuclear and New Energy Technology, Tsinghua University

Open Discussion (20 minutes)

11:00am–12:15pm

Session III: Accelerating Construction of New Plants
Potential for cooperation on accelerating the construction of Generation III plants:

a) Increasing supply-chain capacity to deliver high-quality components

b) Increasing and improving the workforce to construct and operate plants

c) Potential establishment of a pilot program to cooperate on engineering design, construction and commissioning by exchanging knowledge, practices and manpower.

U.S. Presentations (20 minutes)
Grenville Harrop, Westinghouse/ Joe Greene, Shaw Power

China Presentations (20 minutes)
WANG Bin, State Nuclear Power Technology Co.

Open Discussion (35 minutes)

12:15–1:00pm

Buffet Lunch

Co-Chairman:
Prof. WU Zongxin

1:00–2:15pm

Session IV: Ensuring Operational Excellence
Presentation by the World Association of Nuclear Operators (20 minutes)
Sharing Experiences:

China Presentation (20 minutes)
Ye Chen, State Nuclear Power Technology Co.

US Presentation (20 minutes)
David Farr, Institute of Nuclear Power Operations, INPO

Open Discussion (35 minutes)

2:15–3:30pm

Session V: Regulations and Licensing
Harmonization of reactor regulations to enable cross-licensing

U.S. Presentation (20 minutes)
William Borchardt, Nuclear Regulatory Commission

China Presentation (20 minutes)
MIAO Hongxing, State Nuclear Power Technology Co.

Open Discussion (35 minutes)

3:30–3:45pm

Break

3:45–5:15pm

Session VI: RD&D
Review focus of current Governmental Research, Development and Demonstration, including in Multi national agreements

U.S. Presentation (30 minutes)
John Herczeg, DOE, Office of Nuclear Energy

China Presentation (30 minutes)
WU Luping, State Nuclear Power Technology Co.

Open Discussion (30 minutes)

6:00pm

Dinner
Hosted by Atlantic Council and Tsinghua/Tulane at the Sofitel Hotel

MARCH 6

Co-Chairman:
Gen. Richard Lawson

8:00–9:15am **Session VII: Generation IV**

Opportunities to accelerate the development and deployment of Generation IV reactors through a pooling of capital and knowledge, including any issues related to intellectual property rights

China Presentation (25 minutes)
SHEN Wenquan, State Nuclear Power Technology Co.

U.S. Presentation (25 minutes)
Tom O'Conner, DOE, Office of Nuclear Energy

Open Discussion (25 minutes)

9:15–10:45am **Session VIII: Cooperation on Fuel Cycle Research**

Opportunities to cooperate on other fuel cycle research, including GNEP, waste disposal, and fuel reprocessing, including any issues related to intellectual property rights

U.S. Presentation (40 minutes)
Julian Steyn, Energy Resources International, Inc.
Carter "Buzz" Savage, DOE, Office of Nuclear Energy

China Presentation (25 minutes)
SHEN Wenquan, State Nuclear Power Technology Co.

Open Discussion (25 minutes)

10:45am–12:30pm **Session IX: Small Size Nuclear Power Plants**

Opportunities to cooperate on small-sized modular high-temperature gas-cooled reactors for distributed generation and sale in less-developed countries, including any issues related to intellectual property rights

China Presentation (25 minutes)
WU Zongxin, Institute of Nuclear and New Energy Technology, Tsinghua University

U.S. Presentations (45 minutes)
Deborah Blackwell, Hyperion
Megan Rossi, Babcock & Wilcox

Open Discussion (35 minutes)

12:30–1:00pm **Concluding Comments**

1:00pm **Buffet lunch**

The Atlantic Council's Board of Directors