**Andrew C. Kadak, Ph.D.**
**Professor of the Practice**
**Nuclear Science and Engineering Department**
**Massachusetts Institute of Technology**

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*China's Energy Policies and Their Environmental Impacts*

*Panel: US-China Energy Technology Cooperation: Civil Nuclear Energy*
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My name is Andrew C. Kadak. I am a Professor of the Practice in the Nuclear Science and Engineering Department at the Massachusetts Institute of Technology. I received my Ph.D. and Master's degrees from MIT in nuclear engineering. I have spent my entire career, until I joined MIT in 1997, in the commercial nuclear power industry. My last position was President and CEO of the Yankee Atomic Electric Company which operated the Yankee Atomic Nuclear Power Station in Rowe, Massachusetts until it was shutdown and subsequently decommissioned. Yankee also provided engineering, safety analysis, licensing and environmental laboratory support to most of nine then operating nuclear plants in New England. Yankee was also involved in the design and construction of many New England nuclear plants.

Personal Background with the Chinese Nuclear Energy Program:

My introduction with the Chinese nuclear energy program began in 1998 when several MIT professors were invited to Beijing to conduct a workshop on nuclear energy with a large group of Chinese representing universities, regulators, several state agencies and some involved in the design and construction of nuclear plants in China. It should be noted that at that time, China's nuclear energy program was not emphasized by the government as an important element in their energy strategy.

Subsequently, at MIT my research interests began to focus on the design of advanced high temperature gas reactors using pebble bed fuel. This was also an area of research and development by Tsinghua University's Institute of Nuclear Energy Technology (INET). As a result of this common interest and following a visit of the president of Tsinghua University and several of his top scientists and engineers to MIT who were working on the pebble bed reactor, the Nuclear Engineering Department at MIT and Tsinghua University signed a memorandum of understanding for cooperation and technical exchange on pebble bed reactor issues. This agreement was subsequently approved as a separate agreement by then Secretary of Energy Richardson and his Chinese counterparts in a formal Part 810 technology exchange program. To date, we have been able to continue to have mutually productive exchanges at various meetings of the industry and visits to the Chinese HTR-10 pebble bed research reactor. The HTR-10 is the test reactor for China's future commercial pebble bed reactors now being licensed and planned for construction in China.

During this time period, I was also retained as a consultant to be a member of the Senior Nuclear Safety Oversight Board of the China Guangdong Nuclear Power Company that operates four existing 900 Mwe commercial nuclear plants at the Daya Bay site near Hong Kong. I have been spending a week at these plants twice per year for the last 4 years. Thus, my understanding and appreciation of the Chinese nuclear power program is current and in some depth.

I would like to answer your questions as posed with additional thoughts that might be of interest to the committee.

1) How is China's civilian nuclear power industry organized?

Based on my experience, the Chinese are not comfortable with organization charts and I have yet to find one of the Chinese nuclear industry. In March of 2008, there was a significant reorganization of the various ministries that oversee nuclear energy. The key agency is State Council of Ministers. Under the State Council of Ministers is the Commission for Science Technology and Industry for National Defense. This Commission controls the China Atomic Energy Agency which is responsible for planning and managing the peaceful use of nuclear energy and promoting international cooperation. The state-owned State Assets Supervision and Administration Commission (SASAC) is an investor of 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. The National Development and Reform Commission (NDRC) is the agency responsible for assessment and approval of major projects and is responsible for deciding which nuclear projects to pursue.

Also in March of 2008, a new National Energy Commission was created to strengthen the role of government in terms of managing the energy sector. It reports to the NDRC and is charged with developing an integrated energy development strategy and monitoring its implementation. The National Energy Commission will have a state energy bureau to integrate NDRC's energy management functions and to promote various energy development projects and conservation.

There are several other state agencies such as the State Nuclear Power Technology Corporation that is charged with technology selection for new plants that are purchased overseas. The SNPTC reports to China's State Council of Ministers.

National Nuclear Safety Administration is the nuclear regulatory branch which reports directly to the State Council of Ministers. NNSA licenses and oversees the safety of nuclear plants. The State Environmental Protection Administration (SEPA) is now part of the Ministry of Environmental Protection which also reports to the State Council. SEPA is responsible for radiological monitoring and radioactive waste management. A utility that proposes to build a nuclear plant must have approval from both the NNSA and the State Environmental Protection Administration.

The 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 also a major investor in all nuclear plants in China. The China Power Investment Corporation (CPI) is a major power generator and is currently the largest state-owned nuclear power holding company. One of its competitors is the China Guangdong Nuclear Power Company which along with CPI and the China National Nuclear Corporation are the only entities that have been designated to build and operate China's nuclear plants.

China has also decided, at least for the present, to build only pressurized water reactors which are supplied either domestically or purchased from France, Russia, Canada and the United States. 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 completely capable of indigenously designing, supplying all components, and fuel for their reactors.

China has several companies that design and construct nuclear plants. They include: the China National Nuclear Corporation; the China Nuclear Engineering and Construction Group; the China Nuclear Engineering Company; the Shanghai Nuclear Energy Research and Design Institute; the Beijing Institute of Nuclear Engineering; and the China Nuclear Power Engineering Corporation. In addition, as the industry evolves and develops, separate companies are established to own and operate the nuclear power plants. These new plants have multiple owners with shares sold very similar to that which is done in the United States to mitigate risk and provide financing.

The fastest growing nuclear operating company is the China Guangdong Nuclear Power Company who own and operate the two Daya Bay and two Ling Ao nuclear plants with two under construction (Ling Dong). Additionally, China has an advanced pebble bed reactor project underway through another joint venture under a company by the name of Chinergy. Chinergy is owned by Tsinghua University, China National Nuclear Construction Company and Huaneng Group which is the largest utility in China. The high temperature pebble bed reactor – HTR-PM will be built in northeast China in Shangdong province by 2014.

<u>Who determines nuclear energy policy, and who implements that?</u>

Nuclear energy policy is determined by the China Atomic Energy Agency with the approval of the Commission for Science Technology and Industry for National Defense which reports to the State Council of Ministers. The policy is implemented by the National Development and Reform Commission and the state-owned Assets Supervision and Administration Commission which supervises the China National Nuclear Corporation and the China Guangdong Nuclear Power Corporation. The National Energy

Commission and the State Energy Bureau will also be engaged in implementation of the government manager of the energy sector.

What role do state owned enterprises play?

State owned enterprises are the companies that design, build and operate nuclear power stations in China. The utilities, and the companies mentioned above are all either state owned or controlled. They implement national energy policy as set by the State Council of Ministers.

2) What are China's goals for expanding the use of civil nuclear energy, and what impacts will this development have on China's energy supply and emission of greenhouse gases?

China has set extremely aggressive goals for its nuclear expansion. It appears that every year more nuclear plants are planned to meet their energy needs. China plans to generate 20% of its electricity from nuclear plants by 2030. At present, up to 60,000 MW electric of new nuclear capacity is being planned by 2020. Currently there are 11 operating nuclear plants producing about 2.4% of the electricity demand in China. Approximately 21 new nuclear plants are either under construction or about to start construction that have been approved by the State Council. In total, China plans to build at least 160,000 Mwe of nuclear generation by 2030. Unfortunately, due to the huge energy demands of China and the relatively small nuclear contribution to its present electric energy needs, the targeted percentage of nuclear in the electricity mix by 2020 is expected to be only 5% up from 2.4 % today. From an environmental perspective, if they are able to meet the 2030 goals, they will displace **1.2 Billion** metric tons of carbon dioxide per year if the plants were coal plants. Not a small amount!

What concerns exist regarding the expansion of nuclear power in China?

The rapid expansion of any industry is a concern from the standpoint of assuring quality of construction and a trained plant staff and operators. In the United States, during our rapid expansion of the nuclear industry in the 1960's and 1970's when we built over 100 nuclear plants in 25 years, the challenges we faced are similar to those being felt by the Chinese. The Chinese need to train craft labor to build the plants to nuclear standards and educate engineers for nuclear plant design and train operators for the many plants they have planned. China also needs to staff its regulatory agencies with nuclear qualified engineers for oversight and review of new project proposals. Since China would like to transfer foreign nuclear technology to indigenous design and manufacturing, effort needs to be made to assure that Chinese manufacturing companies comply with the strict nuclear quality standards. This will require additional inspections and regulatory attention.

The existing plants such as those at Daya Bay are becoming training grounds for future engineers, operators, craftsmen and the other workmen needed in the design construction, operation and maintenance of nuclear power stations. The Chinese realize that one of their major challenges is developing the needed human resources to support their rapid nuclear expansion. To give you an example, for the China Guangdong Nuclear Power Company alone, they will need to hire more than 13,500 engineers, technicians and operators for their existing and future nuclear plants. To construct the plants that they plan to build, they will need over 4,500 people. While these numbers may seem large and unattainable, China is a country of 1.3 billion people. To put China's expansion plans in perspective, their planned build of plants connected to the grid each year is about 1/2 the US build rate of the 1970's (4.63 US to 2.46 China to 2020). My conclusion is that they can do it.

In order to keep up with this rapid growth, the regulatory oversight of construction and operation must be expanded at a pace to assure that the same level of quality of the first plants is maintained for all future plants. The NNSA must continue to grow and improve its oversight role to be able to cover all the different types of reactors that are presently being built in China. These include plants from Russia, the United States, France, Canada, and their own indigenous designed plants. The Chinese have made a conscious decision to focus on pressurized water reactors which will be standardized around units of approximately 1,000 MW electric. This will be helpful in terms of supporting the plants and in regulatory oversight.

<u>3) What is the status of existing US China nuclear energy cooperation?</u>

US China nuclear energy cooperation is limited. China has recently joined the Generation IV International Forum which is focused on the development of the next generation of nuclear plants. Its entry into this international collaboration took many years to materialize. China has been an active participant with the International Atomic Energy Agencies initiatives aimed at nuclear cooperation. At present, there are international agreements with the Westinghouse Electric Co. for the purchase of the AP 1000 nuclear plants and with the MIT Nuclear Engineering Department on development of the pebble bed reactor.

One of the difficulties in establishing international collaborations with China, which I hope this Commission can address, is the problem of granting Chinese scientists and engineers visas to allow them to come to the United States to meet with researchers, utilities and companies in the nuclear area. The process of technology exchange with China requires months of effort to obtain visas with outcomes in terms of actual attendance at meetings in the United States not decided until the last minute and most of the times visas are rejected. What this means for the United States is that most international meetings with the Chinese must be held outside of the United States to our detriment. Based on my experience with the Daya Bay plants, it would be very helpful to have Chinese engineers, managers and operators visit US plants for benchmarking of good performers so that they can directly observe how we run our plants. Such visits are extremely difficult to arrange.

How has that cooperation changed over the past five years, and what prospects exist for continued cooperation?

The cooperation with the United States over the past five years has not changed due to the problems of granting visas for Chinese nuclear scientists and engineers. Visits are infrequent and can never be assured. As past president of the American Nuclear Society and current Chairman of the International Nuclear Societies Council, I can testify to the difficulty of obtaining visas for distinguished Chinese scholars to receive awards and present papers at our conferences. If this problem can be solved, it's expected that a great deal more cooperation and communication can be established for the mutual benefit of both countries. These benefits include the sale of US commercial technology, collaborative research and development, particularly in technologies which the United States is not a leader such as high temperature gas reactors.

4) Last year, China inked an agreement with Westinghouse to build four AP 1000 nuclear reactors in China. How long will it take to implement an agreement of this type and to complete construction of the reactors?

China's agreement with Westinghouse was the result of a multi-year process which, for the first time, resulted in the sale of a US nuclear power plant to China. The contract includes the supply and engineering for four AP 1000 nuclear islands at the Sanmen and Haiyang sites, fuel supply and a technology transfer contract which became effective on September 24, 2007. At present, site excavation work is in progress at both sites. The preliminary safety analysis report for the Sanmen plant was submitted to the Chinese regulatory authority in early 2008 with the first concrete pour planned in 2009. The first plant is expected to become operational in late 2013 with the remaining three plants to come online in 2014 and 2015.

What technology transfers are expected to occur?

The technology transfer contract provides for the transfer of Westinghouse and Shaw Engineering Company technology in the design and analysis, engineering, licensing, procurement, manufacture, construction, startup operation, and maintenance of the AP 1000 nuclear island. The objective of this technology transfer contract is to provide the Chinese with the capability to lead the design and engineering of future nuclear plants in China based on AP 1000 technology and to localize the capabilities for manufacturing construction, operation and maintenance. The nuclear island contract involves the Shanghai Nuclear Engineering Research and Design Institute and for progressive localization of equipment supply and support of Chinese procurement.

It is expected that these technology transfers will occur as the plants are being built and started up. It is also expected that Westinghouse will continue to play a major role in support of the Chinese development efforts through the supply of parts and services as they continue to do with Korea as part of a contract of technology transfer with the former Combustion Engineering Company which Westinghouse subsequently acquired.

What concerns exist regarding the US export of nuclear energy plants and technology?

Given this rather dramatic transfer of US technology to the Chinese, one must naturally ask whether this is unique in the industry. When one reviews the history of nuclear plant development worldwide, when the United States was the dominant leader, one observes similar types of technology transfers in the form of license agreements which were provided to French, German and Korean companies as they sought to develop their nuclear technologies. Thus, the China contractual relationships are not that unique.

What might be of concern is the loss of competitiveness of the US industries but whether the US transferred the technology or not, others would have be willing to do so to gain a foothold in the China market. I am sure Westinghouse carefully reviewed this business decision in this regard.

In terms of non-proliferation policy, since China is already a nuclear weapons state that issue is not as pressing. In signing the agreement, it is my understanding that both Westinghouse and the Chinese government both had to sign a similar Part 810 petition that limits the technology to transfer to China and prohibits transferring it to another nation without both parties approval and an agreement not to use the technology to create nuclear weapons which commercial nuclear plants are not designed to do.

What implications could be these technology transfers have on US security, and what impacts will this agreement have on US energy security?

The implications of this technology transfer on US security are hard to judge. On the one hand, it is quite clear that if Westinghouse had not agreed to these technology transfer agreements, which were conditions of the sale, other companies would have won the contract. AREVA, a French nuclear vendor, which had already sold six nuclear power reactors to China, would have undoubtedly gotten the Westinghouse contracts without technology transfer agreements. It is my judgment that having a US market presence in China in the nuclear field helps US security. By selling US reactors to China, it positions US technology in their market and establishes relationships with the Chinese nuclear industry. By having these relationships and consequently closer communication and cooperation helps US security. At this point, the Chinese energy market is so huge that most of their effort will be focused on meeting their own needs rather than attempting to compete in the US market with Chinese technology.

In terms of our energy security, the major impacts of China's rapid nuclear expansion will be on the demand for uranium, the needed steel, concrete and heavy forgings which are all part of the world wide market. It is expected that the price of uranium and these other commodities will increase as more nuclear plants are built worldwide including the United States.

Commercial nuclear plants are not themselves proliferation risks. For China, a country which already possesses nuclear weapons, that risk is reduced further. China is capable enriching of uranium and reprocessing its spent fuel and recycling uranium and plutonium into the reactors, if needed. They are also embarking on a breeder reactor program to extend their nuclear fuel supply. The policy of the country is to become as self sufficient on as much of their energy needs as possible.

<u>What opportunities exist for the promotion of further US China cooperation to improve energy security through the diversification of energy supplies and development of clean energy alternatives?</u>

At present, China has an initiative underway at the Tsinghua University Low Carbon Energy Laboratory whose mission it is to develop advanced nuclear technologies, clean coal technology, advanced power transmission and security control technologies and new energy and renewable energy alternatives including hydrogen, biomass, wind power and energy efficiency options. Carbon capture and sequestration are also among the focus areas for this new university collaboration. China has passed national energy legislation that encourages development of these new energy, environment and conservation alternatives. Recently representatives of Tsinghua University visited MIT to explore opportunities for MIT to participate in a collaboration with the Tsinghua Low Carbon Energy Laboratory for research and development.

While development of clean, renewable energy alternatives is now being pursued in China, the question of “scale” remains. The Chinese have determined that nuclear energy is the best large scale clean energy alternative able to meet its energy and environmental needs. Given that nuclear plants can produce over 1000 MWe at one plant, when compared to renewables, rated at several megawatts each, it will be a daunting challenge to expand renewable energy sources to meaningful levels in a short time.

<u>What role can the United States play including joint research and development efforts and technological assistance in influencing the energy policy of the People's Republic of China?</u>

The United States can play a significant role in assisting China both in research and development but also in improving its organizational infrastructure to create a viable and safe nuclear industry. At present, the commercial nuclear industry is directed from the top and implemented by organizations such as the generating companies that rely on institute's and universities that are loosely coupled. There are no equivalent companies such as Westinghouse or General Electric that act as nuclear steam suppliers around which a nuclear industry can be built. Assisting the Chinese in helping structure their new civilian nuclear power business would be an important contribution.

Even though the Chinese are buying western technology, there are still large gaps in their technical capabilities in design in terms of computer codes and analysis capabilities. It is not clear how much of this technology will be transferred to the Chinese from either the Westinghouse or AREVA new plant contract agreements. The Chinese also have an operating pebble bed reactor which is a high temperature helium cooled gas reactor that could be useful for electricity generation and high temperature process heat applications such as the production of hydrogen. Both areas are opportunities for enhanced technology exchange and cooperation.

In the United States, we have a congressionally mandated nuclear plant called the Next Generation Nuclear Plant (NGNP) which is to be built at the Idaho National laboratory in accordance with the Energy Policy Act of 2005. The experience of the Chinese in their operation of their HTR-10 pebble bed research reactor would be of great value to the United States. MIT has a collaboration agreement with Tsinghua University and its Institute of Nuclear and New Engineering Technology for pebble bed technology development. We have had a very productive information exchange program for many years but it has been difficult to find meaningful projects due to the difficulties associated with the visa issue and funding.

In terms of energy policy and direction, I think the US has already set an example for what might be possible in terms of deploying nuclear and other energy alternatives. Our clean coal program, coal gasification development, and coal to liquids programs could be joint programs. Chinese scientists and engineers are smart, clever people that could be very helpful in developing and demonstrating these new technologies. I hope that there can be US funded programs for joint research and development to harness the brilliance of US and Chinese scientists and engineers working on challenging world energy problems.

As China will soon be the world's largest economy, we must begin to be actively engaged not only as consumers of Chinese products but collaborators to address global climate and energy problems. Programs such as the proposed China-MIT collaboration on clean energy should be supported by the government and more technical exchange meetings should be encouraged in the commercial nuclear power sector. It is my belief that our security and overall environment will enhanced by closer cooperation. The more we work with the Chinese, the stronger will be our relationship. The Chinese culture is built on relationships which we should nurture. If we want to affect Chinese energy policy, it will be based on these relationships.

<u>Conclusion:</u>

In conclusion, US China cooperation on nuclear technology could be of benefit to both countries. It is vitally important to the US nuclear program that the Chinese plants are well designed and operated safely. The US should be working to improve regulatory relationships with the Chinese regulatory bodies and Chinese nuclear engineers, maintenance people and operators should be allowed to come to the US to observe operations, engineering and design functions to establish world wide standards for their operations and future designs. To enable this to occur, we need a visa policy that allows for exchange visits without making it a painful process for both sides. My experience at both the academic and commercial levels in China is that the people are bright, open to new ideas, and share experiences once a level of personal trust is established. In my opinion, the market of China is huge and one which the United States industries can become a major player if our policies encourage interaction and cooperation.

In my earlier paper published several years ago in the Brown Journal of World Affairs entitled "Nuclear Power – Made in China", I speculated that since the US industry was in the doldrums at the time, perhaps we would be buying, as we do just about everything else, nuclear power plants made in China. Today, as we are beginning a nuclear renaissance in the US, I see great opportunities to sell China some of the innovative technologies that we have developed such as the Westinghouse AP-1000 reactors. I hope we can find ways to make this process easier so that our American industries can benefit from improved nuclear cooperation with China.

Thank you for your attention.

Andrew C. Kadak