UxC Interview with Dr. Hui Zhang

Mr. Jonathan Hinze, Executive Vice President, International at UxC, LLC (UxC), a leading global nuclear market research and analysis company based in the U.S., was pleased to recently interview Dr. Hui Zhang regarding the current state and future prospects for China's nuclear energy program. Dr. Zhang is a Senior Research Associate at the Project on Managing the Atom in the Belfer Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government. Dr. Zhang is a respected expert on all aspects of China's nuclear energy program. Before coming to Harvard, Dr. Zhang worked at Princeton University and was also a MacArthur Foundation fellow. He received his Ph.D. in nuclear physics from the China Academy of Engineering Physics and is the author of numerous technical reports, book chapters, and journal articles related to China's nuclear program.

Hinze: China has announced ambitious plans for its domestic nuclear energy development. What are your views on this?

Zhang: As of January 2016, China has 30 power reactors (27 GWe) in operation with 24 units under construction (27 GWe). China leads the world in terms of the pace of nuclear development and new reactor construction. The country officially plans its total nuclear capacity to be 58 GWe by 2020 plus 30 GWe under construction, and a new target is currently being set for a total capacity about 120-150 GWe by 2030. Many more reactors are under consideration for construction in the coming decades.

After a relatively slow recovery period over four years in the wake of Fukushima, China's nuclear expansion entered a steady growth stage in 2015. Developing nuclear power has become one key policy in China's economic and energy development strategy. It can be expected that China's nuclear expansion will see steady growth in the coming decade. China's ambitious plans for nuclear energy will not significantly change in the near future.

The major motivations behind China's ambitious nuclear power program are to reduce air pollution and deal with climate change. To address these concerns, China has pledged to obtain around 15% of its primary energy from non-fossil sources by 2020, and 20% of its primary energy from non-fossil sources by 2030. To meet its ambitious goal, China is pursuing a strategy to rely on more electric generation from nuclear, renewable sources, and natural gas to replace some coal. Many Chinese officials and nuclear experts advocate that developing significant nuclear power capacity is an imperative if the country is to increase the share of non-fossil fuel energy in its energy mix.

In practice, a total capacity of about 58 GWe would account for about 3% of total energy use by 2020, a share of about one fifth of the non-fossil sources targeted for 15% of its primary energy. While a fleet of nuclear reactors with 120-150 GWe by 2030 would represent a substantial expansion, it would only account for about 5% of the country's total energy use and would constitute just one quarter of the non-fossil energy needed. Thus, if China hopes for nuclear power to make a significant contribution to its targets for non-fossil sources, the current seemingly ambitious nuclear expansion plans may actually not be so ambitious after all.

Hinze: Considering the recent economic slowdown in China, do you believe there are any reasons to doubt China's commitment to long-term expansion of nuclear power?

Zhang: No. In fact, as China's economic development has slowed down, the central and local governments hope to stimulate economic growth through reactor construction programs. Recently, nuclear expansion has become one important piece of China's domestic economic development strategy. Local governments have welcomed nuclear power projects in their jurisdictions with local officials hopeful that these endeavors will bring remarkable benefits to promote regional economic development, including thousands of jobs, investment in their communities, increased local tax bases, and solutions for air pollution. As a result, many local governments, along with the proposed operators, are lobbying relevant nuclear experts and government officials to approve their own reactor projects.

However, some challenges could affect China's commitment to long-term expansion of nuclear power - for instance, public acceptance issues. As the public increases awareness of nuclear safety (in particular, after the Fukushima accident in Japan) and involvement in the assessment on environmental impacts and social stability, public opinion could ultimately have an increasing impact on nuclear project decision-making. The cancellation of a plan to build a large-scale nuclear fuel processing complex in Jiangmen in Guangdong province in July 2013, after about a thousand people protested against the project on the street, may indicate the significant potential impact of public opinion on nuclear project siting.

Assuring safety throughout the construction and operation of nuclear power plants is the key to guarantee China's nuclear expansion. However, China still needs to take measures to address concerns on nuclear safety and the control of quality issues, including improvement of safety standards, implementation of regulations, inspection, and strengthening nuclear safety culture. While the National Nuclear Safety Administration (NNSA) is an independent regulator, its authority is weakened by a lack of human and financial resources. It does not possess the adequate legal authority, technical and managerial competence, financing, and human resources to carry out its responsibilities effectively, efficiently, and independently.

However, China is taking measures to deal with these challenges. As a result, it is highly likely that China will continue its ambitions expansion plans in the coming decades.

Hinze: Do you expect Chinese companies to utilize non-Chinese firms in order to accomplish the enormous domestic nuclear development they are planning?

Zhang: China's government requires that all new projects after 2016 must meet the safety standards of the world's most advanced nuclear reactors, known as third generation or Generation III reactors. It can be expected that advanced PWRs will be the mainstream technology at least for the coming decade. AP1000, Hualong-1, and CAP1400 will be the three top choices for new units built under the 13th Five-Year Plan.

From the beginning, the government has made a policy decision for its domestic nuclear expansion based on a strategy of "one primary, one auxiliary", i.e. relying mainly on the AP1000 reactor while making the Hualong-1 design a subsidiary design choice. Hualong-1 is China's flagship domestic reactor design, which is targeted mainly for the overseas market. However, such a strategy could be changed. Given that the government is also actively pursuing a policy of exporting nuclear technology including power reactors, deployment of more Hualong-1 and CAP1400 units at home could be increased in the coming decade because such a trend would help improve Chinese reactors' competitiveness in the international market. China's reactor designs that will become the mainstream in the future will depend on their technology development in the coming decade.

To reach the goal of 58 GWe in operation and 30 GWe under construction by 2020, and 120-150 GWe in operation by 2030, China needs to build about 5-6 reactors each year from 2016 to 2025. While China started construction of three Hualong-1 reactors in 2015 (and another one is expected to commence construction soon) and is expected to construct two CAP 1400 reactors in 2016, those indigenous reactors will be operational around 2020. Meanwhile, the first AP1000s will be operational in 2016 and 2017. Thus, it can be expected that the AP1000 reactor design will still account for a major portion (at least a half) of those new built reactors (a total of around 60 reactors between 2016 and 2025) in the coming decade.

Unlike the first four AP1000 reactors under construction at Sanmen and Haiyang, which are under turnkey contracts with Westinghouse, China will build the future AP1000 reactors by mainly using its local companies. The government has promoted localization of plant materials and equipment. The localization rate for all future AP1000s and CAP1400s is expected to be around 80%.

However, China will still need to purchase some critical components from foreign firms, including reactor coolant pumps, squib valves (a key safety technology), and instrumentation systems for future AP1000 construction, a significant market share for those foreign firms.

Moreover, given that these reactor technologies are being developed mainly based on a localization process of imported technologies, China still has a certain gap with truly mastering intellectual property rights in some areas including critical design and quality assurance programs. China also has weaknesses in term of soft power including technical standardization and system management. Thus, it can be expected that Chinese companies still need to continue strong cooperation with foreign companies in order to accomplish the country's planned enormous domestic nuclear development.

Hinze: How is China positioning itself on the international nuclear export market? Why is China interested in nuclear exports at a time when it is building so many new reactors at home?

Zhang: Recently, China's government began to actively pursue a "go global" policy, including exporting nuclear reactors as well as heavy components in the supply chain. China desires its own-designed advanced reactors, such as Hualong-1, CAP1400, and the high-temperature gas-cooled reactor design (HTR), to conquer the international markets.

China made significant progress to enter the international nuclear markets in 2015 as it started construction on three Hualong-1 reactors at home and one in Pakistan. China General Nuclear Power Group (CGN) and France's EDF agreed to join up for the Hinkley Point C nuclear project in the United Kingdom. China signed agreements to build Hualong-1 reactors for projects in the UK at Bradwell B as well as in Argentina. In January 2016, an official at China National Nuclear Corporation (CNNC) stated that the company was negotiating exports for the Hualong-1 design with 20 different countries. China also has actively negotiated or talked about other nuclear power export projects. Moreover, in December 2015, CNNC and CGN formed a 50-50 joint venture company – Hualong International Nuclear Power Technology Co. – aimed at bolstering the performance of Chinese-designed reactors and increasing China's chances of winning overseas reactor orders.

However, Chinese companies are still relative newcomers in the market compared to other experienced foreign companies. It will likely take at least five years before China can really enter the market by selling its whole nuclear power technologies and supply chains. It should be noted that the Pakistan nuclear projects do not truly reflect China's "going out" strategy as they are much more like a government aid project. Also, there are some uncertainties about those Hualong-1 projects already agreed to. The Hualong-1 project in the UK at Bradwell B is conditioned on the reactor design's approval by the UK's Generic Design Assessment (GDA) process that has

much stricter requirements than in China and can take as long as five years.

Currently Chinese companies participate in many foreign nuclear projects mainly using their financing investment and reactor construction expertise (instead of exports of the whole nuclear power technology and key equipment). Moreover, CNNC and CGN are opening up the global market by mainly using money – huge finance investment bundling with nuclear technology export. While such a strategy can win some markets and have some positive results for China's nuclear export in the near term, eventually the key is for China to win a larger global market in the long term, which will be centered on reliable reactor construction and operations based on Chinese technology. Therefore, China will have lots of homework to do to compete with others.

However, China's government has highlighted the nuclear "going global" program as an important strategy to promote its new economic growth model. Chinese leaders hope the country can become a global supplier of high-tech goods and services (instead of low-tech products as in the past decades). Along with high-speed railways, the government views advanced nuclear technology as one of China's new high-tech export brands. Chinese leaders are looking to sell their nuclear power technology worldwide by using China's economic and diplomatic influence. Thus, it can be expected that China's nuclear going global process will speed up in the coming years.

There are several major drivers for China's nuclear exports. After its nuclear power development over the last three decades, China has mastered basically advanced reactor design, manufacturing of key equipment, plant construction and operation, and maintenance. China has become a big nuclear power country (in term of the number of reactors of operation and under construction), but now it wants to become a powerful country of nuclear technology (in terms of quality). Most importantly, China expects a large global nuclear market in the near future and is eager to gain a share of the expected huge economic benefits. China also hopes its nuclear export efforts can be facilitated through its "One Belt, One Road" initiative proposed by President Xi Jinping in 2013 that aims to promote China's economic development through global economic integration and trade. Chinese officials and experts expect there will be over 40 nations along the "One belt, One road" area to develop nuclear power, and, if China can take a share of 20% of the expected global nuclear market, China could export about 30 reactors. This clearly presents tremendous business opportunities.

Hinze: What do you think are China's unique strengths and potential weaknesses as it relates to nuclear exports?

Zhang: There are a number of unique strengths for China's nuclear exports. With 30 nuclear plants in operation and 24 under construction at home, China has gathered lots of expertise on how to build and operate a nuclear plant. China also has the massive domestic market in the future that will further improve its knowledge and capabilities. Moreover, the government strongly supports policies on China's domestic nuclear expansion and nuclear exports.

China has developed its indigenous advanced reactor designs (e.g., Hualong-1 and CAP1400). Four Hualong-1 reactors started construction in 2015 and a few more are likely to be constructed soon. Chinese firms already have the necessary capacity for manufacturing key equipment and the local content for over 80% of any domestic reactor design. Their combined manufacturing capacity should meet the needs of 6-8 new units per year.

China maintains a policy of "self-sufficiency" in the supply of enriched uranium products. Recently China has significantly increased its capacities in conversion, enrichment, and fabrication services to meet not only its domestic requirements but also to support its nuclear "going global" strategy.

It is expected that China's building cost per reactor is generally cheaper than what nuclear companies in Japan, the U.S., and Europe typically charge. Further, China's government supports the overseas projects with generous concessional loans.

Finally, Chinese firms have established a strong relationship with many foreign firms, including AREVA and Westinghouse.

The final goal of China's nuclear exports is to build overseas nuclear power plants with self-sufficient reactor technology, key equipment manufacturing, and human resources. However, China still faces some potential weaknesses to achieve this goal. For instance, China just started construction of its Hualong-1 reactors in 2015 and plans to operate these first units around 2020. There is no construction and operation experience for these advanced reactors. It will take time to show foreign customers the reliability of its new reactor technology. China still needs to improve some aspects of the designs for reactors and key equipment, while standardizing production.

Moreover, given China's emphasis on localization of key equipment, the control of quality will be a major concern. There are also some other safety issues, including safety standards, implementation of regulations, inspection, and strengthening nuclear safety culture.

More important, China does not have a powerful and dedicated state organization or company to unify management and guidance for Chinese companies' engagement in nuclear exports. Currently, China's three major nuclear companies (CNNC, CGN, and SPI) are competing with each other for nuclear projects at home and abroad, which disperses their limited resources and weakens their competition capacity in the global market. China needs to establish a unified organization, responsible for coordinating cooperation among Chinese companies, to avoid friction over nuclear projects overseas. While the newly established Hualong International aims to

increase the export chances of the Hualong-1 design, it is not sure if it can reduce the friction between CNNC and CGN.

Hinze: As for nuclear export projects, do you believe Chinese companies will partner with non-Chinese suppliers as they seek to be part of nuclear development in other countries (e.g., in South Africa, UK, Argentina, Romania, Saudi Arabia, etc.)?

Zhang: Currently China's nuclear exports are still at an early stage that joins the nuclear power projects overseas mainly using financing investment (such as the UK Hinkley Point nuclear project). However, it is a good start for Chinese firms to gain overseas experience and seize some early market shares. At present, China's reactor technology, without being well-recognized by the world, is still difficult to enter into a core competition. At a final stage, China seeks a real "going global" strategy, which is to export its whole nuclear industry supply chain including its own reactor designs, equipment manufacturing, construction and installation, commissioning, operation and management, and fuel supply.

It will likely take many more years for China to realize a real "nuclear export." But, it can be expected that China will explore various forms of international cooperation with non-Chinese firms in a number of areas in the near future, including reactor design, equipment and materials production, technical standards, design verification tools, plant construction, operation and maintenance experience, and personnel training.

Hinze: Finally, what can we expect from the Chinese nuclear industry this year?

Zhang: In 2016, China will maintain its nuclear expansion at a steady growth rate. China will add a capacity about 8 GWe in operation this year. The fourth Hualong-1 reactor for domestic nuclear project will start construction at Fangchenggang 4.

Also, two Hualong-1 reactors at CGN's Ningde site were just approved, with construction now expected to start in 2016 and 2017, respectively. Two CAP1400 reactors at Shidaowan are also to be approved in 2016 and start construction within the year, which will promote this new reactor design. Also, China likely will approve two or more AP1000 reactors in 2016. These efforts will be consistent with China's plans for its total nuclear capacity to be 58 GWe by 2020 plus 30 GWe under construction.

While the frozen inland nuclear power projects are expected to be resumed during the new Five-Year Plan (2016-2020), those inland projects will likely continue waiting for a comprehensive study in 2016.

Meanwhile, the newly established Hualong International will speed up its integration of those two versions of Hualong-1 designs by CNNC and CGN and prepare for future exports.