State of the World Nuclear Power Industry: Present Developments and Significance of Increased U.S.-Korea Cooperation

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By Donald Harker

Although nuclear power plant construction continues at an active pace worldwide, Westinghouse's recent declaration of bankruptcy is perhaps the latest indicator of the health of the U.S. nuclear industry and its considerable challenges. While China and Russia maintain vigorous new build programs both domestically and internationally, current reactor construction projects in the U.S. have suddenly been put in doubt, as the existing fleet faces growing economic pressures from low wholesale electricity prices. In such an environment, the U.S. may need to expand collaboration with its traditional civil nuclear partners, such as South Korea, to preserve its presence in the global market and reinforce strong international norms and standards in nuclear energy.

A Global Perspective on Westinghouse and U.S. Nuclear Power

All the ramifications of the Westinghouse bankruptcy have yet to be fully understood, but it is clear that a major shift in the center of gravity of the commercial nuclear power industry away from the United States is occurring. Despite Westinghouse managers' desires to complete the AP1000 projects at VC Summer and Vogtle, its Debtor in Possession financers have clearly indicated that Westinghouse will limit its losses. The DIP loan documents state: "Limitations on AP 1000 Projects shut-down costs limited to $125 million." The loan financiers also clearly state that none of Westinghouse's assets at the VC Summer or Vogtle sites are considered collateral for the $800 million loan. If the contracts are not cancelled by the bankruptcy court, the loan covenant could trigger repayment.

Contract cancellation would mark the end of large Westinghouse designed nuclear plant construction and the AP1000 design. GE-Hitachi's Advanced Boiling Water Reactor (ABWR) and Economic Simplified Boiling-Water Reactor (ESBWR) are the only non-Westinghouse designs currently certified by the US Nuclear Regulatory Commission. South Korea's Advanced Power Reactor 1400 (APR1400) and NuScale's SMR are the only reactor designs undergoing active review by the NRC. The APR 1400 design certification is expected in 2018.

Globally, Westinghouse is very profitable in its Nuclear Fuel and Component Manufacturing business line and its Operating Plant Business line. Both business lines bring in annual revenues of approximately $ 1.1 billion each, per Westinghouse's bankruptcy filing, and appear to have a combined gross margin of more than $1 billion. Recent media reports have indicated that Toshiba has decided to split off its four in-house companies into four wholly-owned subsidiaries. The restructured and remaining nuclear portion of the company, sans nuclear construction, will be merged with non-nuclear power generation, transmission, and related businesses to form a new company on 1 October 2017. It is important that this new company meets financial standards to maintain special construction licenses for large non-nuclear power projects. Time will tell whether this new company remains part of Toshiba or is sold to another entity.

Consequences of construction default in terms of brand damage and prospects for future business with Southern Company, South Carolina Electric & Gas Company, and their associated AP1000 project partners is unknown. Southern Company is the third largest electric utility holding company, in terms of assets, in the United States.[i]

The specter of four unfinished AP1000 reactors comes at a precarious time for the US nuclear industry. The shale gas revolution has lowered wholesale electric power prices to the point that individual states are attempting to subsidize their nuclear power plants. The legality of these subsidies is uncertain. If they are found illegal, it is anticipated 11 reactors will immediately announce closure dates due to financial distress. This is in addition to 7 reactors that have already announced plans to cease operations in the near term or at license expiration. An additional 25 reactors have licenses expiring by the end of 2035. A total 43% of US nuclear reactors will shut down by the end of 2035. In that year, the United States will drop to third in world rankings with 56 operating plants, slightly behind France and China.

Moreover, in the 60 years since the United States' first commercial nuclear reactor, Shippingport, went critical, the nation has yet to solve its spent nuclear fuel issue. It has defaulted into an expensive, local, store in place policy funded by the federal government. The US has been blessed with the financial resources and unlimited real estate to continue this policy indefinitely. The rest of the world is not as fortunate and US policy is incongruent with other nations' land assets and/or financial capabilities.

Nuclear construction is much more robust and healthier outside of the United States. There are 52 reactors under construction around the globe assuming termination of the VC Summer and Vogtle projects. Figure 1 shows a breakdown of current construction by reactor designer. There are several variants of Russian and Chinese reactors included in the figure.

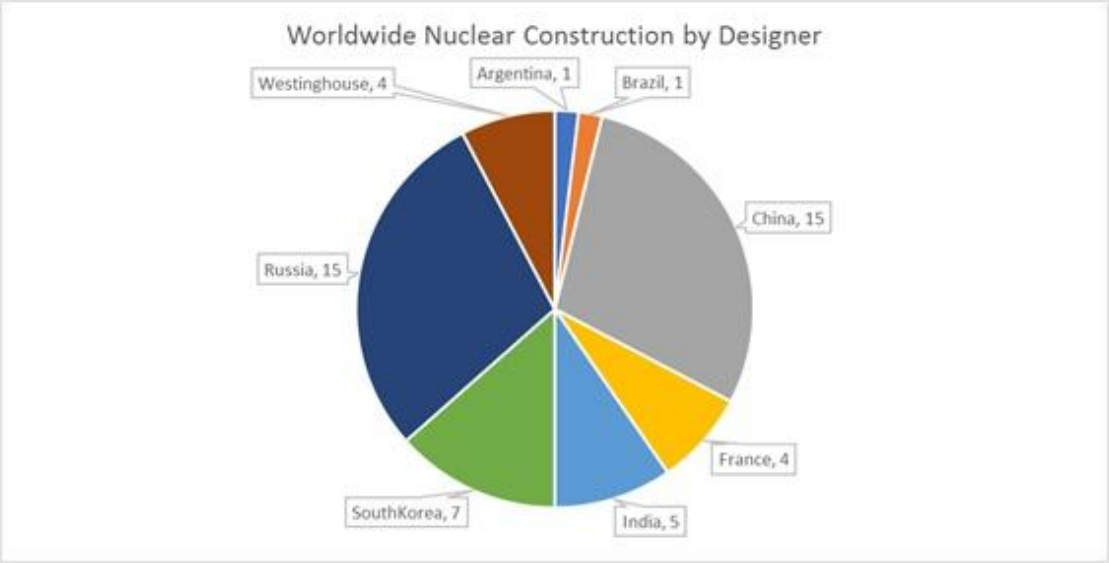

Figure 1 Nuclear Construction by Designer (IAEA PRIS)

Most of these designs incorporate pressurized water reactor technology that was first developed by Westinghouse, but has been improved upon by partners of technology transfer agreements. For example, France, China, and South Korea initially imported Westinghouse reactors but have since developed their own designs for export.

Chinese and Russian Nuclear Build and Export Activities

China has been most aggressive in building foreign designs and quickly incorporating domestic alterations to improve upon the design and make it their own. Of the 20 reactors, currently under construction in China, 4 are Westinghouse AP1000 designs, 2 are French EPR1750 designs, and 2 are Russian VVER-428M designs. In September 2016, China signed an agreement to form a joint venture with Canada to develop, market, and build the Advanced Fuel CANDU Reactor (AFCR), to utilize spent fuel from other reactors as a fuel source.

The AP1000 projects are the template China uses to develop self-reliance, increase domestic capability, modify designs, and develop products for export. The initial AP1000, Sanmen 1, relied on the United States and Republic of Korea to supply major components to the project. The fourth AP1000, Haiyang 2, relied on the US for the supply of only two major components.

Equipment/Component	SM1#	HY1#	SM2#	HY2#
RCP	US	US	US	US SHE、HEC
Squib Valve	US	US	US	US SUFA
RPV	Korea	Korea	CHFI	SEC
SG	Korea	Korea	HEC/ENSA	SEC
RVI	Korea	US	SEC	SEC
CRDM	US	US	SEC	SEC
IHP	US	US	SDNPC	SDNPC
Polar Crane	US	TYHI	DHI	TYHI
Refueling Machine	US	DHI	SEC	DHI
CV	US/SNPTC	SNPTC	SNPTC	SNPTC
RCL Pipe	CSIS	CNE	CNE	CSIS
PRZ	SEC	DEC	SEC	DEC
ACC	SEC	SEC	SEC	SEC
CMT	SEC	HEC	SEC	HEC
RPV / SG / PZR support	CNE / DEC / DEC	CNE / DEC / DEC	CNE / DEC / DEC	CNE / DEC / DEC

Figure 2 Chinese AP1000 Project Sourcing (SNPTC 2013)

The CAP1400 is a larger version of the AP1000 designed by the Chinese and they own the intellectual property to these larger reactors. China is building demonstration plants for all its advanced reactors, including the CPR1000 and CAP1400. The purpose of these demonstration projects is to show China's capacity to successfully design, build, and operate modern nuclear reactors with an eye on exporting its technology. China has already sold its CPR1000 (Hualong-1) design to Argentina and Pakistan.

Russia, through Rosatom, has the largest commercial nuclear power enterprise on the planet. It envisions nuclear power providing 45-50% of Russia's electricity by mid-century, rising to 70-80% by 2100. Its backlog of foreign orders totaled $133 billion dollars (US) at the end of 2016. Currently, it has successfully sold or is currently building nuclear power plants in China, Egypt, Slovakia, Bangladesh, Belarus, Finland, Hungary, Nigeria, Iran, India, and Turkey.

According to the World Nuclear Association, Rosatom's current long-term strategy involves moving to inherently safe nuclear plants using fast reactors with a closed fuel cycle. The goal of the closed fuel cycle is to eliminate the production of long-lived transuranic radioactive waste from power generation. Early this year, the CEO of Rosatom said this about fast reactor technologies: "today we are leading in this field. It's necessary to make this leadership absolute and to deprive our competitors of their hopes of overcoming the gap in the technological race."[ii]

South Korea and the Promise of Expanding the US-ROK Nuclear Energy Partnership

South Korea has followed the same path as China and France. It initially imported Westinghouse and Areva technology and then improved upon it to develop domestic designs. The APR1400 is an outgrowth of the Combustion Engineering (now Westinghouse) System 80+. South Korea imports most of its energy and relies on nuclear power to reduce this import dependency. South Korea has become a major nuclear technology exporter. It is currently building 4 of 14 planned[iii] APR1400 reactors in the United Arab Emirates (UAE) under a $20

billion-dollar contract. The KEPCO led group expects to earn another $20 billion by operating the four reactors over their design life.

Nuclear power costs are low in Korea compared with other generation sources and its nuclear capacity factors have historically exceeded those of the United States. In a February 2016 *Energy Policy* article, "Historical construction costs of global nuclear power reactors," the authors identify South Korea as the only major nuclear country that has consistently reduced the cost of building new nuclear power plants over time. The authors identified an annual 2% decrease in cost for Korean built, foreign designed reactors from 1972-1993 and an annual 1% decrease in cost for domestically designed reactors from 1989-2008. This experience continues with the construction of the APR1400 reactors in the UAE.

Forbes magazine ranks KEPCO, the Korea Electric Power Corporation, as the largest electrical utility firm in the world. As a holding company, KEPCO encompasses electrical generation, transmission, distribution, nuclear fuel fabrication, and engineering services. KEPCO began international projects relatively recently (1993) and aspires to be one of the top engineering and energy firms in the world. Its highest profile foreign nuclear project is the construction of the four APR1400 units in the UAE, but in August 2016, Ukraine also signed an agreement with a KEPCO subsidiary to support the transmission of Ukrainian nuclear electrical generation to the European Union and supplant Russia in completing the Khmelnitski 3&4 nuclear power plants.

The US and the Republic of Korea have a long tradition of strong bilateral alliance and cooperative relationships. A recent example of this cooperation occurred among Belgium, France, South Korea, and the US to support the development of uranium-molybdenum based nuclear fuel for research reactors. Using technology originally developed by South Korea, the aim of this development was to minimize the required enrichment levels of research reactor fuel and support non-proliferation efforts.

As the United States' commercial nuclear industry wanes so will its global influence and the value of its 123 agreements. The US will need to team with a strong technology savvy partner to continue to shape the governance policies and procedures for commercial nuclear power as it expands worldwide. This is especially true in the light of proposed cuts to Department of Energy programs. Increasing cooperation with countries, such as South Korea, that use a build and operate model for exported nuclear power plants, design nuclear power plants to NRC standards, and support non-proliferation policies may be the best way for the United States to maintain relevance in a rapidly changing commercial nuclear world.

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[i] Forbes, 2016 Global 2000
[ii] "Nuclear Power in Russia," World Nuclear Association, Updated 22 March 2017, http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx.
[iii] "Nuclear Power in South Korea," World Nuclear Association, Updated February 2017, http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

Donald Harker is the Founder of DKMT Consulting. He has over 30 years of experience in nuclear submarines, commercial nuclear power plants, critical infrastructure, and business optimization. Prior to founding the firm, he supported the National Nuclear Security Administration in the development and execution of its strategy to consolidate Operations and Maintenance contracts. This led to a first of a kind $22 billion dollar consolidation of Pantex and Y-12 operations.

Global America Business Institute | 1001 Connecticut Avenue NW, Suite 435, Washington, DC 20036 | 202-499-7979 | FLL@theGABI.com | www.theGABI.com

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