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Reactor Race: South Korea's Nuclear Export Successes and Challenges

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Abstract

South Korea hopes to become a major exporter of nuclear plants. Its success in building up its domestic nuclear industry, winning a $20.4 billion contract to build four nuclear power plants in the United Arab Emirates (UAE), building Jordan's first research reactor, and providing training programs and best practices to nuclear newcomer states indicates that established vendors should take this determination seriously. If South Korea draws the right lessons from its experience with the UAE and builds upon its competitive advantages in the international nuclear energy market—low cost, high credibility, high performance, strong political backing, attractive financing, and U.S technology at a low cost—it could record similar success in the future.

Introduction

South Korea hopes to become a major exporter of nuclear plants. Fresh off winning a highly competitive $20.4 billion contract to build four nuclear power plants in the United Arab Emirates (UAE), building Jordan's first research reactor, and providing training programs as well as sharing best practices with nuclear newcomer states, the ROK in 2010 announced that it would seek to export 80 nuclear reactors by 2030.[1] Subsequently, the 2011 Fukushima nuclear accident in Japan, the global financial crisis, and the limitations of South Korea's nuclear industry have forced the ROK to scale back these ambitious objectives. Nonetheless, South Korea remains intent on securing additional global reactor contracts in countries such as India, Vietnam, Poland, Saudi Arabia, and South Africa, as well as bigger markets such as China and the United States. If South Korea draws the right lessons from its experience with the UAE and builds upon its competitive advantages in the international nuclear energy market, it could record similar success in the future.

Nuclear Deals

The UAE selected in 2009 a consortium led by Korea Electric Power Corporation (KEPCO), a South Korean government-owned electric utility, for a contract to design and construct four APR-1400s in Barakah. The APR-1400 design is an advanced version of the Combustion Engineering (now Westinghouse) System 80+. Shin-Kori Units 3 and 4, currently under construction in Korea, will serve as the "reference NPPs" for Barakah 1 and 2.

Jordan has been collaborating with South Korea on building Jordan's first research reactor and training Jordanian personnel. In March 2010, Amman signed a $130 million agreement with South Korea to supply Jordan's first nuclear research reactor. The Korean Atomic Energy Research Institute (KAERI) and Daewoo would construct the reactor at the Jordan University of Science and Technology (JUST). The reactor is expected to be online and operational by 2015. Jordan will receive 3.5 years' worth of fuel supply from South Korea and is looking to either secure additional nuclear fuel from various international vendors or use fuel from Jordanian uranium enriched abroad.[2] South Korea has agreed to finance most of the project, providing a $70 million soft loan, which includes a feasibility study on environmental

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impact. The ROK also plans to establish a nuclear training and technology center at JUST where Jordanian nuclear engineers and technicians would be trained by South Korean experts.[3]

South Korea is also considered a leader in nuclear energy training and human development. KEPCO International Nuclear Graduate School (KINGS), established in 2012 by KEPCO in cooperation with George Mason University, plans to enroll foreigners as half of its student body, stating, "Raising talents from potential export countries such as Turkey, Jordan, Vietnam and Indonesia will produce valuable networks we need in the future."[4] The 62 students accepted in 2013 came from fifteen countries.[5] Additionally, South Korean companies and agencies such as KAERI, KINS, Korea Nuclear International Cooperation Foundation (KONICOF), and Korea International Cooperation Agency provide training for nuclear newcomers.

Of the two deals South Korea secured so far, the UAE deal is far more significant in terms of its financial impact, as a symbol of South Korea's emergence as a global nuclear player, and the precedent it sets for other potential nuclear deals. As such, it is worth examining the factors that led to the UAE contract.

Why the ROK Won the UAE Deal and Lessons for the Future

The ROK's successful bid for the UAE contract can be ascribed to political, technical, business, financial, and cultural factors.

Political Factors

The nuclear deal was not the first large contract the ROK won in the UAE. The countries have been cooperating in strategic sectors, including oil production, finance, and health care. The close ties Korea has cultivated with the UAE in trade and infrastructure projects were of great importance in winning the bid. The UAE is the second-largest oil and natural gas exporter to Korea, and the Emirates have become South Korea's largest export market in the Middle East.[6]

Moreover, the Korean government was adept at using various policy channels to support the Korean consortium, including leadership at the highest levels, including then-Korean President Lee Myung-bak. That Lee was the former CEO of Hyundai Engineering and Construction, a central actor in the Korean consortium, added credibility to the diplomatic exchanges and the Korean bid.

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also not uncommon to add diplomatic "carrots" to a nuclear bid to make it more attractive. In the South Korea case, in addition to the nuclear deal, the countries also agreed to cooperate on renewable energy, education, shipbuilding, information communications technology and human resource development, as well as the strategic storage of six million barrels of Abu Dhabi oil in Korea. As part of the military cooperation, the ROK military committed to provide two years of special forces training to its UAE counterparts. The two countries will also hold joint military exercises and exchange defense industry technology and high-ranking military officials.[7]

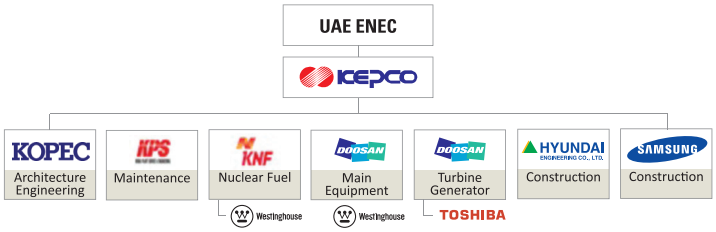
South Korea's close relationship with the United States and Westinghouse's participation in the Korean consortium also played a key role. The UAE appreciated the fact that the South Korean nuclear design is of U.S. origin and Westinghouse would be involved in the project, making it difficult for the United States, its primary security benefactor, to object to the deal.[8]

Technical Factors

With 23 nuclear reactors in operation, KEPCO is renowned for having the highest "capacity factor"—the proportion of time that the reactor is generating electricity—and the lowest "unplanned shutdown" rate in the world, at only 0.3-0.5 times per month compared to 3.2 times per month in France (based on South Korean reports).[9]

South Korea also appealed to the UAE's desire to initiate and complete the project quickly, which not only shortens the time until electricity would be available but also reduces construction and financing costs—the primary cost-drivers in nuclear energy production.[10] Korean companies have proved themselves able to build nuclear power reactors in a relatively short time and follow a predictable schedule. South Korean engineers have

Figure 1: KEPCO Consortium[14]



developed methods to speed up construction through the use of special quick-drying, high-quality concrete and management techniques that allow tasks to be performed simultaneously.[11]

The overseas capacity of Korea's nuclear industry will undoubtedly be judged based on its performance in the UAE, its first project outside of South Korea. While the APR-1400 is a new reactor that has not yet been completed in Korea and will have to be modified in order to comply with the regulatory and geographic specificities of the UAE, so far construction is on schedule, or even ahead of schedule, and Korea seems confident it will complete the project before the deadline.[12]

Business Model

KEPCO and its core group of subcontractors (see Figure 1) have worked together for years on the domestic Korean nuclear power program using a model similar to the one that the UAE is planning to implement. These factors compared favorably with the lack of coordination between Areva and EDF, EDF's late inclusion into the bid, the high cost of EPR technology, and the fact that Areva planned to outsource some aspects of the reactor construction.[13]

In addition, while in the initial French bid construction and operation risks were divided between Areva, TOTAL and GDF-SUEZ, in the Korean consortium all these risks are borne by KEPCO. This risk allocation puts responsibility on one organization, it reduces the litigation risks in case of delays or performance problems and increases the incentives for the contractor to meet the project delivery objectives.

As a nuclear newcomer, the UAE was looking for a supplier that would be willing and able to support local personnel development with extensive training, human resources development and education.[15] According to the UAE, one of the main criteria in awarding the contract to South Korea was the ROK's "commitment and detailed planning for human resource development in the UAE in support of the development of a sustainable, domestically-sourced nuclear energy workforce that is dominated by competent national talent."[16] The ROK has also been assisting the UAE with upgrading its quality assurance standards and capabilities as well as training Emiratis both in the UAE and in South Korea.

Financial Factors

As part of the Korean deal, the Korean government attached a letter of intent to the agreement to finance the project. The financing package includes investments, direct loans and external debt guarantees for the special purpose vehicle as well as preferred loans for domestic suppliers.[17] The 23-year deal carries very low interest rates of 1.75 percent to 2.6 percent, with full government guarantees on the various project risks.[18] KEPCO's profit is intended to come out of the payment for the construction of the nuclear plant, a 60-year contract for equipment replacements and potential equity interest. Additional follow-on contracts for long-term operation and maintenance of the Barakah plant, worth as much as another $20 billion over 60 years, are being discussed with KEPCO and other vendors. Moreover, while the UAE has not declared publicly that it will standardize its nuclear reactor design and choose ROK as the supplier of future reactors, a senior UAE official indicated that this would be the case.[19]

The ROK has relatively low execution costs, a distinct competitive advantage. The APR-1400s built in South Korea are the most inexpensive nuclear reactors in the world (the overnight cost[20] is about 60 percent lower than that of the EPR in France and that of the AP1000 in China).[21] It is estimated that even after taking into account the 10 percent cost of capital and the various adaptations of the reactor design to fit the UAE unique circumstances, the cost of the UAE APR-1400 came in only about 30 to 40 percent above the declared cost of the APR-1400 under construction in Korea—still a very attractive price.[22]

It is not surprising, therefore, that the price tag of the South Korean bid was significantly lower than that of the other bids. While it is unknown what the final bid was for each of the proposals, it was reported that the South Korean price was unmatched.[23] The Korean low price was in fact criticized within South Korea, with the opposition party claiming it was

commercially unviable and that future buyers would expect similar terms.[24]

Cultural Factors

At least from the South Korean side, there is a feeling that the two countries have similar historical backgrounds: both have experienced a colonial period, both are newly developed countries with "similar value systems," and both have a concern for the preservation of traditional "ethics and manners."[25] The UAE leadership appreciated the fact that KEPCO formed a "war room" in the second basement of its Seoul headquarters in which 75-80 executives from the consortium coordinated the proposal and sales push for more than seven months.[26]

Future Export Possibilities

How well will these advantages translate into other ROK nuclear exports? Recently South Korean nuclear insiders have acknowledged that the worldwide decline in nuclear reactor demand after the Fukushima disaster and the global financial crisis, as well as shortages of qualified personnel, mean a more realistic expectation for South Korea to export ten nuclear plants (which can contain several reactors) by 2030.

South Korea's nuclear reactor exports will be shaped by the broad pull of global nuclear demand, the demand of individual potential customers, and how well South Korea stacks up against competitors in meeting those demands. According to the IAEA, 68 reactors are currently under construction in thirteen countries.[27] Of the seventeen reactors commissioned over the past five years, twelve are located in Asia.[28]

Most nuclear plant customers choose to buy their plants based on their political relationship with the supplier and the economic criteria of reactor price (including financing), scheduling, and quality. In the future, the key question for South Korea is whether it will be able to meet these criteria for future customers in the same way it did for the UAE in the 2009 deal. For the economic criteria, two particular areas of importance will be financing and the availability of key resources needed to meet cost, scheduling, and quality goals. On the political side, Seoul's ability to maintain and improve relations with the United States and with certain regional players is likely to prove essential.

Reactor Price, Financing, and ROK Profit Margin. South Korean nuclear insiders have said that the ROK does not expect to offer as generous prices, and especially financing, to future customers as it did to the UAE, with one terming the UAE deal "the golden case that will not happen again." Yet, other customers are likely to seek to pay similar prices as the UAE deal, potentially placing the ROK in a difficult position given the limits of its financial resources. A build-own-operate ("BOO") model would be even riskier for Korea than the UAE financial conditions, and this kind of business scheme has no proven record of success in the nuclear sector. So far, only Russia has made such an attempt, building four nuclear reactors in Turkey, but the arrangement was pushed by the Russian government as part of a broader energy cooperation agreement. Rosatom, as the implementer of the project, is a reluctant participant, doubting the project could prove profitable.

Resource Availability: Personnel. Another concern that could prove an obstacle in future ROK export deals is a shortage of sufficient Korean personnel given the number of domestic reactors under construction and the need to staff the UAE plant. It is estimated that KHNP alone will involve 415 to 1,798 people in the UAE nuclear project between 2012 and 2020.[29] According to Park Goon-cherl, president of KINGS, "Korea is running far short of high-skilled manpower for industrial use of nuclear energy."[30] For future bids, the ROK would need to enhance its personnel and likely need to partner with personnel from other countries including Japan and the United States.

A crucial question will be the degree to which South Korean exports will have to compete for personnel, financial, and manufacturing resources with the construction of domestic plants. Previously, South Korea planned to increase the nuclear share of electricity generation to 59 percent by 2030. For this purpose, five nuclear units are currently under construction and four more units are planned to be completed between 2018 and 2021.[31] According to industry experts, the new government of President Park Geun-hye is unlikely to seek to initiate the construction of additional nuclear power plants as the presidential transition team prioritized ensuring nuclear power plant safety. If the new administration decides to hold off on initiating further construction of domestic nuclear plants this could free resources for exports.

Safety. Following the 2011 Fukushima nuclear accident, South Korea hosted safety reviews by both domestic authorities and the IAEA at all of its operating reactors. As a result, the

government has pledged an investment of $1 billion over the next five years to further bolster nuclear safety.[32] Nonetheless, South Korea's nuclear energy program has recently come under scrutiny after several safety scandals, such as the discovery of microscopic cracks in tunnels that guide control fuel rods and forgery by eight companies of 60 quality and safety certificates for 7,000 parts of "non-core" components used in two reactors between 2003 and 2012.[33] During 2012 the country's nuclear reactors experienced temporary unplanned shutdowns more than fifteen times and in December 2012, due to maintenance, other glitches and the fraud investigation, seven of South Korea's 23 nuclear reactors were closed, and the heads of KEPCO and KHNP resigned.[34] While Emirati officials assessed that the UAE's nuclear plants are "unlikely to be affected by the safety issues dogging Korean reactors," safety, ethic, and organizational culture problems will certainly have to be seriously addressed by the South Koreans to reassure potential future clients.[35]

Political Factor—the US link. As noted above, the ROK's links to the United States, both politically and commercially were important to winning the UAE deal. The connection to Westinghouse provided a testament to the quality of ROK reactors for the UAE which took a risk in becoming the first buyer of the ROK's nuclear power plant exports. Politically, the U.S. connection allowed the UAE to avoid offending its primary security benefactor and provide a U.S. company with a piece of the economic pie.[36] This indicates that the ROK may have a better shot at winning deals in those countries that enjoy similar strategic relationships with the United States such as Saudi Arabia. This is particularly important for the ROK because its major competitors have a more global reach and can offer greater security or other "carrots" while South Korea is considered a "middle power" in global terms.

At the same time, however, it leaves South Korea vulnerable to any disruption in the U.S.-ROK nuclear relationship. In April, South Korea skirted but didn't eliminate this threat when it agreed to a two-year extension of the current bilateral civil nuclear agreement which had been set to expire in March 2014.[37] Assuming that the agreement is approved by the two countries legislatures, it means the countries will have two more years to try again to reach agreement on a new nuclear cooperation agreement.

The decision to extend the agreement is very important to South Korea's ability to cut export deals over the next three years. In addition, a failure to reach an agreement could have had major implications for both the South Korean and U.S. nuclear industries: South Korea is dependent on U.S. nuclear material and technology while many U.S. reactors are built with Korean components. An inability to reach an agreement could also have been perceived as a major blow to the alliance.

The key stumbling block in the talks has been South Korea's desire that the U.S grant advanced consent to enrich and reprocess (pyroprocess)[38] "U.S. origin" nuclear fuel. U.S. law since the late 1970s has sought to discourage nuclear Nonproliferation Treaty (NPT) non-nuclear-weapon states like South Korea from engaging in such "alteration in form or content," which can produce fissile material (enriched uranium or plutonium) that can be used either in nuclear weapons or civil nuclear fuel.

Leaving aside the domestic justifications ROK mentioned for reprocessing and enrichment,[39] one factor some South Korean technical specialists offer for the program is their belief that if the country adopted pyroprocessing for handling its own nuclear fuel it could then supply the reprocessing service to other countries, bolstering its reactor exports or at least enabling KEPCO to avoid the deep discounting that it was forced to offer in the UAE. Such a service, however, is unlikely to be viewed by ROK politicians as politically viable. It is Seoul's difficulties in finding appropriate locations to store or dispose of its own spent fuel which have generated some of the ROK's interest in pyroprocessing. This political opposition is likely to be even higher in highly nationalist South Korea when it comes to accepting foreign spent fuel for reprocessing. And the service is only likely to prove attractive to other countries, however, if South Korea was willing to accept the high-level waste that would remain after pyroprocessing—a political non-starter in the ROK.[40]

Some ROK officials are also interested in enrichment as a nuclear export component to reap both direct profits from selling enrichment services and perceived additional profits from being able to offer more of a "full-service" package when it sells nuclear reactors.[41] Notwithstanding whatever domestic benefits Korea would reap from such an enrichment capability,

South Korean investments in a domestic nuclear enrichment capability make little commercial sense. South Korea would likely find it difficult to compete with established enrichment suppliers who can add additional centrifuges at a much lower cost than building whole new facilities with indigenous ROK technology (Japan has struggled for years to build a domestic enrichment capacity). Nor have the existing suppliers expressed a willingness to transfer technologies to the ROK, even if they could maintain control. In addition, outside of some former Soviet clients who initially had little choice but to buy all front-end services bundled together —uranium mining, conversion, enrichment, and fuel fabrication— utilities prefer to strike separate deals for each service in order to obtain the best price. Not to mention the global enrichment market is a much smaller market in any case than the nuclear reactor market.[42]

While the extension decision does not solve the fundamental disagreements between the two countries on pyroprocessing and enrichment, it does buy time. Negotiations are reported to resume as early as June. Yet, even under a successful negotiation of a new agreement, South Korea is still likely to chafe at some elements of U.S involvement. In particular, the U.S. government is still likely to have a stronger say over ROK nuclear power plant exports than some ROK proponents of "nuclear sovereignty" may like.

KEPCO formed a consortium with Westinghouse and its Japanese partner Toshiba Power Systems because there are technologies that South Korea has not mastered and some technologies that are patented by those companies. The inclusion of U.S. components and technology in the plants and the fact that commercial-scale light-water reactors (i.e., APR-1400) Korea plans to exports are based on a Westinghouse design means that U.S. approval is required for such re-export under sections 123 and 131 of the Atomic Energy Act.[43] In addition, Westinghouse would likely need to seek Part 810 Authorization (named after the relevant section of the U.S. code) from the U.S. Department of Energy and other U.S. agencies before it and its employees can conduct nuclear-related business abroad.

The re-export of major U.S.-origin nuclear reactor components may also require the ratification of a nuclear cooperation agreement between the U.S. and the importing country. Such a requirement may prove a challenge, at least with regard to new nuclear aspirants, until the U.S. decides whether to include obligations to forgo enrichment and reprocessing in future nuclear cooperation agreements. It would also prove problematic for ROK future nuclear export if the U.S.-ROK cooperation agreement was to expire. Any uncertainty and potential delay as a result of an expired nuclear cooperation agreement would undoubtedly be a major source of concern to future Korean customers.

Conclusions

Analyzing the reasons that the UAE has chosen South Korea as a supplier for the first four nuclear units highlights several advantages the ROK enjoys. First, South Korea has developed a distinct competitive advantage in terms of low cost, high credibility, and high performance. Second, South Korea sacrificed some of its potential profit margin to pass on its low costs to the customer and make the deal happen. In addition, it has benefited from strong political support from its government and president, and the deal included attractive financing. Third, South Korea provided U.S technology at a low cost and closely cooperated with Westinghouse, preventing any rupture in the UAE's relations with its key security benefactor.

So far, South Korea has signed nuclear cooperation agreements with 27 states.[44] But based on South Korea's competitive advantages, it is fair to conclude that its most likely prospects, with the lowest risk factors, are in the Middle East—with lesser possibilities in Southeast Asia, South Africa, and even the United States (if it secures U.S. license approval for the APR-1400).

As the UAE experience shows, the Middle East looms as a particularly attractive market for South Korea. Like the UAE, several other countries in the region are faced with growing electricity demand and want to limit the potential economic and environmental costs of using fossil fuel for power generation, and are engaged in, or seriously considering, the development of civil nuclear power. In the Middle East, the main nuclear energy program after the UAE's will be Saudi Arabia, with plans to generate 17.6GW of power progressively by 2032. In December 2011, the Saudi government announced it would invest more than $100 billion in the construction of sixteen nuclear power plants.[45] Even if only some of these investments materialize, Riyadh is clearly looking at an ambitious program where financing will not be a decisive factor and is a country where U.S. ties could prove helpful.

In addition, the ROK has proven experience and prominence in running and operating mega projects in this region, especially in the energy sector. Korean construction companies have played a leading role in new infrastructure—including quality assurance, desalination and grid upgrades—in many Middle Eastern states. Indeed, in 2012 South Korean firms dominated six of the top ten EPC Middle Eastern oil, gas, and petrochemicals contracts, and Doosan is leading numerous thermal water desalination projects in the region.[46] The fact that South Korea understands and operates successfully in Middle Eastern cultures is a great asset and much appreciated by most governments in the region. This could work to South Korea's advantage in securing future nuclear deals.

The experience South Korea will gain from adapting its APR-1400 to the specific security and geographic characteristics of the UAE,[47] as well as providing training, quality assurance and grid upgrade support, will provide South Korea with another competitive advantage over potential competitors. This will further strengthen South Korea's existing advantages such as low cost, high credibility, high performance, strong political backing, and attractive financing.

When discussing future Middle Eastern contracts, especially with oil and gas suppliers, it is important to note that winning the UAE nuclear deal, even with a very small profit margin, proved profitable for South Korea in the long term when considering the multiple contracts other South Korean companies won as a direct or indirect result of the main agreement. Trade between the two countries grew 24 percent to $22 billion in 2011, with UAE exports to Korea rising by 21.2 percent in 2011 and Korean exports to the UAE growing by 32.4 percent.[48] Another benefit the ROK secured as a result of the nuclear deal is a more stable supply of oil and gas. For example, the two countries agreed to store six million barrels of oil from Abu Dhabi in Korea and to enable Korea to use it in emergency situations. South Korea was also able to significantly increase (from 5 to 15 percent) of the ratio of its oil and gas imports secured through development and production by Korean firms.[49] It is easy to envision similar benefits from other Middle Eastern gas and oil producers in the event that South Korea wins nuclear bids in these countries.

Recommendations

First, reaching agreement on a long-term nuclear cooperation agreement with the U.S. is crucial for future ROK nuclear exports. Seoul should use the two-year grace period granted by the extension to carefully weigh its strategic interests. Any uncertainty in the future and potential for delay related to the status of the 123 agreement would undoubtedly be a major source of concern for future costumers. On the other hand, focusing on particular technologies such as enrichment or pyroprocessing should be seen as less important than finding a "win-win" solution where the two countries can work together to address Seoul's core concerns: short-and medium-term storage for spent fuel, sufficient fuel supplies for South Korea's nuclear fleet, and enhancing South Korea's nuclear export potential. In particular, the ROK and U.S. should continue to build on recent initial discussions on how the U.S. can support future ROK nuclear exports.[50]

Second, instead of emphasizing enrichment and pyroprocessing as attractive options for future customers, South Korea should strengthen its competitive advantages. South Korea will be better off expanding into using nuclear energy for desalination, as well as offering training and maintaining qualified and experience engineers, managers, technicians and sales specialists. It could invest in the construction of additional centrifuge capacity at existing enrichment plants in return for guaranteed output.

Third, to minimize Korean reliance on the U.S., the ROK should consider promoting Small Modular Reactors and KAERI's "SMART" small nuclear reactor for export to small countries: smaller reactors that are cheaper, easier to manage and more adaptable to weak transmission networks and, therefore, better address the needs of many newer nuclear clients. For example, the SMART reactor design is not based on American technology, and it was certified by the Korea Institute for Nuclear Safety (KINS) in July 2012.[51] This reactor would allow countries with a limited electricity network to access nuclear energy and could be particularly attractive to some countries in the Middle East due to its advantages in thermal heating, desalination, and lack of U.S.-origin technology.

Fourth, Korea should concentrate on counties that can afford nuclear energy, especially those in the Middle East that can provide the ROK with greater energy security. So far, South Korea has been targeting emerging economies that have limited

financing capacity, and that have made supplier-provided project financing a key criterion; however, a more viable scheme for Korea would be to offer financing through export-import banks. In the long run, a market reform of domestic electricity tariffs in the ROK (that is ending substantial domestic subsidies to industry)[52] would be helpful to support KEPCO's financial capacity for overseas tenders and permit it to offer to take equity shares in future nuclear export tenders and thus reinforce the financial position of the Korean consortium.

Last, while it is so far unclear whether the safety scandals South Korea experienced last year will hamper its efforts to sell nuclear technology globally, quick and decisive action will be important to ensure that it does not damage the ROK's image as a leading nation in nuclear quality and safety.

Should Seoul follow these recommendations, South Korea has the opportunity to make its nuclear reactor exports to the UAE the first of many.

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