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Korea nuclear exports: Why did the Koreans win the UAE tender? Will Korea achieve its goal of exporting 80 nuclear reactors by 2030?

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Korea nuclear exports: Why did the Koreans win the UAE tender? Will Korea achieve its goal of exporting 80 nuclear reactors by 2030'?

Michel Berthélemy² and François Lévêque³

April 2011

Abstract

The success of Korea in winning, in December 2009, a USD 18.6 billion nuclear tender in the United Arab Emirates (UAE) has led to a growing interest in the organization and strengths of the Korean nuclear industry. In this paper, we present the main economic and political factors that explain the success of the Korean consortium. In particular, thanks to an active national program of Nuclear Power Plant (NPP) construction, Korea has developed distinct competitive advantages in terms of low cost, high credibility and high performance. At the same time, due to the important barriers to enter into the nuclear export market in the UAE, Korea has had to sacrifice its profit margin and has benefited from a strong political support from its government through export financing. More importantly, Korea's success is also due to its alliance with Westinghouse and the support of the US diplomacy. Subsequently, we show that while Korea has recently experienced setbacks in nuclear tenders, it will most certainly try to win in the short run a second nuclear tender with another aggressive price. In the longer run, Korea could take a growing share of the international market for NPPs. However, the extent to which Korea can achieve its long term export target will depend upon its capacity to finance nuclear export through export credits and upon the development of its alliance with Westinghouse.

It is important to note that this paper was written before the Fukushima nuclear disaster. The scale of the human and environmental consequences of this accident are still unknown, and will undoubtedly have short and long term consequences on nuclear safety requirements and public attitude toward nuclear energy, which will most certainly impact the outlooks for nuclear new-builds.

¹ This paper is the outcome of a 10-day visit to the Republic of Korea in February 2011.

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Introduction

In December 2009, the Republic of Korea (hereafter, Korea) won its first international tender to build four nuclear power plants (NPPs) in the United Arab Emirates (UAE) beating in the final stage a French consortium led by AREVA and the US-Japanese joint venture General Electric-Hitachi. This success came as a shock to both the French government and public opinion and many observers have pointed out the weaknesses of the, initially favorite, French consortium bid. In particular, they have stressed the high cost of the EPR (AREVA's nuclear reactor) and the initial absence of EDF in the consortium. Instead of focusing on the factors that may explain the French defeat, we seek to understand the contributing factors to the Korean victory.

Thanks to the UAE tender, the Korean nuclear industry has entered the restricted group of international NPPs builders alongside France, Japan, the US and Russia. In a second stage, we therefore analyze the conditions for the success of Korea in future nuclear tenders. In particular, the Korean Government aims to export 80 NPPs by 2030 which would represent a 20% share of the international market for NPPs. Is this objective achievable? Which would be the key factors for the success of Korea on the export market?

In this paper, our analysis of the Korean victorious bid at the UAE and of the future Korean nuclear exports is based on economics and political economy. That is not to say that technological, managerial or cultural aspects⁴ are irrelevant to the study of the past and future of the Korean nuclear industry. These aspects are, however, beyond the scope and expertise of this paper.

This paper was written before the Fukushima nuclear disaster. The scale of the human and environmental consequences of this accident are still unknown, and will undoubtedly have short and long term consequences on nuclear safety requirements and public attitude toward nuclear energy which will most certainly impact the outlooks for nuclear new-builds.

⁴ For a detailed presentation of the role played by managerial and cultural aspects, see Park and Chevalier (2010), *The Winning Strategy of the Late-Comer: How Korea was awarded the UAE Nuclear Power Contract*, *International Review of Business Research Papers*.

I. Margin, costs and credibility of the Korean bid

From an economic point of view, the competitive advantages of the Korean bid can be explained by (i) a low price due to the decision to sacrifice the profit margin and due to a low expected cost, and (ii) a high credibility regarding the on-time delivery of the plants.

Firstly, the course of the UAE tender gives the insight that the Korean consortium was prepared to sacrifice its profit margin to win the tender. Such an outcome would offer Korea its first reference in the international market for NPPs. Once inside this market, Korea might then count on larger and more profitable perspectives. These incentives to reduce profit margins are reinforced by the political pressures on business from the Blue House⁵ to win the tender at any cost: Korean firms have limited bargaining power with policy-makers, especially in the case of state-owned firms, such as KEPCO. For private companies, such as Hyundai, Samsung and Doosan, the State's influence follows other routes. It is important to note that there have always been strong relationships in Korea between government and industry. Industrial policy has historically played a key role in Korean economic development. The government has selected and promoted certain industries to develop exports (e.g. heavy industries, automobiles, IT). Firms acting in these strategic sectors receive loans at preferential rates, benefits from governmental expenditures in research and development (R&D), duty drawbacks to get tax exemptions on imported goods that are used to make exports goods, etc. It is also important to note there are frequent comings and goings between business and politics. For instance, the current President of Korea, Lee Myung-bak, is the former CEO of Hyundai Engineering and Construction.

In addition, the possibility for Korea to make a profit margin is reduced by the presence of the US firm Westinghouse in the consortium. Korea still relies on Westinghouse technology for some critical components of the nuclear reactor. As such, it appears that Westinghouse, unlike the Korean consortium, was able to secure an important profit margin in the UAE thanks to its bargaining power (Box I).

Box I: The cooperation between Westinghouse and the Korean consortium

The Korean Standardized Nuclear Reactors (KSNR), which led to the design of the OPR-1000 and APR-1400 nuclear reactors, is based on the US Combustion Engineering reactor Syst 80+. Subsequently, Combustion Engineering was taken over by Westinghouse, who now owns the intellectual property rights for this reactor design.

Today, Korea has decided not to renew its Westinghouse licenses and to embark in a business cooperation to enable Korea to become self-sufficient by 2012 for the technologies

⁵ The Blue House is the official residence of the President of the Republic of Korea.

for which Korea still relies on Westinghouse. The components that have not received technology transfer to Korea are the following:

- The nuclear design code;
- The Reactor Coolant Pumps (RCP); and
- The Man-Machine Interface Systems (MMIS)

While it is reported⁶ that Korea has completed the designs for the RCP and MMIS, it appears that Korea has difficulties in developing its nuclear design code. However, Korea takes a pragmatic approach on this issue and the Korean Nuclear Society Chairman, Park Goon-cherl, stated: “Saying we have to do it with our own technology is only nationalism. Even if we have the technologies, we still need to purchase it from other countries for the sake of partnerships.”

At the same time, Westinghouse has also increased its cooperation in nuclear fuel supply with Korean Nuclear Fuel (KNF), with the creation in 2009 of a joint venture for the control assembly of nuclear fuel cells⁷.

This business cooperation between Westinghouse and KEPCO led to a USD 300 million contract for Westinghouse for the construction of the Shin Kori 3 & 4 reactors in Korea where Westinghouse is in charge of delivering the three components highlighted above⁸.

In parallel, Westinghouse will also be involved in the UAE where, according to its executives, its role will be “very similar to existing Korean projects”⁹. In that respect, it appears that Westinghouse share in the UAE tender is much higher than in Korea as it ranges between 5 % (USD 900 million)¹⁰ and 7 % (USD 1.3billion)¹¹ of the UAE tender value.

Besides a thin or zero margin, the price of the Korean bid is low because the costs are low. To illustrate this hypothesis one can compare these costs to the public data available on the construction costs of NPPs in the world. To do so, we first need to limit the scope of the USD 18.6 billion¹² tender to the construction stage. Indeed, this “turnkey” tender includes

⁶ JoongAng Daily (June 24, 2010), see: <http://joongangdaily.joins.com/article/view.asp?aid=2922226>.

⁷ Westinghouse Press Release (February 5, 2009), Westinghouse will own 55 % of the joint venture. It is interesting to note that Westinghouse considers in the press release that the OPR1000 and APR1400 are Combustion Engineering reactors “Korea has a number of CE plants (OPR1000 & APR1400) and is currently engaged in constructing six new units”, see: <http://westinghousenuclear.mediaroom.com/index.php?s=43&item=181>.

⁸ World Nuclear Association South Korea country profile (updated March 2011), see: <http://www.world-nuclear.org/info/inf81.html>.

⁹ According to a presentation by Dan Lipman, Senior Vice President of Westinghouse, see: http://www.sais-jhu.edu/bin/a/p/Lipman_SAIS_102510.pdf.

¹⁰ Holt (January 21, 2010), US and South Korean Cooperation in the World Nuclear Energy Market: Major Policy Considerations, *Congressional Research Service*.

¹¹ JoongAng Daily (June 24, 2010), *op. cit.*

¹² While the price of USD20.4 billion was also reported in media, we base our analysis on the official price reported by KEPCO annual report. See: http://multi.kepco.co.kr/annual/2010eng/kepco_eng.pdf.

not only the construction of 4 nuclear reactors, but also the training of the Emirati staff, the delivery of two fuel loads, as well as the initial operating time of the reactors for these two fuel loads that can be approximated to three years (with a refueling every 18 months).

The following table provides an overview of the overall scope of the UAE contract, how this one has been allocated among the different members of the consortium as well as the information publicly available to estimate the allocation of the price of the tender within the consortium:

Table I: The role and the share of Korean consortium members in the UAE tender

	Scope	Firms	Price (USD billion)
Construction / Management	NSSS, Steam Generators & other major components ¹³	Doosan (with Toshiba as subcontractor)	3.9
	Civil Engineering ¹⁴	Hyundai (Prime Constructor)	3.1
		Samsung	2.5
	Technical assistance and royalties ¹⁵	Westinghouse	1.3
	Engineering, Procurement and Construction (EPC)	KEPCO / KHNP	unknown
Training	Training of UAE staff	KHNP, KAIST	unknown
Design	Plants design and modifications	KOPEC	unknown
NPPs launch and first two fuel loads	Nuclear fuel (2 loads) ¹⁶	KNF	1
	Initial O&M ¹⁷	KHNP & KPS	1.2
Cost of Capital	Project Financing	KEPCO	unknown

As table I shows, the Korean consortium is essentially organized around KEPCO and its subsidiaries (KHNP, KPS, KNF, KOPEC) as well as private Korean firms for civil (Hyundai

¹³ World Nuclear News (July 1, 2010), see: http://www.world-nuclear-news.org/NN-UAE_reactor_contract_for_Doosan-0107104.html.

¹⁴ Global Energy Magazine (March 26, 2010), see: <http://www.globalenergymagazine.com/?p=1142>.

¹⁵ As a 7 % share for Westinghouse (see Box 1) is the latest number reported by Korean officials, we will base our estimates on this number.

¹⁶ IEA (2010), Projected Cost of Generating Electricity, 2010 Edition, IEA/OECD, Paris. The IAE reports the fuel cost to 7.9 USD/MWh. Our estimate is based on a capacity factor of 90 %, two fuel loads and a recharge period of 18 months.

¹⁷ IEA (2010), opt. cit. The IEA reports Operation and Maintenance (O&M) costs to 8.95 USD/MWh. These costs estimates are used as a proxy to the cost of launching the NPPs and can be considered as conservative as one may expect that this stage could generate extra costs compared to the commercial stage. Other estimates are equivalents to those made for fuel costs.

and Samsung) and mechanical engineering (Doosan). As aforementioned, Westinghouse assists the consortium for various components while its parent company Toshiba acts as a subcontractor of Doosan for supplying turbines. We estimate the cost of the two initial fuel loads and reactor launch to respectively USD 1.2 billion and USD 1 billion based on cost data reported to the IEA by Korea. Hence, assuming a zero profit margin for the consortium (but not for Westinghouse), we estimate the net cost of the UAE APRI400 to USD 16.4 billion or 2930 USD per kWe. Note that this figure is supposed to include the cost of capital. However, we do not know the interest rate entered into the calculation of the bid made by the Korean consortium.

To compare the cost advantage of the Korean bid, the following table updates the IEA (2010) nuclear energy costs estimates under different cost of capital scenarios, and compares these estimates to the price of the UAE tender, without including the costs of fuel and the launch of the plants as these costs are usually not included in the construction costs of NPPs.

Table 2: Cost comparison of the Korean bid compared to other cost data under various investment costs scenarios

NPPs	Net capacity	Overnight Costs	Costs of capital		Sources
			5 %	10 %	
	MWe	USD/kWe	USD / kWe		
APRI400 - Braka (UAE)	1400	< 2930	2930?	2930?	Authors estimates excluding fuel loads and plants launch
APRI400 - Shin Kori 1&2 (Korea)	1400	1550	1750	1960	IEA (2010)
EPR - Flamanville 3 (France)	1650	3860	4480	5220	IEA (2010)
EPR - Taishan 1&2 (China)	1650	2310	2690	3130	AREVA CEO, Anne Lauvergeon, has been reported to say that China builds the EPR for 40 % less than the EPR in Flamanville ¹⁸
API000 (China)	1250	2300	2540	2800	IEA (2010)
CPRI000 - Fujian (China)	1000	1760	1950	2140	IEA (2010)

¹⁸ Bloomberg (November 24, 2010), see: <http://www.bloomberg.com/news/2010-11-24/china-builds-french-designed-nuclear-reactor-for-40-less-areva-ceo-says.html>.

A number of observations can be drawn from table 2:

- To date, the APRI400 in construction in Korea is, according to the cost estimates forecasted and reported by Korea to the IEA, the most affordable nuclear reactor in the world. In particular, its overnight cost is about 60 % less expensive than the EPR in construction in France and 32 % less expensive than the EPR and AP1000 in construction in China;
- In addition, the APRI400 overnight cost is comparable to the cost of the Chinese CPR1000 nuclear reactor with only a 12 % cost difference;
- With a 10 % cost of capital, the cost of the UAE APRI400 would be about 30% above the declared cost of the APRI400 built in Korea. This cost difference would rise to about 40 % with a 5 % discount rate; and
- With a 10 % cost of capital, the cost of the US AP1000 in China would be equivalent to the price of the APRI400 in the UAE.

However, in order to draw conclusions on the cost difference between the APRI400 in construction in Korea and in the UAE, one needs to bear in mind that the UAE tender includes a number of differences in terms of design and geographic characteristics. In terms of design, the UAE APRI400 will include, for instance, a containment wall 15 cm thicker compared to Shin Kori 3 & 4 to withstand airplane crashes. The UAE site will also have substantial geographic differences as it is located in the desert with a higher sea water temperature compared to Korea, as well as frequent sand storms which require changes in the design of the plants in particular regarding the cooling system. Hence, these differences will undoubtedly lead to higher costs compared to Shin Kori 3 & 4.

This cost comparison also shows that the financing conditions of the UAE deal will play a key role in ensuring the profitability of the project for the Korean consortium. Indeed, a rise of the cost of debt from 5 % to 10 % leads on average to a 10 to 15 % increase in the project overall costs. While the exact financial arrangements of the UAE deal have not been made public yet¹⁹, we already know that the Korean Export Import Bank (KEXIM) will provide up to USD 10 billion through project financing loans to the UAE²⁰. Hence, and we will return to this point in section 3, the capacity of KEXIM to raise this loan on the international financial markets will be a key challenge for the profitability of the UAE deal.

Based on our hypotheses, it appears that depending on the ease of raising the project finance, the UAE tender has a 30 to 40 % cost difference compared to Shin Kori 3 & 4. While we do not know whether this cost difference will be sufficient for Korea to break even on the UAE project, it is clear that the two challenges for Korea will be to provide the project finance at a minimum cost whilst at the same time adapting the APRI400 design to the UAE requirements and geographic constraints.

¹⁹ In particular, the sensitivity of the UAE project overall cost to the cost of debt depends upon the debt to equity ratio of the project as this impacts in turn the risk premium asked by banks.

²⁰ Business Week (July 10, 2010), see: <http://www.businessweek.com/news/2010-10-07/south-korea-may-lend-10-billion-for-uae-nuclear-plant.html>.

In addition, given the level of risks associated with the construction stage of NPPs it is not possible to know precisely in advance whether the project will be delivered within the time and cost schedules. However, the Korean consortium can rely on the competitive advantages of its national nuclear program to meet these schedules:

- Firstly, the Korean nuclear fleet has been continually expanding since 1978 with a shift from “turnkey” projects led by foreign nuclear firms toward technological self-reliance²¹. This continuous investment of Korea in nuclear technologies, while at the same time nuclear programs were put on hold in other economies, has allowed the Korean industry to benefit from important economies of scale and learning effects.
- Secondly, Korean civil engineering firms in general have an impressive track record not only in Korea but also in the Middle-East and can capitalize on their experience with large projects in the region²².
- Thirdly, Doosan is actively present as an EPC contractor on the market for thermal water desalination plants²³, with most of the market actually taking place in the Middle-East region.

Furthermore, the low price offered by the Korean consortium is reinforced by a number of contractual and technical advantages that were not priced in the Korean bid²⁴ and shift the balance of risks to the benefit of the UAE. In particular, the risk allocation within the consortium is a key advantage of the Korean bid. While for instance in the initial French consortium, construction and operation risks were divided between AREVA, TOTAL and GDF-SUEZ; all these risks are carried out by KEPCO in the Korean consortium. This risk allocation has important implications for the NPPs buyer as it reduces the litigation risks in case of delays or performance problems and increases the incentives for the EPC contractor to meet the project delivery objectives. In addition, unlike the initial bids of its competitors, approximately 80 % of the Korean bid was made through a lump-sum contract which means that the risks linked to a rise of inputs’ price (e.g., raw materials) are also to be carried out by the Korean consortium.

Finally, the advantages of the Korean bid also come from the high credibility of the Korean consortium in undertaking large infrastructure projects. The construction of NPPs in Korea has always been done within reasonable and constantly decreasing construction time schedules²⁵. As aforementioned, Korean civil engineering firms have a strong presence in the

²¹ The Korean nuclear technology is based on US technology transfers from Westinghouse and Combustion Engineering in the 1980s and 1990s. For a detail view on the progressive technological independence of Korean nuclear industry, see: Word Nuclear South Korea country profile (updated March 2011), *op. cit.*

²² Financial Times (July 4, 2010), in 2009, Korea won USD 36 billion of contracts in infrastructure projects in the Middle East, which represents a quarter of this market, see: <http://www.ft.com/cms/s/0/50a7ec64-8794-11df-9f37-00144feabdc0.html#axzz1FSVBo6KO>.

²³ Doosan website, see:

http://www.doosan.com/en/pressRelease.do?cmd=viewPressRelease&no=20090506093859803392&from=service_desalination.

²⁴ These arguments are based on interviews with Korean executives and officials.

²⁵ While the construction of the first NPP in Korea (Kori 1) took 64 months, on average the Korean standardized reactor OPR1000 takes 52 months to be built and the estimated construction time for the APR1400 in the UAE

Middle East through Oil & Gas projects. In parallel, Korea has the world record in terms of NPPs performance with a load factor above 93 % and some of the lowest unplanned outages rates. While Korea has never exported its nuclear technology, it has already sold thermal power plants in a number of countries including the UAE, Malaysia, China, Jordan and Saudi Arabia). In addition, the credence of the Korean consortium also comes from the cooperation between its different members. The KEPCO holding is vertically integrated and provides the design, construction coordination, operation, fuel and maintenance of NPPs in Korea. In parallel Doosan, Hyundai and Samsung have been associated with the construction of NPPs in Korea since the start.

2. The role of Korean policy and the implication of the U.S. diplomacy in the UAE Tender

Policy interventions are a constant feature in large international tenders such as NPPs construction. Indeed, diplomatic considerations intervene between the buyer and the seller countries both because the economic scale of the contracts often means that government guarantees are necessary and because of the risks in terms of nuclear proliferation and nuclear safety. The role of diplomatic interventions in the UAE tender is reinforced by the fact that the tender was organized by the State. Indeed, while the contract was signed between KEPCO and the Emirate Nuclear Energy Corporation (ENEC), it is evident that the latter did not play any role in the tender as it was legally created only 4 days before the signature of the contract. Similarly, the Federal Authority of Nuclear Regulation (FANR) was established less than three months before the deal and could not have played a role in selecting the nuclear reactor technologies²⁶.

Hence, one may wonder how a country with a limited diplomatic network and few strategic interests in the Middle-East region²⁷ could compete with the influence of countries such as France. In that respect, we will argue that Korean policy interventions were not the only ones at stake and that its success also needs to be understood in light of the US diplomacy.

2.1. The support of the Korean Government for its national consortium

The Korean government has provided a key support for the Korean consortium, using most of the policy channels available. In particular, the Korean President, Lee Myung-bak, has made five official visits to the UAE, and has been presented as being personally involved in

is 48 months. The Korean objective is to build the APR1400 within 36 months. See: World Nuclear Association South Korea country profile (updated March 2011), *op. cit.*

²⁶ FANR was established on 4 October 2009, ENEC on 23 October 2009 and the announcement of the Korean consortium victory was made on the 27 December 2009. For more information on the UAE nuclear tender timeline, see: <http://www.dubaifaqs.com/nuclear-power-uae.php>.

²⁷ Unlike France, the UK or the US, Korea does not have a defense treaty with the UAE. Likewise, Korea is not part of the negotiations surrounding Iran.

leading the consortium²⁸. Beyond this leadership of the Korean President, two direct policy interventions must be highlighted.

Firstly, the support of the Korean government is economic through the financing arrangements of the project. The state-run Korean Export-Import Bank (KEXIM) has pledged half of the project finance with a USD 10 billion loan to the UAE²⁹. This loan, which was joined to the bid through a Letter of Intent, but is not part of the contract *per se*, includes a number of financial arrangements with overseas investment financing, preferable loans, loan guarantees and export credits for domestic suppliers and has a repayment time of 28 years. In parallel, the Korea Trade Insurance Corporation (K-sure) will also provide loan guarantees to Korean companies. While these funds have not been raised on the international financial markets yet, it is important to stress the unprecedented scale of this project financing operation for KEXIM³⁰ as it equals the level of all its operation in Middle-East in 2009³¹ and amounts for 20 % of the bank commitments for the same year³². These export credits will also have to comply with the OECD guidelines for export credits agencies and in particular the sector understanding for nuclear projects³³.

Secondly, the support of the Korean government also took place through military assistance to the UAE. While this kind of support is not unusual in large contracts, Korea has agreed to dispatch a battalion of Special Forces to train their Emirati counterparts³⁴.

More generally, the involvement of the Korean State in the UAE tender is part of Korea's long term economic strategy to make nuclear technology a major contributor the Korean exports by 2030. In particular, the Korean government has declared an objective of exporting 80 nuclear reactors by 2030 which would represent 20 % of the international market for NPPs and USD 400 billion in contracts³⁵. This new market³⁶ and other markets related to energy technology (e.g., cleantech, smart grid) are viewed as contributing to future Korean exports by progressively replacing the current sectors leaders such as shipbuilding and semiconductors, which now face fierce competition from China. It also

²⁸ Park and Chevalier (2010), *op. cit.*

²⁹ Korea Exim (March 8, 2010) press release, see:

http://www.koreaexim.go.kr/oversea_common/popup/exim_news_read.jsp?nCP=1&nRegNo=438&nSSecNo=9&sSKeyword=

³⁰ It is interesting to note that the cost of the project may actually be cheaper if the project financing originated from the UAE instead of Korea as the former has a better notation from rating agencies than Korea.

³¹ Business Week (October 7, 2010), see: <http://www.businessweek.com/news/2010-10-07/south-korea-may-lend-10-billion-for-uae-nuclear-plant.html>.

³² Korea Exim Financial results (2010), see: http://www.koreaexim.go.kr/en2/01_exim/01_exim/07.jsp.

³³ OECD (2009), Sector understanding on export credits for nuclear power plants, OECD/Paris. Export credits for nuclear projects have to follow rules with respect to base points, scope and repayment period. See:

<http://www.oecd.org/officialdocuments/displaydocumentpdf/?cote=tad/pg%282009%2919&doclanguage=en>

³⁴ The National (January 13, 2011): <http://www.thenational.ae/news/uae-news/south-korean-elite-forces-arrive-in-uae>.

³⁵ World Nuclear Association South Korea country profile (updated March 2011), *op. cit.*

³⁶ Note that Korea is not only targeting the NPPs construction markets but also the market for NPPs operation, maintenance and repair whose market value is estimated at USD78 billion. World Nuclear Association South Korea country profile (updated March 2011), *op. cit.*

reflects the Korean long term economic development strategy based on government leadership relayed by family conglomerates³⁷. While some of these conglomerates are today globalized firms, their ties with the government remain close.

This strategic vision also comes from the fact that the outlook for NPPs construction in Korea shows that the Korean nuclear fleet would be saturated by 2030. Korea remains a small country and does not have any electricity grid connections with other countries. The share of nuclear in final electricity consumption is expected to grow from 36 % in 2010 to nearly 60 % in 2030 with the construction of about one NPP per year. With 60 % of electricity generation coming from nuclear, it will see profitability dropping as nuclear stops being baseload leading to a decline in construction. As a result, the future of the Korean nuclear industry must be on the export market, unlike China whose electricity demand is constantly rising, or Japan whose nuclear fleet is aging.

2.2. The influence of US interests in the UAE tender

Given the US influence in the UAE, one may wonder whether its position toward the tender has influenced its outcome. Indeed, the U.S. interests in the UAE are substantial. Due to the proximity and the tensions between Iran and the UAE³⁸, it is realistic to argue that the UAE national security relies partly on the US military presence in its territory. The UAE military base in Al Dhafra hosts 2,000 soldiers. More generally, there are about 30,000 US residents in the UAE, some of whom occupied key positions within the UAE nuclear organization; the Federal Authority of Nuclear Regulation's (FANR) executive director, William Travers, is a former executive of the US Nuclear regulatory Commission (NRC) and has contributed to the establishment of UAE nuclear strategy since 2008. Similarly, the American David F. Scott was nominated to the ENEC Board of Director in December 2009³⁹.

The US influence needs to be understood from three different aspects as detailed below. Firstly, the US diplomacy could have blocked the Korean bid as the Korean nuclear technology is still partly based on American technology and needs to comply with the US nuclear technology export control laws. Secondly, there are signs that the US have sought to favor an international tender. This influence has indirectly favored the Korean bid, as before the opening of the tender the negotiations were only taking place between France and the UAE. Thirdly, they might have directly sought to support the Korean bid as a strategic choice.

These three different points are examined in detail below:

³⁷ In particular, Hyundai, Doosan and Samsung remain family conglomerates. As aforementioned, these conglomerates, called Chaebols, have close ties with the government and the current President is the former CEO of Hyundai.

³⁸ Washington Times (July 6, 2010), The UAE are in favor of a pre-emptive military action against Iran. See: <http://www.washingtontimes.com/news/2010/jul/6/uae-ambassador-endorses-bombing-irans-nuclear-prog/>.

³⁹ Wall Street Journal (April 2, 2009), previously David F. Scott occupied various positions in the UAE administration, the US Administration. See: <http://online.wsj.com/article/SB123862439816779973.html>.

Firstly, it is clear that the US diplomacy did not try to undermine or stop the Korean consortium. Indeed, the American Congress agreement was necessary for Korea to be allowed to export its nuclear technology. As the APRI400 is based on an American design, the ratification of a so-called “123 Agreement”^{40, 41} was necessary between the UAE and the US and is a precondition for the export of US civil nuclear technologies. While its ratification by the Congress was subject to debates in Capital Hill⁴², essentially because of fears of nuclear proliferation with Iran, the UAE conducted a large lobbying campaign to gain support from US officials⁴³. This illustrates how important the cooperation with the US was to the UAE. Likewise, GE⁴⁴ and Westinghouse⁴⁵ officially lobbied in favor of this agreement in 2009 when the nuclear tender was finally launched.

In addition, after the ratification of the “123 Agreement”, a specific authorization was also needed for Westinghouse employees and contractors to be part of the Korean consortium. This authorization named “810 Authorization”⁴⁶ is required for US citizens to be part of the production of any materials oversea that enter the nuclear fuel cycle and has to be reviewed by the US DoE and the other US agencies dealing with US interests in the region⁴⁷.

Secondly, the US influence seems to have also been devoted to convincing the UAE to organize an international tender. For most of the observers, the UAE nuclear deal was initially supposed to take place through an Over-the-Counter (OTC) agreement to the benefit of the French consortium. The announcement of an International Tender Bid (ITB) in February 2009⁴⁸ took everyone by surprise. Even the Korean themselves initially thought that the ITB was only made to reduce the price of the French bid.

This shift from an OTC to a competitive ITB is especially intriguing as it was determinant in the French defeat. While we do not have any factual public information on this topic, the US influence in the organization of a tender is based on a number of clues:

⁴⁰ The term « 123 Agreement » refers to the section 123 of the 1958 US Atomic Act which deals with the export of US nuclear technologies. This cooperation agreement, between the US and another country, deals with matters surrounding the civil nuclear fuel cycle. In particular, it includes for the UAE the commitment not to enrich or reprocess its uranium in order to limit proliferation risks in the region.

⁴¹ UAE Embassy in Washington press release (December 17, 2009), see: <http://www.uae-embassy.org/media/press-releases/17-Dec-2009>.

⁴² The Hill (June 2, 2009), see: <http://thehill.com/opinion/op-ed/8186-nuclear-cooperation-with-uae-in-our-interest>.

⁴³ UAE lobby reports can be accessed on the following website: <http://foreignlobbying.org/registrant/US-Emirates%20Alliance/>.

⁴⁴ GE press release (November 4, 2009), see:

<http://www.genewscenter.com/content/detailEmail.aspx?ReleaseID=8886&NewsAreaID=2&changeCurrentLocale=5>.

⁴⁵ Westinghouse official lobbying report (2009), see:

<http://soprweb.senate.gov/index.cfm?event=getFilingDetails&filingID=CB425B89-958C-4C86-98C6-D08D88643100>.

⁴⁶ The 810 Authorization is named after the part 810 of the US Code of Federal Regulation and implements the Section 57b of the US Atomic Energy Act.

⁴⁷ For more information about the shortcomings of the US-Korea nuclear cooperation, see Holt (2010), *op. cit.*

⁴⁸ Zawya (update March 2, 2011), see: <http://www.zawya.com/projects/project.cfm/pid220307020544?cc>.

- A confidential interview with a Korean executive;
- The key positions awarded at the ENEC and the FANR to US citizens (see above); and
- The involvement of two US engineering consultancy firms, Thorium Power and CH2M Hill, selected by the UAE in October 2008⁴⁹, i.e. 4 months before the choice to open an ITB. While one should not necessarily see in this choice the US diplomacy influence, there is little doubt that the US consultancy firms, essentially made of former staff from General Electric and Westinghouse, may have been more in favor of a US bid, and by extension of the Korean bid⁵⁰, as they would be more familiar with their approach in terms of nuclear design and safety.

However, the US influence in the shift to an international tender might not be the only explanation. The importance of the international financial crisis, and its impact on the UAE economy, need to be taken into consideration. In particular, the Abu Dhabi Emirate pledged in 2009 more than USD 10 billion in direct loans to rescue Dubai⁵¹. Hence, one could argue that the UAE become more sensitive to the cost of developing nuclear power generation than they were during the OTC negotiations with the French consortium in January 2008.

Thirdly, Korea could have directly benefited from US support. While no clear evidence exist to support this argument, we argue that this hypothesis stands as a rational proposal given the US influence during the UAE tender. As aforementioned, the US government has influenced to some extent the outcome of the UAE tender through the negotiation of its cooperation agreement with the UAE. In addition, strong ties exist with the UAE both through the US-UAE defense agreement and more directly through the presence of former US executives in the utility (ENEC) and the safety authority (FANR). To what extent did this influence favor the Korean bid? While it is clear that the US would have first thought to favor the GE-Hitachi bid, we argue that the rationale for the US to back the Korean bid are threefold:

- The GE-Hitachi was reported to be the most expensive bid⁵² and, as the price criteria played an important role in the UAE choice, it had little chance of winning. Hence, by supporting the Korean bid, the US would prevent its French competitor from reinforcing its interests in the region.
- On the other hand, by supporting the Korean bid associated with Westinghouse, the US could still exert a control on the UAE nuclear project as the Korean technology is based on an American design.
- In addition, as highlighted in section I, while the economic benefits of the UAE deal would still be significant for Westinghouse (up to 7 % of the contract value), the cost of the project finance and the risks would still be carried by Korea. In other words, the US took a large interest in the project without the risks associated with large nuclear

⁴⁹ Zawya (update March 2, 2011), *op. cit.*

⁵⁰ The Korean APR1400 reactor is derived from the US Combustion Engineering reactor design "Syst80 +", now owned by Westinghouse.

⁵¹ BBC (December 14, 2009), see: <http://news.bbc.co.uk/2/hi/8411215.stm>.

⁵² The National (December 28, 2009), see: <http://www.thenational.ae/business/energy/nuclear-bid-to-be-industry-norm>.

tenders, risks that they would have had to take to some extent if the GE-Hitachi was successful.

In short, the Korean success in winning the UAE tender came from its capacity to gather its economic advantages and the political support from the Korean government as well as the US attitude toward the Korea bid. Korea has now entered the international market for NPPs and aspires to become a major exporter of NPPs, along with fuel and maintenance services. Can Korea achieve its ambitions for NPPs new-build exports?

3. What is the prospect of the Korean consortium on the international market for NPPs?

After studying, in the two previous sections, the economic and political factors that explain the Korean success in the UAE, we now turn to a prospective analysis for Korea NPPs export outlooks. However, this analysis is not disconnected from the previous one. After a first success where the incentives to sacrifice the profit margins were high, will Korea keep its low price advantages? Will nuclear export receive the same support from the Korean government? Is the partnership with Westinghouse sustainable? Will the US diplomacy attitude towards Korea NPPs exports continue? Will new advantages (e.g. large range of reactors) or weaknesses (e.g., industrial capacity, balance of NPPs national construction program with export) change the picture?

To answer these questions, one needs to distinguish between nuclear exports in the short run with the long run outlook for Korea.

3.1. The outlook for Korea NPPs exports in the short run

The UAE victory has reinforced Korea ambitions on the international market for NPPs. In particular, Korea's ambition is to reach ten exports of NPPs⁵³ by 2012. The political pressures to win another tender are high as another success would be seen as the proof that Korea did not win the UAE by chance. However, at the same time, the financial and military supports from the Korean government, which were not disclosed when Korea won the tender, have led to a number of criticisms concerning the cost of this first NPPs export for Korean taxpayers⁵⁴. Will Korea make a second aggressive nuclear bid? We argue that despite the economic cost of a second aggressive bid, Korea will most certainly try to repeat its UAE success for political reasons.

⁵³ World Nuclear News (January 13, 2010), this number includes the 4 APR1400 for the UAE. This means that Korea needs to export 6 extra NPPs before the end of 2012 to fulfill its export target, see: http://www.world-nuclear-news.org/NP-South_Korea_seeks_to_boost_reactor_exports_1301104.html.

⁵⁴ Korea Times (February 16, 2011), see: http://www.koreatimes.co.kr/www/news/nation/2011/02/119_81531.html.

In that respect, the recent setbacks experienced by Korea in Turkey and Jordan illustrate the financial limits of the Korean consortium:

- In Jordan, Korea was not shortlisted as a bidder despite the fact that KAERI exported a research reactor⁵⁵ in 2009. While the tender is still ongoing, it is reported that KEPCO was not shortlisted in May 2010 as a bidder because of disagreements surrounding the construction site and the project financing⁵⁶.
- In Turkey, Korea was in the final stage of bilateral negotiations to build four nuclear reactors. However, the negotiation failed in November 2010 as Korea and Turkey did not reach an agreement for the NPPs financing arrangement⁵⁷. Indeed, Turkey wants to finance its NPPs through a Public-Private Partnership (PPP) where the repayment of the equity brought by the Korean consortium would be based on the sale of electricity from the NPPs with a Build-Own-Operate (BOO) system. These financial conditions would have been more risky for Korea than the UAE conditions and it is said the negotiations failed on the electricity tariffs.

In that respect, the Turkey and Jordan tenders show that Korea financial capacities are limited and that it may be economically costly for Korea to offer the same conditions as for the UAE for future nuclear tenders. In particular, the possibility should not be excluded that these countries expected to benefit from the same price offer as for the UAE tender whilst Korea aims to access more lucrative nuclear deals. In addition, while Korea has benefited from the US influence in the UAE tender, its limited diplomatic strength is still an important weakness when trying to export to a country outside of the US influence. In particular, it has been reported that Korean decision to drop out from bilateral negotiations with Lithuania was due to pressures from Russia⁵⁸.

This difficult prospect in the short term for Korea on the international export market can be understood by the fierce competition it faces following the failure of its competitors in the UAE. For instance, Korea was also competing against Japan for the Vietnam nuclear tender but lost as Japan offered a very aggressive package⁵⁹. This aggressive Japanese bid can be

⁵⁵ World Nuclear News (December 7, 2009). KAERI and Daewoo have won a tender in early December 2009 to build a 5 MWe research reactor for the Jordan University for Science and Technology. See: http://www.world-nuclear-news.org/NN-Korean_consortium_for_Jordans_first_reactor-0712097.html.

⁵⁶ Yonhap News Agency (May 11, 2010), Besides the disagreement surrounding the project financing, it should be noted that Jordan's nuclear plan faces a number of technical difficulties as the country has limited access to water. See:

<http://english.yonhapnews.co.kr/business/2010/05/11/12/0501000000AEN20100511002400320F.HTML>.

⁵⁷ Joongang Daily (December 24, 2010). <http://joongangdaily.joins.com/article/view.asp?aid=2930092>.

⁵⁸ The Lithuania Tribune (March 12 2011), In particular, the Lithuanian energy minister was reported stating when asked about a possible Russia's involvement in the Korean KEPCO withdrawal "I won't miss an opportunity to remain silent after hearing such good questions." This Russian attitude towards the Lithuanian nuclear project can be explained by Russian reluctance to see Eastern Europe countries reducing their dependency on Russian gas imports. See: <http://www.lithuaniatribune.com/2010/12/03/koreans-withdrew-from-lithuanian-nuclear-project-after-medvedev%E2%80%99s-visit-to-seoul/>.

⁵⁹ World Nuclear News (January 21, 2011), It is worth noting the importance of the political pressures surrounding the deal as it has not yet been decided whether Japan would sell boiling or pressurized water reactors. See http://www.world-nuclear-news.org/NP-Japan_and_Vietnam_sign_cooperation_deal-2101114.html.

explained by the political pressures faced by the Japanese nuclear industry following their UAE defeat. Hence, these short term failures may also be part of political pressures also faced by national nuclear industries in other countries and should not be considered as a long term indicator for Korea long term nuclear export outlook.

As previously mentioned, political pressures to win international nuclear tenders are strongly present in Korea and despite the economic cost of a second aggressive Korea bid, it should be expected that, in the short term, Korea will offer a new aggressive bid for political reasons. In particular, Korea should again be competing with the French consortium in the upcoming tender in South-Africa and it can be expected that Korea will develop an aggressive bid for this large nuclear tender.

3.2. Can Korea export 80 Nuclear reactors by 2030?

Korea's long term ambitions on the international market for NPP new builds are impressive. In 2010, the Korean government announced its objective to sell 80 nuclear power plants by 2030. According to this political objective, this target, which corresponds to a 20 % market share, would make Korea the third largest exporter behind France and the United-States. These exports would represent USD 400 billion of export value according to the Korean government⁶⁰. In particular, Korea expects to sell NPPs in emerging economies in South-East Asia (e.g. Malaysia, Thailand). Korea also targets in the long run more mature economies such as Western Europe⁶¹ or the US⁶².

Can Korea achieve this export target? We argue that, following the success of the UAE tender, four factors would be key in the success of Korea in future NPP tenders: its cost and credibility advantages, its human and industrial capacities to meet both the export and national markets, its financial capacity and the relationship with Westinghouse and the US diplomacy in general.

Korea's low cost advantage

Firstly, it can be expected that the cost advantage of the Korean industry will be maintained or even reinforced. In particular, the Korean nuclear industry seeks to increase its competitive advantage through more competition between Korean firms. For instance⁶³, Hyundai had to team up with Samsung in the UAE project to enable Samsung to improve its expertise in nuclear projects and compete against Hyundai in future nuclear tenders.

⁶⁰ Korea Times (January 13, 2010), see:

http://www.koreatimes.co.kr/www/news/biz/2010/04/123_58930.html

⁶¹ World Nuclear Association South Korea country profile (updated March 2011), *op. cit.* In Europe, Korea has announced its plan to develop an EU-APR1400 which would comply with European safety requirements (e.g. core catcher and second containment wall).

⁶² Nuclear Business (January 2010), the Alternative Energy Holding Inc. (AEHI) CEO, Don Gillispie, has expressed its interest in building an APR1400 nuclear reactor in the US, stating that "*such technology should give AEHI a serious competitive advantage*".

⁶³ These arguments are based on interviews with Korean executives.

Similarly, Hyundai, which used to forge large nuclear components, seeks to reopen large forges to compete with Doosan on the national and international market for large nuclear components. Hence, by enhancing the competition within its national industry, Korea aims to bring down the costs of its NPPs.

At the same time, while tensions exist between KHNP, which manages NPP construction in Korea, and KEPCO, its mother company in charge of project management for overseas⁶⁴, the consequences of these tensions should not impact the efficiency and credibility of the Korean consortium abroad, as the management of the nuclear export business is ultimately in the hands of the Korean Ministry of Knowledge Economy (MKE). However, the credibility of the Korean consortium will also depend upon the timely completion of the NPPs in construction in Korea and in the UAE. While it is not possible to predict the outcome of the UAE project, Korea's nuclear industry capacity overseas will undoubtedly be judged on this first project. On the one hand, the APRI400 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 project. On the other hand, Korea appears to be confident and even expects to achieve the project before the deadline to earn a USD200 million bonus⁶⁵.

Human and industrial capacities constraints

Secondly, the human and industrial capacities may also represent a challenge as Korea would need to balance and expend its human resources and factories to meet both its national and export targets. As far as human resources are concerned, Korea is expected to train more than 2,800 nuclear engineers in 2011⁶⁶. More generally, Korean universities have excellent reputations, large nuclear engineering departments and Korea should manage without difficulties to orientate its university students toward carriers in the nuclear industry.

Industrial capacities may be more challenging for Korea as large nuclear components require some of the biggest and most precise forging capacities in the world. In that respect, reports indicate that Doosan is rapidly expanding its forging capacities with a new 17,000 tons forging press which would break the monopoly of Japan Steel Works on some specific large nuclear components. It has taken over the Czech turbine maker Skoda Power and the UK forge Babcock to increase its capacity in Europe, and has also made some alliances with IHI

⁶⁴ These arguments are also based on interviews with Korean executives. In 1999, the Korean government planned to privatize the electricity sector and created KHNP as a subsidiary of KEPCO with the aim to privatize the former. While the restructurisation of Korean electricity has eventually opted-out, KHNP has now acquired a large autonomy from its mother company. With the prospect of NPP exports, KEPCO now wants to reintegrate KHNP as one of its divisions. This plan leads ultimately to conflicts between KEPCO and KHNP top management.

⁶⁵ Korea Times (February 9, 2011). It is interesting to note that while this incentive clause had been made public, no information has been made public regarding the penalty clause. See http://www.koreatimes.co.kr/www/news/biz/2011/02/123_81100.html.

⁶⁶ World Nuclear News (January 13, 2010), See http://www.world-nuclear-news.org/NP-South_Korea_seeks_to_boost_reactor_exports_1301104.html.

and Toshiba⁶⁷. In addition, as aforementioned, Korean industrial capacities could be reinforced with Hyundai reopening forges for nuclear components. Finally, it is worth noting that Korea could benefit from some flexibility in deciding, if required, to prioritize its nuclear exports over its national construction program.

Financial capacity constraint

Korea, along with its competitors will have to face the challenge of financing nuclear new-builds in the ensuing decades. In that respect, as previously mentioned, the financial package of the UAE project has been largely criticized in Korea by the opposition party. At the same time, the recent tenders in Turkey and Jordan failed surrounding disagreements concerning the financing role of Korea in the projects and indicate that, for the moment, Korea may not be ready to take the risk of nuclear financing through a BOOT arrangement, where repayment is based on the price of electricity. In addition, Korea has up to now targeted emerging economies with limited financing capacities for which the project financing brought by the supplier is a key criterion. To predict Korea's financial capacity one needs to answer two key questions: Does Korean firms' financial status allow them the finance NPPs? Can the Korea Export-Import banks afford to raise large financing for NPPs?

With respect to Korean firms' financial capacities, it is worth noting that KEPCO has been the only Korean firm to bring equity for the UAE project finance. Whilst KEPCO has good financial capacities compared to other large utilities in the world⁶⁸, it faces the growing challenge of its regulated low retail electricity tariffs which have led to losses in the past three years⁶⁹ and are reported to have already led to KEPCO losing bids for thermal plants construction in Indonesia and Egypt. Hence, whilst a market reform of electricity tariffs is not expected in the short term, it is clear that one will be necessary to support KEPCO financial capacities for oversea tenders. At the same time, one could also expect that private firms, such as Doosan or Hyundai, which did not bring financing for the UAE tender, could do so in future nuclear export tenders and reinforce the financial capacities of the Korean consortium.

However, these equity investments for nuclear tenders often have to be financed through debt. In the case of Korea's nuclear export, the Korea Export-Import bank, KEXIM, is used in the UAE tender to raise the equities. Does KEXIM have the financial strength to bring the financing for Korea's long term export target? The UAE tender financing is, as previously mentioned, an unprecedented challenge for the export bank and has not been completed

⁶⁷ World Nuclear Association (updated December 2010), see: http://www.world-nuclear.org/info/inf122_heavy_manufacturing_of_power_plants.html.

⁶⁸ Moody's (August 31, 2010), KEPCO analysis, see: http://www.kisrating.com/report/moodys_rating/Korea%20Electric%20Power%20Corporation/Korea%20Electric%20Power%20Corporation20100831.pdf.

⁶⁹ Korea Jeongang Daily (February 11, 2011). In particular a KEPCO official was reported stating "If rival countries raise the issue, KEPCO's losses could act as the biggest weakness in Korea's nuclear power exports", see: <http://joongangdaily.joins.com/article/view.asp?aid=2932071>.

yet. In addition, while KEXIM is a state-run bank it also has to finance the exports of other sectors and needs to balance its books between nuclear and non-nuclear projects financing. Indeed, a large proportion of nuclear project financing would ultimately lead to higher interest rates for the rest of Korean exports⁷⁰. In that respect, Korea is now trying to diversify its export funding sources by attracting Islamic finance⁷¹. In the longer run, Korea is also seeking to modify its nuclear exports financing structure by putting nuclear projects in a specific “task force” separated from KEXIM and directly backed by the government⁷².

This potentially large reorganization of Korea’s nuclear export financing strategy shows that Korea’s financing capacities are, at the moment, limited. Most certainly, it also illustrates that Korea, which was heavily impacted by the 1998 Asian financial crisis, is seeking a sustainable solution to the problem of nuclear new-build financing, a problem it shares with all large NPP export countries.

Korean relationships with Westinghouse and the US diplomacy

Finally, the last factors that need to be taken into consideration are Korean relationships with Westinghouse and the US diplomacy. As aforementioned in box 1, Korea relies on Westinghouse for critical components and has, to some extent, benefited from the positive attitude of the US diplomacy toward their UAE bid. While Korea has started an ambitious program to improve its technological self-reliance, we argue that Korea will need to continue its cooperation with Westinghouse and will also seek to be supported by the US diplomatic influence.

Indeed, as box 2 shows, Korean nuclear technology is mostly based on nuclear technology transfers, based essentially on Westinghouse and Combustion Engineering patents from the 1980s and 1990s. Hence, even if Korea succeeds in developing its own technology for the components still under Westinghouse intellectual property rights, i.e. the reactor coolant pumps, MMIS and nuclear design code, it can be argued that Korea will still need Westinghouse cooperation for the export business. While information about nuclear intellectual property rights are partial it is worth noting that a UAE official was reported stating after the UAE deal that “ultimately much of the [Korean] technology has a US thumbprint on it”⁷³. In turn, this US origin of Korean nuclear technology would imply that without a nuclear cooperation agreement between the US and the buyer country “you find yourself in a

⁷⁰ Business Week (March 3, 2011), For instance, Korea ship building industry aims to win USD 50.1 billion of contracts in 2011. See, <http://www.businessweek.com/news/2011-03-03/korea-export-bank-to-overshoot-debt-sale-target-as-orders-boom.html>.

⁷¹ The Korea Times (February 25, 2011). To that end, Korea would need to modify its tax law to enable sukuk transactions. Amusingly, this project has led to heavy protest from the Protestants political base of President Lee Myung-bak, see: http://www.koreatimes.co.kr/www/news/biz/2011/02/123_82105.html.

⁷² Korea Herald (March 9, 2011), see: <http://www.koreaherald.com/business/Detail.jsp?newsMLId=20110309000846>.

⁷³ UAE Interact (August 23, 2010), see: http://www.uaeinteract.com/docs/UAE_set_nuclear_precedent_of_%C3%A2%E2%82%AC%CB%9Cgold_standards%C3%A2%E2%82%AC%E2%84%A2/42290.htm.

licensing scenario where every component and every piece of material has to be licensed separately. It is very difficult to manage a project in those circumstances”.

In that respect, the insights from patent data (box 2) show the predominance of foreign firms in applications for nuclear patents in Korea and their resurgence since 2004. This could be interpreted as the sign that foreign nuclear firms, and in particular Westinghouse and Areva, are filing defensive patents in order to maintain their influence on Korean nuclear technology.

Beyond this reliance on foreign nuclear technologies, the Korean nuclear fuel-cycle is also reliant on its US cooperation agreement which prohibits Korea from enriching or reprocessing its uranium. As mentioned in section I, Korea has to buy its uranium from foreign companies and in particular Westinghouse, which has created a joint venture with KNF, for the control element assembly for nuclear fuel. In turn, this reinforces the US control on the Korea national nuclear program and nuclear exports.

Box 2: Patents, innovation and the self-reliance of Korean nuclear technology

Patent applications are often used by economists as a proxy to measure innovation⁷⁴. The following figures come from the Patstat database⁷⁵ and present nuclear patents filed in Korea since 1975. In total, 717 patent applications⁷⁶ have been filed in Korea between 1975 and 2008 in the field of electricity generation from nuclear fission.

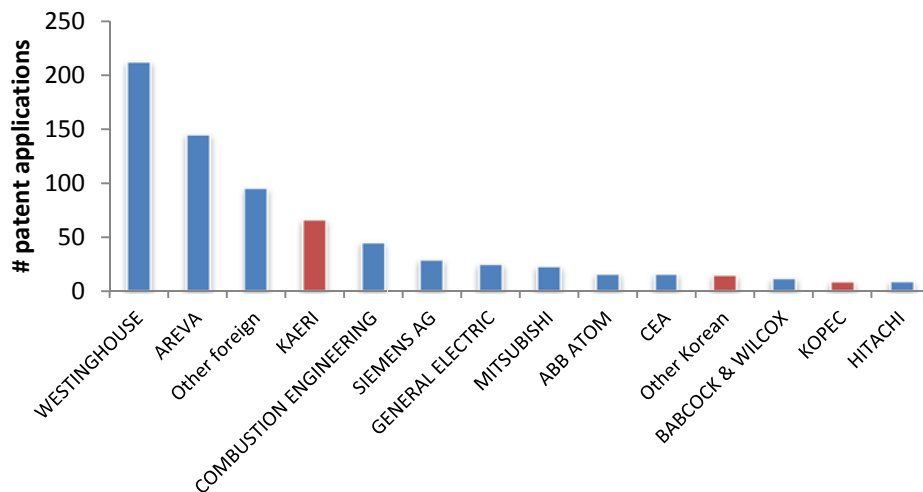
Figure I presents the distribution of nuclear patents among both Korean and international firms. It is clear that nuclear patents are essentially dominated by foreign applicants and in particular Westinghouse. Indeed, while nuclear patents were filed by about 85 different applicants, only 7 of them were Korean. These Korean applicants, with 90 patent applications, only account for 12.5 % of the patents filed, and KAERI accounts for two thirds of these. On the other hand, patents from Westinghouse (with Combustion Engineering) and Areva dominate nuclear patents in Korea with respectively 257(50 %) and 145 (20 %) patents. In that respect, it is reasonable to argue that the intellectual property of Korea's nuclear technology is still dominated by foreign firms. However, this does not indicate the extent to which the Korean nuclear program is reliant on foreign patents as we do not have access to the licenses agreements made by foreign firms, such as Westinghouse, with Korean firms.

⁷⁴ While this measure only allows a partial view of innovation (for instance it cannot capture innovations kept secret and may be biased because of strategic behavior such as defensive patents), it provides a general overview of innovation efforts in the long run. In addition, it enables the identification, inter alia, of the origin of innovators, as well as when and by which firm the application was filed.

⁷⁵ Patstat is a patent database developed by the European Patent Office (EPO) in collaboration with the OECD. It is the most comprehensive Patent database and covers 80 countries since 1970. For more information, see http://www.epo.org/searching/subscription/raw/product-14-24_fr.html

⁷⁶ To collect these data we use the EPO new classification Y02E30:30 “Energy generation of nuclear origin / Nuclear Fission”.

Figure 1: Distribution of patents among Korean and the main international firms



At the same time, Figure 2 illustrates how patent applications have evolved in Korea over time and links this evolution with the general steps of the Korean nuclear program⁷⁷. From this figure a number of comments can be made:

-During the “turnkey” phase in the 1970s, NPP construction by foreign firms was not associated with intellectual property rights, which can be seen as a sign of no licenses;

-In the 1980s, Korea embarked on a “non-turnkey” phase which led to most of the patent applications originating from Westinghouse and Combustion Engineering. These patent applications coincided with licenses and technology transfers from Combustion Engineering in particular⁷⁸;

-The “technology self-reliance” period in the 1990s saw the development of a Korean research and development nuclear program. As such, Korean patents slowly started to emerge while at the same time foreign patents declined. One may argue that this decline in foreign patents came from the fact that Korea had acquired all the licenses of foreign technologies it needed in 1980s and decided to embark on development of its own nuclear reactor based on these foreign technologies; and

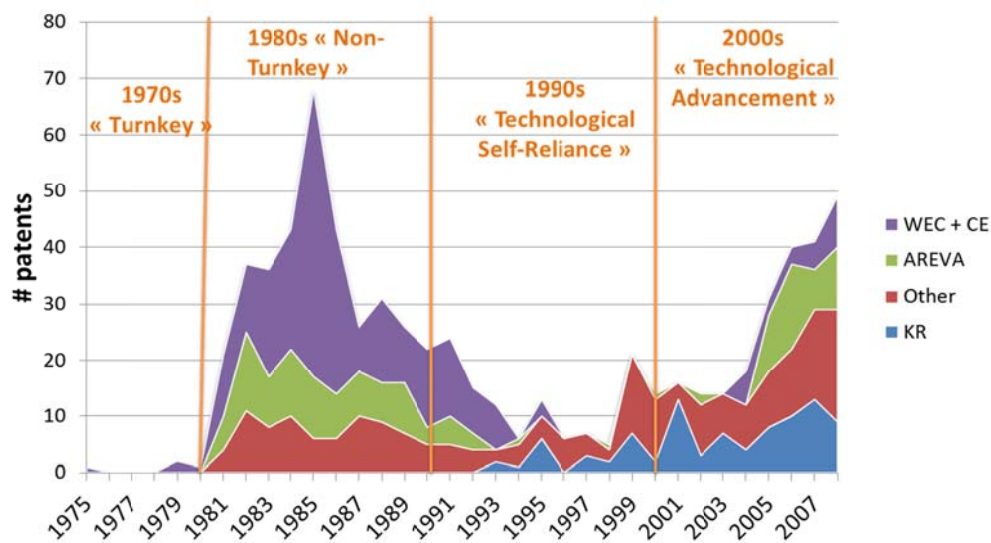
-Finally, since the early 2000s, Korea has started a “technological advancement program” which has led to the development of the APR1400. This program has witnessed the rise of Korean patents but also the resurgence of foreign patent applications. In that respect, the fact that foreign companies continue to patent in Korea has two explanations:(i) These foreign patents may be defensive patents made to protect the intellectual property rights of their inventors at a time when Korea aims to develop new technologies and (ii) they may also be linked with some new licenses⁷⁹.

⁷⁷ The history of Korea nuclear program is usually presented in four steps used in figure 2. For instance, see: <http://www.kaif.or.kr/eng/includes/Brochure.pdf>.

⁷⁸ In 1987, Korea started a ten year technology transfer program with Combustion Engineering. See World Nuclear Association South Korea country profile (updated March 2011), *op. cit.*

⁷⁹ In that respect, Korea decided not to renew its Westinghouse licenses in 2007 and instead to embark on a business cooperation program to replace the APR1400 Westinghouse’s licenses. See World Nuclear Association South Korea country profile (updated March 2011), *op. cit.*

Figure 2: Patent applications in Korea between 1975 and 2008 (Total = 717)



Hence, Korean nuclear technology appears to be mostly based on foreign technologies, predominantly those of Westinghouse (with Combustion Engineering) and Areva. In that respect, it can be argued that this US origin of Korean nuclear technology means that the US still have an influence on Korea's nuclear program especially when exporting nuclear technologies⁸⁰.

These effects do not only have negative impacts on Korean nuclear exports, as the alliance with a US manufacturer reinforces its credibility both in terms of design and fuel supply. In addition, it allows Korean firms to enter new markets with Westinghouse. For instance, Doosan supplies large components for the construction of the two AP1000 in Shanmen and Haiyang, China⁸¹ and is also expected to cooperate with Westinghouse for the construction of AP1000 reactors in the UK⁸². At the same time, Korea depends on the support of the US diplomacy in general as it lacks a strong diplomatic network. The possibility that pressure exerted by the Russians, previously mentioned, forced Korea to opt-out of the Lithuania nuclear tender in late 2010, highlights that Korea may struggle to access markets where other countries exert large influences.

On the other hand, the dependence on US support and the technological reliance on Westinghouse mean that Korea may not be able to enter markets without a cooperation agreement with the US or targeted by Westinghouse with its AP1000 nuclear reactor. Similarly, because Toshiba now owns a majority stake in Westinghouse, it can be expected that Toshiba may ask for Westinghouse to cooperate with Japanese manufacturers instead of

⁸⁰ While we do not have any details on nuclear licenses in Korea, it can be expected that these licenses are restricted to the construction of NPPs in Korea and that new agreements are needed for nuclear exports.

⁸¹ Korea Times (April 27, 2007), Doosan will supply the steam generators and reactor vessels. See: http://www.koreatimes.co.kr/www/news/biz/2010/11/123_1672.html.

⁸² World Nuclear News (March 11, 2011), see: http://www.world-nuclear-news.org/C-Areva_Rolls_Royce_team_up_for_UK_EPRs-1103114.html.

Doosan. Hence, it should not be excluded that, depending on the nuclear tender, the US will favor or not the Korea consortium.

However, in the long run, Korea may be able to enter some new markets for nuclear reactors without the American technology and diplomatic support. Indeed, KAERI's small nuclear reactor "SMART" is not based on an American design and its design is expected to be certified by the Korea Institute for Nuclear Safety (KINS) in 2012⁸³. According to Korean sources, this reactor would allow countries with limited electricity network to access nuclear energy. This reactor could also generate associated advantages with thermal heating and desalination. While small nuclear reactors have generated a growing interest for their technical and economic advantages⁸⁴, these reactors are still at the prototype stage and it is too early to predict what share of the future demand for nuclear new-build they will take.

In that respect, it can be expected that if Korea wants to meet 20 % of the international demand for nuclear new-build in the long run, it will have to be through a combination of large reactors (APRI400, APR+) but also through small, and more numerous, nuclear reactors.

Conclusion

The development of the Korean nuclear program is characterized by its exceptional and continuous expansion. Less than two decades after the end of the Korean war in 1953, Korea embarked on an ambitious nuclear program where it progressively acquired foreign technologies before developing its own standardized reactor design in the 1990s and subsequently improving the design of its reactor with the APRI400. In that respect, nuclear exports can be seen as a natural step for the Korean nuclear program. In the UAE tender, Korea was able to capitalize on the competitive advantages it has acquired at home: a low cost, a high credibility regarding on time delivery and effectiveness and the excellent performance of its nuclear fleet. At the same time, our study shows that the strong political support from the Korean government has also played a key role in the success of Korea in the UAE along with the support from the US firm Westinghouse and the US diplomacy.

While it is difficult today to anticipate what the future demand for nuclear new-build will be in the long run, we argue that the cost advantages of Korea will continue in the future along with a strong support from the Korean government. Nevertheless, Korea will also have to face upcoming challenges for financing nuclear exports and it is expected that Korea will restructure its nuclear project finance organization. More importantly, Korea is aware that it has a limited amount of time in which to enter the market for nuclear new-build: while

⁸³ World Nuclear Association South Korea country profile (updated March 2011), *op. cit.* The SMART reactor could generate up to 100 MWe of electricity with a 60 year design lifetime and a 3 year refueling cycle, see <http://www.world-nuclear.org/info/inf81.html>.

⁸⁴ For more information on the economic advantages of small nuclear reactors see: Ingersoll, D.T. (2009), Deliberately small reactors and the second nuclear era, *Progress in Nuclear Energy* 51, 58-603.

China has to focus, at the moment, on its fast growing national nuclear program, it will most certainly enter the export market in- the next decade, and could prove to be a fierce competitor for Korean nuclear exports.

However, Korea has also realized the importance of alliances in the international market for NPPs. In that respect, its business cooperation with Westinghouse, discrete but effective, will be a clear asset for Korea's long term exports outlook. While it may prevent Korea from entering mature markets such as the US, it will certainly be an advantage in the new-entrant market, through the credibility it adds to the Korean bid and the support of the US diplomacy.

Post-Scriptum

As referred to in the introduction, the Fukushima accident will have both short and longer term implications for nuclear new-builds. While it is too early to anticipate what the various political responses to this nuclear accident will be in the short and longer run, some tentative conclusions can be drawn.

Firstly, public opinion against nuclear and its associated risks is likely to grow. In response, policy makers would increase the safety requirements, postpone the construction of new NPPs and maybe close some aging NPPs (e.g. Germany). It may also be expected that these effects will take place in mature economies with large nuclear reactors fleets (e.g., Western Europe, the US) and for new entrants seeking "turnkey" reactors and that emerging economies with ambitious NPPs construction programs will continue their programs with increased safety scrutiny (e.g. China). Such a reduced demand for nuclear new-builds would likely increase competition between NPPs makers as well the competitive advantages of reactor designs with enhanced safety features. More generally, it would also increase the cost of nuclear power generation, and therefore reduce its competitiveness compared to other energy sources, due to the cost of these additional safety features, but probably also due to the fact that the financial sector would be more reluctant to finance nuclear new-builds and would demand higher risk premiums.

Secondly, given the outlook highlighted above, one may expect that the competitive advantages of the Korean APR1400 would be reduced, as safety would take relatively more importance over price in future nuclear tenders. While Korea has experienced excellent performances in terms of unplanned outage rate, it is clear that increasing the safety of its nuclear reactor design could be a key challenge for Korea in order to maintain its position on the international market for nuclear new-builds. For instance, Korea has declared its intension to propose a core catcher for future nuclear tenders but no demonstration has been made about the capability of Korea to modify its nuclear design to include this component. Hence, improving nuclear safety should become a key priority for Korean R&D and could take the lead over technology self-reliance ambitions, as Korea would seek

cooperation with firms, such as Westinghouse, to design and implement these safety improvements.