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THE INTERNATIONAL TRADE OF NUCLEAR POWER PLANTS: THE SUPPLY SIDE

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The international trade of nuclear power plants is usually studied from a demand perspective. Which new countries are willing to access to this technology? How the Fukushima Daiichi catastrophe has changed the market forecasts? What risks of proliferation new entrants entail? This paper takes an opposite direction. It looks at the structure and the organising of the supply side. Which countries are the major exporters? How their ranking has changed? Is the nuclear export industry becoming a global industry? Part 1 provides a short description of the worldwide market. Surprisingly, its size is modest and the US only plays a minor role. This part also provides a view on the relationship between domestic and export markets. Part 2 discusses the industrial organization of the nuclear industry. It compares the nuclear industry with the armament industry and the oil and gas supplies and services. Part 3 concludes in analysing the conditions nuclear industry could become a global industry.

1. NATIONAL MARKET AND EXPORTING PERFORMANCES

1.1. A small market

International trade in nuclear goods is a small market. This may seem surprising as public attention often focuses on large contracts for the sale of

power plants costing tens of billions of euros. Understandably the news that the South Korean consortium led by the Korea Electric Power Corporation had won the \$20-billion tender to build four reactors in the United Arab Emirates made a powerful impression. But the payments for such contracts are spread out over about 10 years – the time it takes to build the plant – and, above all, there are very few large contracts of this nature. In 2000-10 the global export market amounted to orders for two new reactors a year, some awarded following a call for tenders, others by mutual agreement (US GAO, 2010). Furthermore a nuclear power plant is a complex assembly comprising a pressure vessel, steam generators, piping and a control room, associated with equipment for generating electricity with steam. As with any thermal power plant, it is necessary to install turbines, alternators, capacitors and such. The nuclear island – the specifically nuclear part of a plant – accounts for roughly half its cost, with the conventional part making up the rest. Thus reduced to its essentials, the global reactor market is worth less than €5 billion a year.

However, to this relatively low figure for annual sales of new reactors must be added trade in uranium, fuel, maintenance services, spare parts, reprocessing of spent fuel and waste management. These specifically nuclear up and down-stream activities multiply by three the value of the world market (WNA, 2012). For integrated companies, such as Areva or Rosatom, which cover the whole cycle, business connected to building new reactors represents, at the most, only one-fifth of total revenue. Up and down-stream activities are crucial for such companies, for they are recurrent and profitable. They are also less erratic than orders for new equipment, less subject to intense competition (OECD/NEA, 2008). The operators and owners of nuclear power plants are to a large extent tied by their inputs to the company which built the reactor. For reasons of compatibility, know-how and technical information, the vendor has a competitive advantage over other suppliers of enriched fuel, spare parts and maintenance services. It enjoys market power allowing it to increase prices, and thus profits. Industrial economists, who focus on markets for complementary goods (printers and ink cartridges, razors and blades, coffee machines and pods) are familiar with this mechanism (Carlton & Waldman, 2002). The first item is sold at cost price, or perhaps even subsidized, but the supplier makes up the initial loss on sales of recurring products¹.

1 Anne Lauvergeon, former Areva CEO and well known for being plain-spoken, cited the pods invented by Nestlé in 2008: 'Our model is Nespresso, we sell coffee machines

1.2. The US decline

On the supply side, the US dominated the international market for many years. Until the mid-1970s three-quarters of the plants built elsewhere, were either built by US firms or under licence (Piram, 2009). But this dominant position subsequently crumbled. Its share has dropped to less than a quarter of all the reactors built in the past 20 years. By value, the US accounts (US GAO, 2010) for less than 10% of global exports of nuclear equipment (reactors, large components and small parts), and about 10% of materials (natural uranium and plutonium). Indeed it has become a net importer, amounting to \$15 billion a year. Meanwhile Canada, Russia and France have increased their market share (Finon, 2014). The first two export their proprietary reactor technology; France too, though its technology was originally derived from US imports. South Korea recently joined the nuclear exporters' club, taking a similar route gradually to achieve technological independence (Nam, 2013). Japan is poised to do likewise. Its nuclear engineering companies have responded to calls to tender by new entrants such as Turkey and Vietnam. Former General Electric and Westinghouse licensees, they have gone further than their French and Korean counterparts, purchasing the nuclear assets of the two US companies².

The decline in US nuclear sales abroad is not due to the arrival of more powerful competitors, rather to the collapse of domestic demand. From the mid-1970s to the end of the 2010s not a single contract was signed for a new nuclear power plant in the US. Engineering firms have had to weather more than 30 years without any domestic demand, preceded by years of uncertain profits sapped by the vicissitudes of regulatory pressure, with a major accident in 1979 (Three Mile Island) to crown it all (Joskow & Parsons, 2009). Enough to floor any industrial operation. The decline at home led to a massive loss of industrial capacity and skills in enrichment, the manufacture of large forged parts and construction engineering. On the other hand reactor R&D and design has survived and is

and the coffee to go with them. And coffee is very profitable.' *Le Point*, 10 December 2010, http://www.lepoint.fr/economie/areva-un-geant-de-l-atome-de-la-mine-d-uranium-au-traitements-des-dechets-10-12-2010-1273598_28.php

2 Hitachi holds an 80% share of GE-Hitachi Nuclear Energy, a company resulting from the merger of the two companies' nuclear interests. Toshiba acquired Westinghouse in 2006 over which it has enjoyed full control since 2012.

still of first-class quality. The first new reactors to be built on US soil are Westinghouse AP 1000s. In 2006 China ordered four of these innovative next-generation reactors. General Electric has developed advanced boiling-water reactors too. So the US still features in new nuclear and the international market thanks to innovation and technology transfer. Westinghouse now sells brainpower rather than equipment. It is still earning money thanks to licence fees. For example it received its share of fees on the construction of the four Kepco reactors in the UAE (Berthélemy & Lévêque, 2011). The export version of this reactor still contains parts which belong to Westinghouse, including the software which controls the nuclear chain reaction in the reactor core. In short, the nuclear industry still operating in the US no longer comprises many factories and is partly controlled by Japanese firms, but it is still alive and profitable.

1.3. Domestic market and exports

In general the state of a nuclear engineering firm's domestic market and its export potential are very closely connected (Lévêque, 2013). Just as with the US, it is difficult to enjoy a significant share of the export market, without at the same time building nuclear power plants at home. The industrial fabric is not responsive enough, highly trained staff are not available in sufficient numbers and the technical skills are lacking. Oddly enough, when a domestic market is enjoying powerful growth, there is also less scope for exports: all efforts are focused on success on the home front, meeting deadlines, coordinating production and construction. China is a good example of this point. It is currently building 28 reactors at various places in the People's Republic. Bearing in mind that the manufacture of heavy engineering parts is scheduled several years ahead of the construction project, winning foreign contracts would mean reallocating manufacturing output originally intended for the home market. This would slow down the national programme and delay the projected supply of additional electricity. So the ideal situation for exports is somewhere between non-existent and booming domestic demand. This is the case in Russia, which has exported the largest number of reactors in the past 15 years. Unlike the US, work building new capacity never stopped, though new orders were temporarily shelved in the aftermath of Chernobyl and the collapse of the Soviet Union. Exports to Iran, China and India helped compensate for the momentary drop in demand at home. Ten new reactors

are at present being built in the Russian Federation, and since the end of the 2000s additional contracts have been signed with India and China, but also Turkey and Vietnam. Another case in point is South Korea. Much as in many other sectors this country has succeeded in developing a top-grade national nuclear industry in a very short time. Initially output catered exclusively for the domestic market, building a fleet of reactors, which now numbers 23 and supplies a third of the country's electricity. The aim is to reach 60% by 2030. There is little likelihood of the fleet growing any more. South Korea is a small island, in electrical terms, with no scope for selling surplus output to either its neighbour in the north, or Japan. So without exports there is no room for South Korea's nuclear engineering industry to expand further, or even maintain its present size. Just as it has done in shipbuilding, car manufacture or consumer electronics, it must export or die. It scored its first success with the UAE and it very much hopes others will follow soon.

2. WHICH MODEL: THE ARMAMENT INDUSTRY, OR OIL AND GAS SUPPLIES AND SERVICES?

The nuclear industry is very similar to defence procurement in many respects, but in the future it could resemble oil and gas supplies and services. In addition to the reasons cited above, the international nuclear market is small because individual states keep their orders for national industry, just as for arms. They give priority to technology that is either indigenous (Canada, Russia) or was originally licensed but has subsequently been developed locally (France, South Korea). In the immediate future, it is hard to imagine Russian or South Korean utilities issuing an international call to tender for the construction of a nuclear power plant on their home ground. China today and India tomorrow – if the latter launches an ambitious construction programme – also rely primarily on national firms and their own reactor models. The international market is thus restricted to the delivery of the first plants to be built by one of the main new entrants – in other words countries which will subsequently develop their own fleet – and to supplies to countries which will never possess more than a few units. In both cases, a certain proportion of local content is one of the factors determining the outcome of a tender. The market is more open for large engineering components. EDF recently

purchased 45 steam generators, worth an estimated €1.5 billion, to refurbish its plants, entrusting a quarter of the order to Westinghouse and the rest to its traditional French supplier Areva. As there is only limited global capacity for producing the pressure vessels fitted to the largest reactors, two China's AP 1000s are fitted with boilers manufactured by Doosan, of South Korea, whereas the French EPRs being built in Finland and China will use pressure vessels made by Japan Steel Works.

2.1. Similarities with the arms industry

Another feature reminiscent of the arms industry is the active involvement of government in export contracts. Ministers and even heads of state intervene at a diplomatic level, but also meddle in finance, strategy and even organization. The UAE tender is emblematic in this respect. By 2009 two national consortiums remained in the running for the contract to build the Barakah nuclear power plant. One, led by Kepco, brought together Doosan for the steam-supply system, Hyundai for civil engineering, Korea Hydro and Nuclear Power for system engineering and Korea Power Engineering for design. The rival team, led by Areva, consisted of the utility GDF-Suez, turbine manufacturer Alstom, oil company Total and civil engineering specialist Vinci. Each consortium enjoyed the political and diplomatic backing of their respective head of state. Mr Sarkozy and Mr Lee Myung Bak visited Abu Dhabi several times to persuade UAE President Sheikh Khalifa bin Zayed al-Nahyan to choose their champion. To clinch the deal they offered financing facilities to the buyer, a move that seems almost laughable given the UAE's ample liquidity. The Import-Export Bank of Korea subsequently took out an international loan to fund half the project, no doubt borrowing at a higher rate than UAE banks would have obtained. The two political leaders very probably offered additional sweeteners. It is commonplace for large nuclear contracts to be associated with offers of military assistance, arms sales or infrastructure development projects, but such information is not always made public. Regarding the Korean bid, the only detail which leaked to the press³ was that a battalion had been promised by Seoul to train Emirati armed forces. More surprisingly heads of state may even become involved in details of organization. In the run-up to the final

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

decision Mr Sarkozy intervened to bring EDF into the French consortium, alongside Areva and GDF-Suez. On the Korean side, Mr Lee behaved like a commander-in-chief hectoring and encouraging his troops (Chevalier & Park, 2010). He intervened repeatedly in the preparatory stages of the project and negotiations to seal the contract.

State involvement at the highest level in nuclear export contracts results in companies rallying round the flag. Consortiums are national. Unlike major gas and oil infrastructure projects, they do not field companies from all over the world, which choose to make a joint bid for a tender on the basis of their respective affinities and complementary assets. This inevitably means nuclear consortiums are less competitive. Despite being less effective in terms of costs or know-how a civil engineering firm or own-equipment manufacturer may nevertheless be co-opted because, like the other members of the team, it is French, South Korean, Japanese or Russian. State intervention is not necessarily an advantage for the vendors either. It forces them to reduce their margin, sometimes excessively. As a large nuclear contract attracts considerable media attention, any head of state is very keen it should be awarded to his or her country, in the hope of basking in the glory of successful national firms, particularly as an election campaign approaches. To clinch the deal a head of state may push the national consortium to offer the buyer more favourable terms and prices. It is particularly easy to exert such pressure when, as is often the case, nuclear companies are wholly or partly state-owned. The shareholder in person orders senior management to make do with a pitiful margin, or even to sell at a loss. The winner of a tender is often the biggest loser!

So on the one hand the consortium needs the diplomatic, financial and strategic support of its state apparatus, but on the other hand this may come at a high price.

When it comes to political intervention Russia leads the pack. Civilian nuclear exports are a priority for this country. Much as most gas and oil exporting countries it has very little industry which can compete on the export market. It must rely on raw materials. There is no manufacturing sector which can compete in global markets with top international firms. The only exception is nuclear power. In this field Russia possesses considerable scientific and technical skills, a range of recently designed, powerful

reactor models, and dense industrial fabric. Russian leaders see the export of nuclear technology as a matter of national pride and a source of great prestige. Above all it helps to achieve their diplomatic and strategic goals. The Russian reactors sold abroad are pieces on a global checkboard. In 1995 Russia carried on the job started by Siemens, building a reactor at Bushehr in Iran, on the shore of the Persian Gulf. After a whole series of setbacks it was finally connected to the grid in 2013. The Russians lost a great deal of money on this scheme. In the same part of the world they won a contract with Turkey in the late-2000s for the construction of four reactors. Moscow is funding the whole project, drawing to a large extent, if not wholly, on the federal budget⁴. This subsidy makes perfect sense when seen in the larger context of Russian gas interests. Turkey agreed to allow the projected South Stream gas pipeline to run through its territorial waters. In so doing it changed sides, withdrawing its earlier support from the rival Nabucco project, backed by the European Union. The sale of Russian reactors to Vietnam at the end of the 2010s was also sweetened by advantageous financial terms, this time in the form of export credits. Vietnam has long been a Russian ally in Southeast Asia, particularly on the military front. For nuclear vendors from France, Japan or South Korea, Russia is a particularly tough competitor, the authorities being prepared to invest massively to facilitate reactor exports. Thanks to its gas rent Russia's pockets are well lined. French, Japanese and South Korean heads of state are keen to help their nuclear companies win large contracts abroad, but they do not enjoy the same latitude as Vladimir Putin, nor are their arms so heavily laden with gifts.

State intervention obviously plays a key role in importing countries. Reactor vendors have two customers: the utility which will be operating the nuclear power plant, and the state. It is often more important to win over the latter, particularly if it is the former's only shareholder. The political dimension which dominates the importer's choice of a reactor vendor is manifest in mutually agreed bilateral agreements. For example China and Vietnam did not organize an open call for tenders prior to choosing the plants they purchased from Rosatom in the late-2000s. An opaque selection process enables government to exercise its political and strategic

4 In 2012 State-owned Rosatom received an initial payment of \$750 million. This sum was taken out of the national budget, as a share in the assets of the company specially created to build, own and operate the NPP at Akkuyu.

preferences more freely and obtain often unavowable forms of compensation. Allowing an electric utility to organize an international call for tenders substantially reduces government's discretionary powers. However, in some cases the transparency and competitive openness of the tendering process is merely a front. What really counts is not the score awarded by the expert committee which analyzes the bids, but the opinion of government. It may choose the losing party. Or the loser may be brought back into the running for equally political reasons. China opted to base its first four third-generation reactors on Westinghouse's AP 1000, not Areva's EPR. But it nevertheless ordered two EPRs from the firm shortly afterwards.

2.2. The oil and gas industry as a future model?

Taking the oil and gas supplies and service industry as its model would make the nuclear industry truly international (Locatelli & Mancini, 2012). This industry comprises the firms which supply the infrastructure for oil and gas exploration and production. It is cited here as an example of the engineering, procurement and construction industry, commonly known as EPC. It covers the whole supply chain which contributes to delivery of an oil rig or refinery, but in a broader context refers to any major industrial installation. So it can equally well apply to nuclear power plant construction projects, which involve drawing up an overall plan, adapting to a given site, purchasing hundreds of thousands of parts and the corresponding services to implement the project, and of course its overall completion. Who does what in this huge puzzle depends on the specific contracts, customers and suppliers. Some buyers just want to take possession of a turnkey project. In this case it will be delivered by a single contractor, as is the case with the plant supplied by Areva at Olkiluoto in Finland. It may also be the work of a consortium comprising various contractors, as with the Barakah plant in the UAE. Other buyers want separate contracts for the various parts of the job, for instance making a distinction between the nuclear island and the conventional generating units. In this case the customer must take charge of, or delegate to a design office, the coordination of the various contractors and their respective work packages. The utility may also opt to draw up a large number of supply contracts, acting as its own architect and engineer, as EDF has done at Flamanville, France. Or alternatively it may hire an outside service provider. The diversity of approaches to project management is no different

in oil engineering, procurement and construction. Firms such as Technip, Halliburton or Schlumberger organize themselves in much the same way depending on the circumstances and the demands of the oil companies for which they are working. What is strikingly different in the nuclear industry is the uniformity of the national colours flown by individual companies making up a consortium, and most of their main customers. Russian firms work primarily for Russian utilities; the same is true in Japan; and so, and so forth. Basically the nuclear industry is not a global industry selling to customers all over the world, working with similarly diverse partners and suppliers. In oil engineering, procurement and construction issues related to national politics are only apparent on the demand side, as the world's largest oil companies are publicly owned, from Saudi Arabia to Venezuela, through Norway and Russia.

So could the supply side of the nuclear industry become a multinational undertaking? Could the various companies open up to foreign, private capital, form alliances which disregard their nationality, and cast off the yoke of domestic politics? Or in other words could the nuclear industry take its cue from oil engineering, procurement and construction, rather than mimicking defence procurement?

2.3. International alliances

Two examples the Korean-US alliance in the UAE and the Franco-Japanese partnership in Turkey suggest this may be possible.

The consortium which won the UAE tender was not exclusively South Korean (Berthélemy & Lévêque, 2011). Westinghouse, headquartered in Pittsburgh, Pennsylvania, is part of the team, supplying parts, technical and engineering services, and licensing its intellectual property. Toshiba, which holds a majority share in the US firm, is also involved. The contract does not explain its role, but it will be supplying equipment as a subcontractor for Doosan. The South Korean companies did not have much option but to accept the presence of these two partners. As they are not yet fully independent regarding technology, they needed Westinghouse's agreement. But in turn the latter needed to be authorized by both the US Administration, which controls exports of nuclear equipment, and by its Japanese shareholder. Without the agreement of these two parties, South

Korea stood no chance of honouring an export contract. But the US and Toshiba used this bargaining power to their economic advantage. Over and above such legal considerations, US involvement also brought the South Korean bid a valuable political endorsement to counter the French offer. Indeed the project to build the nuclear power plant started life as a mutual agreement between France and the UAE. The latter's decision to issue an international call for tenders came as a surprise, marking the beginning of the end for the French consortium led by Areva. The US purportedly had a hand in this volte-face. It was bound to take an interest in a nuclear project in the Gulf, opposite Iran. The US has a very strong presence in the UAE, with about 2,000 military and 30,000 residents, some of whom hold key positions in civilian nuclear power⁵. The tender reshuffled the cards and brought General Electric into the game, through its joint venture with Hitachi, GE Hitachi Nuclear Energy. Washington would no doubt have rather General Electric had been awarded the contract, but it soon emerged that its bid was more expensive than the others. At which point US support switched to the Korean option.

The order, which has yet to be finalized by Turkey, is for a medium-sized Atmea reactor, designed by Areva and Mitsubishi Heavy Industries. The consortium is led by the Japanese firm and also comprises Itochu, a Japanese fuel supplier, and the French energy company GDF-Suez. The latter, which operates Belgium's nuclear fleet and boasts a highly qualified team of nuclear engineers, took an early interest in the new reactor. Acting as both architect and engineer it hoped to build and operate one in France, but it ran into opposition from the government and trade unions at EDF. As well as being a potential buyer, it has also positioned itself as a partner in future consortiums, when the customer wants plant operation to be entrusted to an experienced nuclear generating company, at least for the first few years. GDF-Suez has taken on this role for the Turkish project. Japan has several companies with experience in this field, but never overseas. Furthermore their financial predicament has been very challenging since the Fukushima-Daiichi accident, not to mention the stain on their reputation. Parliamentary inquiries have shown that Tokyo Electric Power

5 Before the tender, former NRC Director-General William Travers was the Executive Director of the Emirati authority. He contributed to framing Abu Dhabi's nuclear strategy. David F. Scott is on the board of the Emirates Nuclear Energy Corporation, which will be operating the plants.

was not the only Japanese operator to cut corners on safety in the past (Gundersen, 2012). The bid for the project in Turkey was however largely Japanese, not Franco-Japanese as the French media rather hastily claimed. Indeed the agreement was sealed by the President Tayyip Erdogan and Prime Minister Shinzo Abe, with no French representatives to be seen. This project is nevertheless much closer to oil engineering, procurement and construction than its UAE counterpart, the political dimension having played a much smaller part on both sides of the deal. All the firms in the consortium are privately owned⁶ and two-nation alliance is the result of a strategy based on industrial cooperation on a new reactor model, not some legal obligation.

CONCLUSION: THE CONDITIONS FOR GLOBALISATION

However one swallow does not make a summer. These alliances, between US and South Korean, or French and Japanese companies, are not the first signs of a shift towards multinational consortiums exporting nuclear power plants. At least not in the immediate future. A change of this nature is not on the cards, for it would have to satisfy several improbable conditions. The national character of most bids is due to the diplomatic and geopolitical stakes for nuclear power. We have seen how government meddles in these contracts, on both sides of the bargaining table. If only with respect to the risk of proliferation the stakes will remain just as high. For nuclear companies keen to export their technology, collaboration with government – and the collective game they must consequently play – is all the more critical, given that the firms are dependent on domestic orders. It would make no sense to take the risk of undermining their position at home in exchange for a few sales abroad, as part of multinational consortiums disapproved of by government. Only companies confronted with a moribund domestic market have sufficient latitude to break loose. Substantial growth of the international market, driven by widespread adoption of nuclear power or the opening up of protected

6 The French state owns a 36.7% stake in GDF-Suez but in this capacity has no say in the firm's international development policy, unlike EDF in which it holds an 84.5% share.

home markets, would certainly encourage the formation of multinational consortiums. But hopes of a nuclear renaissance are fading and the main domestic markets, in China, Russia and even South Korea, are closed. As long as the export market for nuclear power plants remains so restricted, there is little likelihood of the industry developing in the same way as its oil counterpart. Finally a change of paradigm of this sort would require massive industrial reorganization. The global nuclear industry is still dominated by vertically integrated companies, spanning the entire cycle, such as Areva, Rosatom, China Nuclear Power and even Korea Electric Power⁷. Furthermore these companies are wholly or partly under state control. It seems unlikely that a subsidiary specializing in fuel preparation, reactor design, engineering or operation would go it alone and join a consortium. Such a move would mean joining forces with foreign competitors of its fellow subsidiaries. Why should the mother company's management and shareholders encourage behaviour of this sort? You can count the potential candidates for creating international consortiums on the fingers of one hand. They are all private companies, with limited vertical integration and an almost non-existent home market: General Electric and Westinghouse in the US, GDF-Suez a company with international interests and the incumbent operator of Belgium's nuclear fleet, and maybe one or two Japanese firms.

To conclude it is likely that the organizing of the nuclear export industry will largely remain nationally-based and shaped by national domestic and foreign policies. As a consequence, one may infer some performance losses in terms of cost minimizing and innovation. Instead of gathering the best complementary firms in the world, the organising of consortia will continue to be constrained by the passport issuance of companies.

7 The Korean case is unusual in the sense that the longstanding publicly owned monopoly was split into various units, including KHNP, which operates hydraulic and nuclear power plants. It was due to be privatized, but a change of government derailed this plan and all the subsidiaries, including numerous firms involved in nuclear power, are still wholly owned by Kepco, in which the state holds a majority stake.

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