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Russia's Nuclear Export Programme

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A B S T R A C T

Since 2009, after a largely dormant period since the Chernobyl disaster, Russia, through Rosatom, has come to dominate the world reactor export market with a new design it claims achieves equivalent safety standards to the latest designs from other vendors. In this paper we examine the structure of the Russian nuclear industry and the technology offered and the political backing that has allowed it to achieve this dominance. We review construction and operation experience with new orders since Chernobyl. We then examine the status of the large number of orders Rosatom has won, the estimates of construction cost and how they compare with those of its competitors. We then examine whether Russia and Rosatom will have the financial and supply chain capability to fulfil more than a small proportion of its order book. Finally, we draw lessons for countries that have placed or are considering placing orders for Russian reactors.

1. Introduction

In 2007, after little activity in the previous two decades following Chernobyl, the Russian nuclear industry re-emerged with a new design, AES-2006, and ambitious sales targets. Initially, the Russian home market was expected to provide three reactor orders per year. However, these forecasts were quickly proved unrealistic and a combination of life extension of existing reactors, low electricity demand and shortage of finance mean that the home market is unlikely to provide a significant flow of orders. In Russia, between 2007 and 2017 construction on only seven reactors started including five using the AES-2006 and two used a pre-Chernobyl design. However, construction of one of the AES-2006s was suspended in 2013, a year after it started and is unlikely to restart and there has been no other construction starts since 2010. The projections in 2016 foresaw only 11 more reactors being built for the home market up to 2030 and those forecasts may prove too high (see Table 3).[1] However, Rosatom has been more successful in export markets and, by 2018, Russia was claiming firm orders for about 35 reactors in 10 countries with advanced negotiations in several other countries. In 2012, Rosatom claimed an order book worth US$50bn[2] but by March 2016, the Chief Executive of Rosatom, Sergey Kiriyenko, said Russia's reactor order book would be worth US$110bn over the following decade and more than US$300bn over the life of existing reactors.[3] If we look at the reactor export market from 2009, when Russia's export drive appeared to take off, to 2018, and count only firm orders with sites specified, Russia accounts for 23 of the 31 orders placed.[4] In this article we focus mainly on orders reported as firm but on which construction has yet to start or is at an early stage.[5] We assume that issues of finance and supply chain will have been largely resolved by the time construction starts and the risk of project abandonment is much lower. Other countries, such as Czechia and Uzbekistan are negotiating with Rosatom for further orders and Bulgaria is reported to be considering reviving the Belene project abandoned s few years ago. We cover the home market only where it gives context to the export effort. We review:

- What factors led to the sudden re-emergence of the Russian nuclear reactor industry;
- The technologies offered;
- The status of its export orders;
- Whether Russia can provide the finance and supply chain to fulfil these exports;
- Russia's nuclear industry's export strategy;
- Policy issues raised for countries considering importing Russian nuclear technology.

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1 For an account of the current state of the Russian home market, see http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx (Accessed April 15, 2016).

2 De Carbonnel, A. 2012. Russia Doubles Nuclear Exports despite Fukushima. Reuters, March 23. http://af.reuters.com/article/energyOilNews/idAFL6E8EN4WP20120323 (Accessed November 15, 2016).

3 Nuclear Intelligence Weekly ‘Kiriyenko Argues Case for Russian Nuclear Expansionism’ March 4, 2016, p 6.

4 The 23 Russian exports include 2 orders each for Jordan and Vietnam which appear unlikely now to go ahead.

5 Orders are regarded as firm when withdrawal by either party would incur penalty charges. It is not always easy to determine when orders are firm as press reports and press releases imply an order is firm when the agreement is no more than a Memorandum of Understanding which does not commit either side.

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Russia competes strongly in fuel cycle activities, but these are not covered.

2. Literature review

There are major problems in analysing Russia's nuclear industry because of the lack of up-to-date, independent and authoritative analysis. This article draws heavily on the trade press, especially nuclear newsletters with correspondents with good access to Russian sources. Pomper (2009) and Mukhatzhanova (2007) provide important political details about the sudden re-emergence of the Russian nuclear industry in 2007. Khlopkov (2016) reviews prospects for nuclear power in the Middle East focusing particularly on Russia's interests.

The damage the Chernobyl disaster did to the credibility of the Russian nuclear industry and rebuilding of the political institutions that followed the collapse of the Soviet Union mean that a temporary withdrawal from competing in the nuclear sector was understandable. The revitalisation of the Russian nuclear industry in 2007 with an aggressive pursuit of export markets is often seen as being closely related to the appointment in 2005 of Sergey Kiriyenko as the Chief Executive Officer (CEO) of the Federal Agency for Nuclear Energy in 2005, renamed Rosatom two years later (Mukhatzhanova, 2007). Kiriyenko had served briefly as Prime Minister of Russia under Boris Yeltsin in 1998 and was a close ally of the Russian President, Vladimir Putin. Mukhatzhanova (2007) argues that the appointment of Kiriyenko was part of a strategy to change the management of the Russian nuclear industry from inefficient government planning to corporate mode. Mukhatzhanova argues it was aimed at consolidating all the diverse elements of the Russian nuclear industry under one company controlled by the President.

3. Historical development

Prior to the 1986 Chernobyl disaster most of orders won by the Russian nuclear industry were for the Russian version of the most widely used reactor type, the Pressurised Water Reactor (PWR), known as the VVER[6] (see Table 1) (Mussapi et al., 1997). The first commercial orders were for a 440 MW design, while later orders used a 1000 MW reactor, most of which were the V-320 version.[7] This design was ordered for two reactors built at Rostov in Russian on which construction started in 2009/10.

In 1986, about 30 reactors of Russian design were under construction worldwide. Some were nearly complete and were brought on line soon after, for example, Paks 3 and 4 in Hungary; others were at an earlier stage and construction was halted before being restarted and completed sometimes without Russian assistance, for example Temelin in Czechia, while others were abandoned, for example, Zarnowiec in Poland.

After the Chernobyl disaster, winning new export orders did not seem to be a high priority for Russia until 2007 (see Table 2). Nevertheless, where strategic opportunities presented themselves, Russia did compete. For markets in Europe, this necessitated that the designs meet the standards required for European markets. A new design was developed for Finland in 1990 in cooperation with the Finnish utility, Fortum. The Finnish Parliament halted these plans in 1993 but the design work formed the basis for the AES-91 design exported to China. The AES-92 design was developed for the Belene project in Bulgaria, not proceeded with, and this design was sold to India.

The Bushehr nuclear power plant in Iran on which construction started in 1975 was for Siemens plants comprising two reactors each of 1200 MW. However, construction was suspended in 1978 at the time of the Iranian revolution. Russia agreed to complete one reactor and construction restarted in 1996 but commercial operation was not until 2013. The single reactor is a V-320 housed in the existing Siemens containment (Khlopkov and Lutkova, 2010).

Table 1
Russia's nuclear power orders up to 1986.
Source: IAEA PRIS reactor data base: https://www.iaea.org/PRIS/home.aspx (Accessed September 8, 2016)

Country	Design	No of reactors	Completion date
Russia	VVER other	2	1964–68
Russia	VVER-440	6	1972–84
Russia	VVER-1000	10	1980–2012
Russia	RBMK-1000	11	1973–90
Russia	Breeder	1	1981
Armenia	VVER-440	2	1977–80
Bulgaria	VVER-440	4	1974–82
Bulgaria	VVER-1000	2	1988–93
Czech Rep	VVER-440	4	1985–87
Czech Rep	VVER-1000	2	2002–03
Finland	VVER-440	2	1977–81
German DR	VVER-440	5	1974–89
Hungary	VVER-440	4	1983–87
Lithuania	RBMK-1500	2	1985–87
Slovak Rep	VVER-440	8	1980-
Ukraine	VVER-440	2	1981–82
Ukraine	VVER-1000	15	1983-
Ukraine	RBMK-1000	4	1978–84

Notes: Includes only reactors with output of greater than 150 MW which were in service or under construction by end 1986 and were subsequently completed or are still under construction.

3.1. *The technologies*

3.1.1. *AES-91 and AES-92*

These designs, developed for but not sold to European markets, were supplied to China (AES-91, Tianwan) and India (AES-92, Kudankulam). Construction of these started in 1999/2000 and 2002 respectively. Rosatom states these designs are essentially V-320 reactors with additional safety systems and changed plant lay-out. For example, Rosatom claims the AES-91 was the first reactor in service with a ‘core-catcher’.[8]

AES-91 with the V-428 reactor was designed by the St Petersburg design office of Rosatom. It was chosen for Tianwan in 1997 and for this site, enhanced earthquake protection measures were included. An updated version (AES-91/99 with the V-466 reactor) was developed for the 1999 Finland reactor tender but the tender did not go ahead.

AES-92, using the V-412 reactor designed by the Moscow office, was destined for the Belene plant in Bulgaria. It was chosen for the Kudankulam project in 1997. While the AES-91 and AES-92 were superseded by the AES-2006, the designs are still being marketed, for example, AES-91 for China and AES-92 for India and Jordan.

3.1.2. *AES-2006*

New safety features developed for AES-91 and AES-92, including reliance on a combination of active and passive safety features and use of a core-catcher, were incorporated in the AES-2006. There was relatively little change to the nuclear steam supply system other than an increase in thermal power output from 3000MWth to 3200MWth. Rosatom's stated priority was to further increase safety in part through greater use of passive safety.

The St Petersburg version of the AES-2006 (using the V-491 reactor) was ordered for the Leningrad site in 2007, was subsequently chosen for

[6] VVER is the acronym for Vodo-Vodyanoi Energetichesky Reaktor. It is sometimes known as WWER.

[7] For an account of the different Russian VVER designs, see: http://www.rosatom.ru/en/resources/b6724a80447c36958cfface920d36ab1/brochure_the_vver_today.pdf (Accessed November 18, 2016).

[8] http://www.rosatom.ru/upload/iblock/0be/0be1220af25741375138ecd1afb18743.pdf (Accessed September 7, 2016).

Table 2
Russia nuclear orders post-1986.
Source: IAEA PRIS reactor data base: https://www.iaea.org/PRIS/home.aspx (Accessed September 8, 2016)

Country	Site	Technology	No of units	Construction start	Commercial operation	Construction time months	Lifetime load factor
Russia	Beloyarsk 4	Breeder	1	2006	2016	123	85.2
Russia	Baltic	AES-2006 St Petersburg	1	2012	?	–	–
Russia	Leningrad 2–1, 2–2	AES-2006 St Petersburg	2	2008–10	*2018, 21*	*120, 120*	-, -
Russia	Novovoronezh 2–1, 2–2	AES-2006 Moscow	2	2008–09	2017, *20*	102, *120*	-, -
Russia	Rostov 3, 4	VVER-1000 (V320)	2	2009–10	2015, *2018*	*72, 96*	79.5
Belarus	Ostravets 1,2	AES-2006 St Petersburg	2	2013–14	*2019, 20*	–	–
China	Tianwan 1, 2	AES-91	2	1999–2000	2007	91, 83	85.5, 87.9
China	Tianwan 3, 4	AES-91	2	2012–13	2018, *19*	*64, 64*	-, -
India	Kudankulam1, 2	AES-92	2	2002	2014, 17	153, 171	55.7, -

Notes.
1. For reactors not yet complete but claimed to be within 2 years of completion, the construction time is estimated from the most recent estimate.
2. Includes only reactors with output greater than 150 MW and on which started construction after 1986.
3. Construction of Baltic 1 was suspended in 2013.
4. Dates in italics are forecasts.
5. Lifetime load factors are to end 2016.
6. In December 2017, Rostov 4 went critical but by June 2018, it was not in commercial operation.

Belarus and Baltic, and is being offered to Finland and Czechia. The Moscow version (using V-392M) was chosen for Novovoronezh and for Turkey. Rosatom lists several detailed differences between the designs including somewhat higher accident probabilities for the Moscow design as well as some dimensional differences.[9]

3.1.3. VVER-TOI

In 2010, Rosatom announced that AES-2006 was being superseded by VVER-TOI, with strong claims on cost and buildability, including costs reduced by 20 per cent, and the construction timeframe limited to 40 months. The design, designated V-510, was developed by the Moscow office. However, it had not been ordered by January 2018, six years after it had been expected to be offered.[10] The first unit of this new design was planned for the Nizhny Novgorod site in Russia, but there is no immediate prospect of this order being placed.[11] It was expected to be used for the Smolensk site but in May 2015, first structural concrete for this plant was put back five years to 2023. Nevertheless, in its plans for reactor construction in the home market, all the large VVER reactors planned use the VVER-TOI and none the AES-2006 (see Table 3). In April 2018, Rosatom poured first concrete for the first of two VVER-TOI reactors at the Kursk site to replace two RBMKs. Expected completion is November 2022, a construction time of 54 months, significantly longer than the 40 months originally projected but still ambitious, especially for a first-of-a-kind design.[12]

3.1.4. VVER-600

One of the 11 reactors planned by 2030 for Russia (Table 3) uses a small design, VVER-600. This design is not an element of Rosatom's export efforts and is not considered further.

3.1.5. RBMK

At the time of the Chernobyl disaster, 10 reactors using the Chernobyl design, the 1000 MW RBMK, were operating in Russia, four in Ukraine at Chernobyl, all shut down and two 1500 MW reactors, both closed, in Lithuania. No further RBMK orders have been placed and this design is not considered further.

Table 3
Russia's home market to 2030.
Source: Nuclear Intelligence Weekly 'Russia Slashes Newbuilds Planned by 2030′ August 12, 2016, p 3

Site	Design	No of reactors	Completion date
Central	VVER-TOI	2	2030
Smolensk	VVER-TOI	2	2030
Nizhny Novgorod	VVER-TOI	2	2030
Tatarskya	VVER-TOI	1	2030
Kola	VVER-600	1	2030
Beloyarsk	BN-1200	1	2030
South Urals	BN-1200	1	2030
Seversk	BREST-300	1	2025

Note: The Beloyarsk, South Urals and Seversk projects are for fast reactors.

3.1.6. Fast reactors

Russia has long pursued fast reactors and, unlike most countries that have built fast reactors, is still actively developing this technology. A 50 MW reactor was built in Kazakhstan and closed in 1999, there are two plants in operation at Beloyarsk (Russia) and the 2030 plans call for three more fast reactors to be built. There are reports that China is interested in Russia's fast reactor technology. At a meeting between Russian Prime Minister Dmitry Medvedev and Chinese Premier Li Keqiang on November 7, 2016, the two governments expressed an intention to cooperate in the development of fast reactors.[13] However, fast reactor technology does not seem to be central to Russia's nuclear export efforts and is not considered further.

3.2. The construction record since 1986

The record of the plants that started construction after 1986 is poor in construction times and in operating performance (see Table 2).[14]

3.2.1. AES-91/92

The experience with these two designs has been bad especially in India where huge delays have occurred and the one unit with a complete calendar year of commercial operation has been unreliable. For China, the operating performance has been good but while the construction time is much shorter than in India, it is still significantly longer than contemporary plants in China built by Chinese vendors, which averages about six years (see Thomas, 2017 for a review of the

[9] http://www.rosatom.ru/upload/iblock/0be/0be1220af25741375138ecd1afb18743.pdf (Accessed September 7, 2016).
[10] Economic News (Information Agency Oreanda) 'Atomenergoproekt OJSC to Develop VVER-TOI Standard Project' June 21, 2010.
[11] Nuclear Intelligence Weekly 'Newbuild Slows but Only Slightly' October 24, 2011.
[12] Nuclear Intelligence Weekly 'Briefs' May 4, 2018, p 8.
[13] Ibid.
[14] Construction times and operating performance are all taken from the IAEA's PRIS database. https://www.iaea.org/PRIS/home.aspx (Accessed October 19, 2016).

recent performance of reactor vendors in terms of construction times and plant reliability).

3.2.2. AES-2006

Only one of the four AES-2006s in Russia had been completed by June 2018, Novovoronezh 2–1, after more than eight years of construction. Initial operation of the plant resulted in two major equipment failures requiring expensive repairs.[15] The other plants are expected to be at least four years late. There is little detail about the causes of these delays (see Thomas, 2015) for a more detailed account of the delays). Given that the Russian plants are likely to take 8–10 years to build, the claims that VVER-TOI, evolved from the AES-2006, can be built in little over three years seem implausible.

The Russian Auditor Chamber blamed funding shortages,[16] but given that the Rostov 3 and 4, which use the pre-Chernobyl design, were not so delayed, this suggests funding shortages were not the only problem. There have been reports of construction failures at the Leningrad plant and an alternative explanation would appear to be difficulties of building the AES-2006. In February 2018, Rosatom announced it was delaying completion of the second units at Novovoronezh and Leningrad overtly to diminish the financial burden on industrial energy users. The 2016 launch of the first unit of Novovoronezh-2 and the BN-800 fast reactor led to a 30 per cent increase in the price of the nuclear power component that users paid.[17]

4. Export markets

As Table 3 shows, the home market for Russian reactors is limited and a draft plan for 2017 foresaw a budget for domestic nuclear build in 2017 of 68.7bn Roubles falling to 57.5bn Roubles in 2018 and to 54.8bn Roubles in 2019, with an increasing proportion of the budget going to completing existing projects.[18]

Up to 1986, Russia's nuclear reactor exports were to countries within its sphere of influence, Soviet Republics or Comecon countries. The customers and regulatory bodies in the importing countries had little influence over the plants they bought so the Russian nuclear industry had little experience of having to meet specific requirements requested by its customers. The exception to this was the order of two VVER-440 reactors in 1970 for Finland. Significant elements of these plants came from other sources, including the Instrumentation & Control system supplied by Siemens and the steel containment and ice condensers supplied by Westinghouse (Linden, 2015). The export markets now being pursued are predominantly open countries, albeit with little experience of nuclear power, where Russia sometimes competes with other vendors and where significant local requirements could arise.

We divide analysis into markets on which construction has already started (Table 2) and new markets, those on which construction had not started by January 2018 (Table 4).[19]

One of the reasons Russia has won many more export orders in the past 10 years compared to the previous period might simply be that there was little or no market for reactors in the period 1990–2005. However, it might equally be argued that Russia played a large part in creating the market that emerged after 2005. Countries like Egypt, Turkey, Vietnam and Nigeria have, for many decades, had publicly funded bodies to develop and promote nuclear power, but the high cost and the difficulty of financing reactors meant that proposals for nuclear orders were not realised and generally did not reach an advanced stage. Rosatom's promise of low prices and finance meant that nuclear power appeared feasible. When Vietnam's order for nuclear reactors from Russia was cancelled, an unnamed Vietnamese official said: 'initially there's a notion that the host country doesn't need to budget for this program, Russia will come in and build this, and then we'll get the electricity.'[20]

Whether Rosatom has deliberately underestimated prices is hard to know but it is a common experience for countries to launch a nuclear power programme based on low prices, only to find, when firm orders were ready to be placed and it was difficult to withdraw, the actual costs were much higher (Rangel and Lévêque, 2013).

How far Rosatom's claims that its new designs meet latest standards were instrumental in winning these orders is hard to determine. The stigma attaching to the Chernobyl disaster required that the new designs be clearly distanced from pre-Chernobyl designs. For European markets, these features would be essential and for some markets with little nuclear history, the apparent assurance that approval by an experienced European nuclear regulator, would be valuable. Some markets seem still willing to order earlier designs, notably China and India, but also Jordan if the order goes ahead.

4.1. Established markets

4.1.1. China

In 1997, China became the first customer post-Chernobyl for Russian nuclear power plants with two reactors of the AES-91 design for the Tianwan site.[21] This was before the surge in reactor ordering that took place in China from 2007 onwards (Thomas, 2016). China ordered two more reactors of the same design for this site on which construction started in 2012/13. However, when, in 2007, China decided on which advanced reactor design to import as a basis for further reactor orders it does not appear to have seriously considered the AES-2006 choosing between the Areva EPR and the Westinghouse AP1000. Exports to China would undoubtedly be attractive to Russia economically as well as politically because of the size of the market and because China would be able to finance reactors. At a meeting between Russian Prime Minister Dmitry Medvedev and Chinese Premier Li Keqiang on November 7, 2016, it was announced that two further reactors of Russian design would be built at Tianwan.[22] There is no suggestion that Russia will win a large share of the nuclear orders placed by China.

4.1.2. India

Like China, India has long been forecast to be a large market for reactors, but this large market has yet to materialise.[23] From 1975 and because of the detonation of its 'Peaceful Nuclear Explosion', the Nuclear Suppliers Group (NSG), which includes all the major nuclear supplier countries, effectively prohibited exports of nuclear facilities to India. However, in 2005, the US Bush administration negotiated an agreement (the '123 Agreement') under which India would separate its civil and military nuclear facilities and place all its civil nuclear facilities under International Atomic Energy Agency (IAEA) safeguards. In August 2008, the IAEA approved the safeguards agreement with India and the NSG allowed it to access civilian nuclear technology and fuel. Most of the world's reactor vendors, including Areva, Westinghouse,

[15] Nuclear Intelligence Weekly 'Russia's newest PWR grapples with large equipment failures' July 14, 2017, p 7.

[16] Nuclear Intelligence Weekly 'Auditor Report Illuminates Rosatom's Financial Challenges' January 23, 2015.

[17] Nuclear Intelligence Weekly 'Newbuild Rollout Impacts Large Energy Users' March 2, 2018, p 4–5.

[18] Nuclear Intelligence Weekly 'Moscow Plans Nuclear Power Spending Cuts' October 14, 2016, p 1.

[19] We follow the normal convention of taking pouring of first structural concrete as the point of construction start as this is the point when major expenditure begins. There are reports from many of Russia's markets of construction starting, for example, Bangladesh and Iran, but this was not structural concrete.

[20] Nuclear Intelligence Weekly, Why Vietnam is Dropping its Nuclear Ambitions, November 11, 2016, p 5.

[21] http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx (Accessed April 15, 2016).

[22] Nuclear Intelligence Weekly, Briefs, November 11, 2016, p 8.

[23] http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx (Accessed April 15, 2016).

Table 4
Russia's export order book in 2018.
Source: Author's research

Country	Site	Units	Technology	Original start to on-line	Status	Expected completion	Cost at agreement	Russian finance
India	Haripur	6	AES-2006					?
India	Kudankulam	2	AES-92/AES-2006	2014–2019		Preliminary works sanctioned		Yes
India	Kudankulam	2	AES-92/AES-2006	2014–2019				Yes
Turkey	Akkuyu	4	AES-2006/VVER-TOI Moscow	2011–2016	Deal signed 5/10[a]	Construction start forecast 2018, on-line 2023–26[b]	US$22bn	Yes
B'desh	Rooppur	2	AES-2006	2008–2013	Deal signed 1/13[c]	Construction start 2017, on-line 2024/25[d]	US$11.8bn	Yes
Vietnam	Ninh Thuan	2	AES-2006 St Petersburg	2014–2020	Deal signed 4/10[e]	Construction start forecast 2022/23, on-line 2028. Order abandoned 11/16	US$10bn[f]	Yes
Finland	Hanhikivi	1	AES-2006 St Petersburg	2018–2024	Deal agreed 9/13[g]	Construction start 2018, on-line 2024	€4–6bn	Yes
Iran	Bushehr	2	AES-92	2015–	Deal agreed 10/14[h]	Construction start forecast 2019	?	Yes
Hungary	Paks	2	AES-2006 St Petersburg	–2023	Deal agreed 1/14[i]	Construction start forecast 2020, on-line 2025–26[j]	€12bn	Yes
Jordan	Al Amra	2	AES-92	–2020	Deal agreed 10/13[k]	Completion 2025[l]	US$10bn	Yes
Egypt	Dabaa	4	AES-2006 St Petersburg	2016–	Deal signed 12/17	Construction start 2018, on-line 2024	US$26bn	Yes
S Africa	Several	8	1200 MW	– 2022–29	No deal confirmed		US$50bn	Yes

Notes: Includes only reactors on which construction had not started by September 2017.

[a] Nucleonics Week 'Akkuyu plant construction to begin in 2011, says Turkish energy ministry' May 27, 2010.

[b] Nuclear Intelligence Weekly 'Moscow Meeting Breathes New Life into Akkuyu' July 29, 2016, pp 4–5.

[c] Nucleonics Week 'Bangladesh, Russia initial contract for construction of Rooppur' December 17, 2015.

[d] http://www.reuters.com/article/us-bangladesh-nuclear/bangladesh-to-start-work-on-first-nuclear-reactor-next-month-minister-idUSKBN1D14KV (Accessed November 1, 2017).

[e] Nucleonics Week 'Russian industry to build Vietnam's first nuclear plant' April 29, 2010.

[f] Prime Tass 'Rosatom to start designing Vietnamese nuclear plant in 2013′ November 12, 2012.

[g] Power in Europe 'Fennovoima aims for 2024′ September 16, 2013.

[h] ITAR/TASS 'Iran to fund construction of 2 new nuclear power units in that country' November 11, 2014.

[i] Nucleonics Week 'Russia financing new units at Hungary's Paks' January 16, 2014.

[j] Nucleonics Week 'Hungary to go ahead with Paks II plan despite EU concerns: government' November 26, 2015.

[k] BBC Monitoring Middle East 'Jordan's first nuclear reactor to start operating by 2025 – official' March 20, 2016.

[l] Ibid.

GE-Hitachi and Rosatom promptly announced deals with India typically for at least six reactors. By 2017, construction of only one reactor, Kudankulam 3 supplied by Rosatom, had started. One problem was the Civil Liability for Nuclear Damage Act, 2010, which holds the operator wholly liable in the event of an accident, gives it a right of recourse against suppliers, albeit limited to a maximum of US$250 m, if the accident is caused by defective equipment (Ramana, and Raju, 2013).

The order for the first two units for Kudankulam was placed in 1988 before Russia became a member of the NSG, but the order was not carried out because of the collapse of the Soviet Union. It was revived in 1998 and construction started in 2002. From 2008 onwards, there were frequent reports that start-up of the reactors was imminent, but it was not till 2013 that the first unit began to produce power. It was declared commercial in December 2014 even though it did not receive an operating license from the Atomic Energy Regulatory Board until six months later. It has proved unreliable in its first three years of operation. In August 2016 the second unit was connected to the grid, but the plant did not enter commercial operation until March 2017.[24] A report to the Indian Parliament in May 2016 listed several components, such as the Reactor Coolant Pump, that need either redesigning and replacement, further inspection, or maintenance.[25] There was a highly critical report by the Indian federal auditor criticising the high cost and the failure to pursue Rosatom for the higher than expected costs.[26]

In 2008, India was expecting to start construction of up to 15 new Russian reactors, four more reactors at the Kudankulam site with six further reactors to be built at two other sites. It was not specified what design would be used but the first of the additional units at Kudankulam use AES-92 technology.[27] Russia claims it has negotiated terms that do not expose it to accident liability. India has stated it could finance its nuclear programme itself. In April 2014, it was reported that Rosatom had signed an agreement with the Indian customer, NPCIL, to build two reactors at Kudankulam[28] but, despite this, construction start on the third and fourth Kudankulam units did not start till June and October 2017 respectively. It appears the issue of vendor liability is still a problem despite India signing the ‘Convention on Supplementary Compensation for Nuclear Damage’ in February 2016.[29] India has massive nuclear expansion plans with a forecast that 49.5 GW of new nuclear capacity not already under construction would be on-line by 2032 at a rough cost estimated by the NPCIL's director of projects of US $155bn. This forecast was a reduction from its submission to the UNFCCC of 2015, which foresaw 62 GW in operation by 2032.[30] Of this new capacity, nearly 80 per cent would be imported, including reactors from Russia. Even if Indian sources such as NPCIL and the government can provide some equity, it is likely that the imported capacity will only be possible if the vendor's government provides the finance or guarantees the loans.[31]

The Kudankulam project is expected to cost Rs39750 crore (about US$6bn) with construction time of 69 months. It was announced that the general framework agreement and credit protocol on construction of units 5 and 6 had been finalised, with their signing to take place before the end of 2016. It was expected that construction of units 5 & 6 would start before construction of units 3 & 4 was complete (about 2023).[32]

4.1.3. Belarus

In 2009, Belarus announced it would order two reactors, expected to be complete in 2016.[33] It had intended to issue a call for tenders but only Rosatom was ready to complete the plant on the schedule required with Areva and Westinghouse not willing to bid.[34] Construction did not start until 2013 for the first unit at the Ostravets[35] site when completion was scheduled for 2018/19. It was reported that Russia would lend Belarus up to US$10bn via a long-term state loan for up to 25 years on preferential terms covering 90 per cent of the expected cost.[36]

The plant was said to still be on schedule in April 2016 but in March 2015, Atomstroyexport admitted the plant would cost more than forecast. It appears this is due to depreciation of the Rouble. At exchange rates of March 2015, the Rouble was valued at about half the level of 2014 of only a year earlier.[37] The contract is denominated in US dollars and the collapse of the Rouble has meant that Atomstroyexport has had to ask Belarus for support despite the contract being reported to be a ‘turnkey’ or fixed price one.[38]

In July 2016, one of the reactor vessels was dropped while being manoeuvred. Belarus has required Rosatom to replace the vessel. This will delay completion of the plant by at least a year.[39] This followed another significant accident in April 2016 when the supporting structure in one of the maintenance buildings collapsed. In August 2016, a worker was killed by an explosion involving an oxygen cylinder. In the first two cases the site management initially denied the accidents had occurred.[40] There is no expectation of further orders for Belarus.

Rosatom states that the construction approach used is applied only in Belarus and Russia. Rosatom CEO, Alexei Likhachev stated: ‘We decide everything ourselves, this reduces the amount of time greatly and lays the mechanisms that insure us against higher costs.’[41] This suggests that experience in Belarus has limited relevance to other export markets.

4.2. New markets

4.2.1. Turkey

Turkey has long planned to build nuclear power plants but has failed so far to turn these plans into orders.[42] In 1983, it announced it would build three reactors with construction expected to start at the Akkuyu site in 1984.[43] There were three subsequent attempts before 2008 to order nuclear plants. In 2008, Turkey launched a tender for

[24] World Nuclear News ‘Kudankulam II project launched’ October 15, 2016, http://www.world-nuclear-news.org/NN-Kudankulam-II-project-launched-17101601.html (Accessed October 17, 2016).

[25] Nuclear Intelligence Weekly ‘Kudankulam-2 Delays Due to Faulty Designs, Components’ May 13, 2016, pp 7–8.

[26] Nuclear Intelligence Weekly ‘Government Auditor Slams Kudankulam Project’ January 5, 2018, p 5.

[27] Nucleonics Week ‘Russia to supply more reactors to India, bringing total to 12’ December 18, 2008.

[28] ITAR-TASS ‘Russia, India sign agt to build second unit at Kudankulam NPP’ April 24, 2014.

[29] Bloomberg ‘Nuclear Liability Concern Lingers Despite India Signing Treaty’ February 25, 2016.

[30] http://www4.unfccc.int/Submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf (Accessed June 4, 2018).

[31] Nuclear Intelligence Weekly ‘Scrambling to Fund a $155 Billion Newbuild Program’ October 14, 2016, p 4–5.

[32] Subramanian, T. S., 2016. Kudankulam ready for more. Frontline, November 11, 2016. http://www.frontline.in/the-nation/kudankulam-ready-for-more/article9266675.ece (Accessed November 15, 2016).

[33] http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/belarus.aspx (Accessed April 15, 2016).

[34] Nucleonics Week ‘First reactors in Belarus to be built by Russians, energy official says’ January 15, 2009.

[35] The site name is sometimes written as Astravyets or Ostrovets.

[36] Nucleonics Week ‘Russia and Belarus to speed up Ostrovets plant construction’ February 7, 2013.

[37] http://www.atomstroyexport.ru/wps/wcm/connect/ase/eng/journalists/press/9e84aa00478814e2b1d9f36578d50f5d (Accessed March 16, 2015).

[38] http://www.world-nuclear-news.org/WR-Belarus-adopts-radwaste-strategy-09061501.html (Accessed June 15, 2015).

[39] Nuclear Intelligence Weekly ‘Rosatom Agrees to Replace Dropped Reactor Vessel’ August 12, 2016, pp 3–4.

[40] Belarus Digest ‘Mysteries of the First Belarusian Nuclear Power Plant’ September 6, 2016. http://belarusdigest.com/story/mysteries-first-belarusian-nuclear-power-plant-27097 (Accessed September 12, 2016).

[41] Russia & CIS Energy Newswire ‘Russia reaffirms interest in building nuclear plant in Uzbekistan, suggests Belarusian partnership model (Part 2)’ May 30, 2018.

[42] http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/turkey.aspx (Accessed April 15, 2016).

[43] Nuclear News ‘Going for three plants’ Nuclear News December 1983.

5000 MW of reactors with six companies expressing an interest including the Atomstroyexport (ASE) subsidiary of Rosatom.[44] The terms of the tender required the supplier to take an equity stake in the plant on the Build Own Operate (BOO) model, a model never used for a nuclear power plant, and required the bidder to specify the electricity sale price. None of the other interested vendors was willing to submit a bid on that basis and by September 2008 they had withdrawn. The initial bid by ASE of €211.6/MWh was rejected. A revised bid of US $153.5/MWh was under negotiation when a Turkish court ruling forced the tender to be scrapped. The Turkish government continued to negotiate and eventually agreed a bid of US$123.5/MWh in May 2010 for four reactors using the AES-2006 design with construction expected to start in 2011.[45]

Since then, there have been continual delays, for example, due to the environmental impact study, but more fundamentally because of the difficulty in attracting Russian and Turkish investors. Rosatom would retain at least 51 per cent of the equity but Turkish investors would take up the balance. In 2014, Rosatom said that of the estimated US$22bn cost of the plant, US$4 billion would be provided from the Russian state budget, with 50–70 per cent provided by Russian and Turkish investors.[46]

The shooting down of a Russian jet by Turkey in 2015 put further doubts on the project.[47] In July 2016, the design of the reactors was said to be AES-2006 with 'elements' of the VVER-TOI, and in December 2017 first structural concrete was expected to be poured in March 2018 with first power in 2023.[48] In June 2017, a consortium of Turkish investors agreed to take the 49 per cent of the project required to be taken up by Turkish investors[49] and in October it was announced GE-Alsthom would supply the turbine generators.[50] However, in February 2018, the three Turkish investors, a consortium of Cengiz, Kolin and Kalyon withdrew.[51] Rosatom has stated it expects to announce new partners to take up this stake in 2019[52] but that it could finance the plant entirely by itself.[53] Despite these problems, first structural concrete was poured in April 2018.[54]

4.2.2. Bangladesh

In 2009, Bangladesh signed agreements with Russia for the construction of reactors at the Rooppur site.[55] At that time, the Bangladesh energy minister claimed a 1000 MW reactor would be in service within 5 years.[56] The cost of two reactors was expected to be US$1.5bn. There were continual delays to the ordering of the reactors and time-scales continued to slip despite the laying of a foundation stone in 2013.

In December 2015, Bangladesh and Russia reached an agreement which foresaw power from the first unit in 2022 with the second unit following a year later. The expected cost was US$13.15bn with Russia providing financing for 90 per cent of the total costs, US$11.8bn and Bangladesh providing the rest.[57] In July 2016, the Bangladesh and Russian governments signed an agreement for Bangladesh to borrow US $11.385bn, 90 per cent of the expected construction cost. The loan cost would be six-month Libor plus 1.75 per cent per annum with a cap of 4 per cent, to be repaid in 28 years, starting in 2026.[58] In November 2017, first concrete was poured with completion of the two units expected in 2023/24.[59] However, there were serious concerns about the project including shortage of qualified personnel and doubts about the site such as the risk of flooding, earthquakes and water shortages.[60] In March 2018, Bangladesh, Russia and India signed a three-way Memorandum of Understanding for cooperation on nuclear power including India's participation in the construction of Rooppur.[61]

4.2.3. Vietnam

In 2010 the Vietnamese government announced it had chosen Rosatom to supply the first two of seven reactors to be ordered by Vietnam, on turnkey terms, for the Ninh Thuan site. It planned to have all seven reactors in service by 2030.[62] Construction on the Russian reactors was expected to start in 2014 with first power in 2020.[63] Subsequently the 2030 target was increased to 14 reactors and the order for Ninh Thuan had an option for two more reactors added. Rosatom competed with Areva and a Japanese consortium comprising three Japanese vendors (Hitachi, Toshiba and Mitsubishi). Subsequently the Japanese consortium won an order for four reactors and a Korean consortium was negotiating to supply two reactors.

In 2011, Russia agreed to lend US$7.7bn to finance the plant.[64] The original schedule slipped continually and despite reports that construction had started in 2011, by 2015, construction was not due to start till 2020.[65] In November 2016, Vietnam scrapped its nuclear programme.[66] One of the reasons cited was that the expected price for the two Russian reactors had doubled to US$18bn. There were reported to be safety concerns (Khai, 2016). The proposal to build two reactors supplied by Japanese companies was scrapped.[67]

4.2.4. Finland

The experience of building the French Olkiluoto reactor in Finland has been poor. By 2017 its expected completion date was ten years late, it was about three times over-budget. Despite this, in 2007, when it was clear that construction at Olkiluoto was going badly, three consortia were competing to build plants, two using sites of existing reactors and a third, Fennovoima, using a new site, Hanhikivi. The proposals for the

[44] Nucleonics Week 'Turkey to pick reactor vendor by end of 2008′ January 31, 2008.

[45] Note, the original report gives the price as Eurocent, but subsequently the prices are given as US cents. Nucleonics Week 'Akkuyu plant construction to begin in 2011, says Turkish energy ministry' May 27, 2010.

[46] Nucleonics Week 'Turkey's Akkuyu nuclear project affected by ruble fall: minister' January 29, 2015.

[47] International New York Times 'Standoff hardens as Russia and Turkey trade blame over jet' November 27, 2015.

[48] Nuclear Intelligence Weekly 'Russia sweep in the Middle East' December 15, 2017.

[49] http://www.world-nuclear-news.org/C-Turkish-consortium-to-buy-into-Akkuyu-project-2006175.html (Accessed June 20, 2017).

[50] Nuclear Intelligence Weekly 'Briefs: Hungary' January 19, 2018, p 8.

[51] Nuclear Intelligence Weekly 'Akkuyu Reactor Investment Talks Collapse' February 9, 2018, p 3.

[52] Turkey Today 'CEO of Russia's Rosatom expects sale of 49% in Turkey's planned Akkuyu nuclear power plant in 2019′ March 29, 2018.

[53] https://www.aa.com.tr/en/todays-headlines/russia-capable-of-constructing-akkuyu-nuke-alone-novak/1110370 (Accessed June 7, 2018).

[54] Nuclear Intelligence Weekly 'Putin-Erdogan Relationship Key to Akkuyu Progress' April 6, 2018, p 4.

[55] http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/bangladesh.aspx (Accessed June 15, 2015).

[56] BBC Monitoring South Asia 'Bangladesh nuclear power plant to generate power in five years – minister' June 6, 2009.

[57] Nucleonics Week 'Bangladesh, Russia initial contract for construction of Rooppur' December 17, 2015.

[58] Daily Star 'Dhaka, Moscow sign $11.385bn credit deal for nuke plant' July 26, 2016. http://www.thedailystar.net/country/dhaka-moscow-sign-11385bn-credit-deal-nuke-plant-1259767 (Accessed September 9, 2016).

[59] http://www.world-nuclear-news.org/NN-Construction-under-way-at-Rooppur-1–3011177.html (Accessed December 1, 2017).

[60] Nuclear Intelligence Weekly 'Is Bangladesh Ready for Nuclear?' December 22, 2017.

[61] https://economictimes.indiatimes.com/news/defence/india-russia-bangladesh-sign-tripartite-pact-for-civil-nuclear-cooperation/articleshow/63127669.cms (Accessed June 4, 2018).

[62] Nucleonics Week 'Russian industry to build Vietnam's first nuclear plant' April 29, 2010.

[63] http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/vietnam.aspx (Accessed April 15, 2016).

[64] TASS 'Russia, Vietnam agree on loan for nuclear plant construction' October 25, 2011.

[65] ITAR TASS 'Russia to construct nuclear plant in Vietnam despite rescheduling of construction launch - First Deputy PM' December 16, 2015.

[66] http://www.dw.com/en/vietnam-ditches-nuclear-power-plans/a-36338419 (Accessed November 14, 2016).

[67] Nuclear Intelligence Weekly, Why Vietnam is Dropping its Nuclear Ambitions, November 11, 2016, p 5.

existing Olkiluoto and Loviisa sites are no longer actively being pursued.[68]

The Fennovoima consortium was led by the German utility, E.ON but it withdrew in 2012. In 2013, an agreement was reached with Rosatom under which it would supply an AES-2006 reactor using the St Petersburg variant and would take a 34 per cent stake in the Fennovoima consortium. The Finnish consortium wanted the remaining stake to be held by Finnish investors and this has proved problematic. By 2017, there were signs that some of the Finnish investors wanted to exit the project.[69] Rosatom's stake of €2.4bn was to come from Russia's National Welfare Fund.[70] The expected cost was estimated by Fennovoima in 2014 as €4–6bn,[71] but in 2015, this had increased to €6.5–7bn.[72] Construction is expected to start in 2019 with completion in 2024 although by October 2016, Rosatom was a year late in submitting design documentation to the Finnish safety regulator, STUK.[73] In January 2017, STUK warned of a delay of about nine months in it completing its safety assessment due to lack of skills in the project management team.[74] In April 2018, delays in issuing the construction license and additional regulatory requirements for the manufacture of the reactor vessel meant that construction start would not be before 2020 and the 2024 target completion date was implausible.[75] In August 2017, it was announced that GE-Alsthom would supply the turbine generator.[76]

4.2.5. Iran

Iran's first nuclear power agreement with Russia was signed in 1992 when Russia agreed to complete construction of a reactor, Bushehr, purchased from Siemens on which construction had started in 1975 (see above). This deal obliged Russia to build four more reactors. In November 2014, a deal was announced for the construction of two reactors at the Bushehr site with six more reactors to follow.[77] At that time, construction was expected to start in March 2015. Since then, there has been uncertainty about the scale of the programme, its timing and finance. In October 2015, Iran expected to start building up to 9 GW of capacity in the following decade with 2 GW, the two units at Bushehr, to be supplied by Rosatom, 1 GW by China and 6 GW by 'Western' suppliers.[78] In April 2016, construction start on Bushehr had been delayed 'due to some technical issues and different views on some indicators'.[79] First concrete was then not expected to be poured before the second half of 2019 with first power in 2026 and a second reactor would be two years behind.[80]

In 2014 the Atomic Energy Organisation of Iran (AEOI) planned to finance the programme then estimated to cost US$9–10bn, on its own,[81] but by October 2016, the low world oil price was having an impact. The budget of AEOI had been significantly cut, and the government was no longer willing to commit to underwriting the addition of 9 GW of new nuclear capacity. In 2014, Moscow offered a "soft loan" of US$3bn for non-nuclear infrastructure projects in Iran. However, in October 2016, Iran was asking for the US$3bn to be re-allocated to the Bushehr project.[82]

4.2.6. Hungary

In the 1980s, Hungary built four 440 MW reactors supplied by Russia at the Paks site with the expectation that two units of about 1000 MW would be built there.[83] In 2006, the Hungarian utility, MVM, re-opened the plans for new reactors at Paks hoping an open call for tenders would take place in 2012. The tender did not take place and in January 2014 the government signed an agreement with Rosatom to build two reactors at Paks, with Russia providing 80 per cent of the finance, amounting to €10bn. Hungary must pay annual interest of 3.95 per cent on portions of the loan already drawn, starting in 2014. Repayment of the loan principal will commence upon completion of the new units or in March 2026 — whichever occurs first — and will last 21 years.[84] The terms of the loan have caused concern because of the risk that Hungary might have to start repaying loans on a facility that was not yet generating income. The European Commission was concerned that the loans represented unfair state aid. In November 2016, it announced that the case had been closed with no in-depth investigation needed.[85] The Commission accepted Hungarian government's claim that only Rosatom could meet the technical requirements, a claim disputed by the nuclear vendor, Westinghouse.[86] In November 2017, Hungary began to draw on the Russian loan and in January 2018, contracts for the turbines were awarded to GE for €793 m.[87]

The Russian Vnesheconombank (VEB) was chosen to lend the money for the project, however, by December 2015, it was in deep financial difficulties, requiring US$16bn to bail it out.[88] In June 2016, Hungary was examining alternative ways of financing the project borrowing from the open financial market.[89]

4.2.7. Jordan

In 2007 Jordan began the process to order nuclear capacity when it expected 30 per cent of its electricity would be supplied by nuclear power by 2030 (Ramana and Ahmad, 2016).[90] Jordan contacted several vendors including AECL for CANDU technology, Mitsubishi-Areva for the ATMEA design, KEPCO (Korea) and Rosatom (AES-92). The vendors other than Rosatom were not pursued and there were difficulties finding a suitable site because of seismic concerns and lack of cooling water. In October 2013, the Jordan Atomic Energy Commission (JAEC) announced it would build two Rosatom reactors using the AES-92 design at the Al Amra site with expected completion of the first unit by 2022.

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[68] http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/finland.aspx (Accessed April 14, 2016).

[69] Nuclear Intelligence Weekly 'Cracks in Mankala Model Expose Hanhikivi's Vulnerability' February 10, 2017, p 4.

[70] Nucleonics Week 'Hanhikivi funding not affected by economic crisis: Rosatom exec' June 4, 2015.

[71] Nucleonics Week 'Fennovoima signs agreements with Rosatom for reactor, investment' January 2, 2014).

[72] http://www.fennovoima.fi/uutiset/uutiset/vastaus-greenpeacen-avoimeen-kirjeeseen (Accessed October 26, 2016).

[73] http://www.hs.fi/talous/a1476932738035 (Accessed October 26, 2016).

[74] Nuclear Intelligence Weekly 'Dearth of Qualified Personnel Stalls Hanhikivi' February 24, 2017, p 6.

[75] Nuclear Intelligence Weekly 'Hanhikivi Faces Licensing and RPV Delays' April 20, 2018, p 4.

[76] Nuclear Intelligence Weekly 'Briefs: Hungary' January 19, 2018, p 8.

[77] Al-Akhbar 'Russia to build nuclear power plants in Iran as talks near deadline' November 11, 2014.

[78] Nuclear Intelligence Weekly 'Iran's Massive Civil Nuclear Plans', October 2, 2015, p 3.

[79] Mehr News Agency 'Bushehr plants construction delayed for 'technical issues'' April 3, 2016.

[80] Nuclear Intelligence Weekly 'Briefs' November 3, 2017.

[81] RIA Novosti 'Construction of 2nd Unit at Bushehr NPP May Start in March - Iranian Ambassador to Russia' February 8, 2016 and ITAR-TASS 'Iran to fund construction of 2 new nuclear power units in that country - Russian nuclear chief' November 11, 2014.

[82] Nuclear Intelligence Weekly 'Falling Oil Prospects Dim Iran's Nuclear Prospects' October 7, 2016, p 6.

[83] http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/hungary.aspx (Accessed April 14, 2016).

[84] Nucleonics Week 'Hungary approves Eur10 billion Russian funding for new Paks units' June 26, 2014.

[85] http://ec.europa.eu/atwork/applying-eu-law/infringements-proceedings/infringement_decisions/index.cfm?lang_code=EN&r_dossier= &noncom= 0&decision_date_from= 17%2F11%2F2016&decision_date_to= 17%2F11%2F2016&active_only= 0&EM=HU&title= &submit=Search (Accessed November 18, 2016).

[86] http://www.politico.eu/article/questions-grow-over-hungarian-no-bid-nuclear-deal/ (Accessed November 25, 2016).

[87] Nuclear Intelligence Weekly 'Briefs: Hungary' January 19, 2018, p 8.

[88] Channel News Asia 'Putin removes head of VEB state development bank as crisis bites' February 18, 2016.

[89] Intellinews 'Hungary eyes nuclear options as doubts grow over Paks deal' June 20, 2016. http://www.intellinews.com/hungary-eyes-nuclear-options-as-doubts-grow-over-paks-deal-100206/ (Accessed September 9, 2016).

[90] http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/jordan.aspx (Accessed April 15, 2016).

The plant would be built on the BOO model proposed for Turkey with Rosatom taking a 49 per cent stake and the Jordanian government holding the rest.[91] By March 2016, the completion date for the first unit had slipped to 2024/25[92] and the Chairman of the Jordan Atomic Energy Commission put the odds of the plants being built as about 70 per cent and other options not involving Russia, such as Small Modular Reactors were being examined.[93] The financing model for the US$10bn project is that the project would be 30 per cent equity funded with the rest from debt (borrowing) meaning the Jordanian government would have to contribute US$1.5bn in equity. To reduce this burden on the Jordanian government, JAEC was asking for tenders to build the conventional part of the plant from suppliers such as the Chinese company, CNNC, who would bring export credit financing but by September 2017, no deal had been done.[94] By mid-2018, it appeared the plan to build large reactors had been abandoned because of the scale of investment and Jordan was investigating building Small Modular Reactors with amongst others, Rosatom, China National Nuclear Corp and Rolls Royce linked with the project.

4.2.8. Egypt

Egypt has on several occasions pursued orders for nuclear power plants over the past three decades but with no success. In October 2013, after Abdel Fattah al-Sisi assumed power in the July 2013 coup, Egypt solicited bids from five reactor vendors, three of which responded, Rosatom, China National Nuclear Corp and KEPCO. In November 2015, Russia and Egypt signed agreements for Russia to supply and finance four 1200 MW reactors for the Dabaa site. The contract was for US $26bn, with Russia providing finance of US$25bn covering 85 per cent of the costs, with Egypt covering the rest.[95] Egypt will pay an interest rate of 3 per cent annually, according to the report in the country´s official gazette in May 2016. [96] The loan will be used from 2016 to 2028, repayments will be over 22 years in 43 instalments with first repayments in 2029.[97] First power was expected in 2024, although al-Sisi claimed in February 2016 that construction would start in ‘the coming few weeks’.[98] By October 2016, negotiations seemed to be going rapidly with an Engineering Procurement and Construction contract to buy four 1200 MW reactors expected to be signed ‘within weeks’ with completion of the first unit expected within eight years of this signing.[99] In December 2017, the deal, by then estimated to be for US$30bn, was completed with first power forecast for the end of 2024.[100]

4.2.9. Nigeria

In 2015, Nigeria and Russia were negotiating the purchase of four 1200 MW reactors. The first two would be in the state of Kogi at Geregu while the second two would be in the Akwa Bom state at Itu. In April 2016, it was not clear whether a formal contract had been signed.[101] The Nigerian government was claiming construction would start in 2016 with first power in 2025. No details of how the plants would be financed have been given but given the low world oil price, there is an expectation that Nigeria would need finance from Russia. In October 2017, Nigerian Atomic Energy Commission and Rosatom signed an agreement on the construction and operation of a nuclear power plant. The initial steps were feasibility studies, suggesting construction start is some way off.[102]

4.2.10. South Africa

South Africa operates two reactors imported from France, commissioned in 1984/85.[103] From 1998, South Africa has tried to pursue further nuclear orders on several occasions but with no success. In 2008, it conducted a call for tenders for about 3 GW of nuclear capacity, but this had to be abandoned because of difficulties of obtaining finance. Nevertheless, in 2010, the government carried out an Integrated Resource Planning exercise and, despite nuclear power not being the lowest cost option, imposed a programme of 9600 MW of new nuclear capacity to be complete by 2030.[104] Progress was slow but in 2013, memoranda of understanding had been signed with six countries – Russia, USA, Canada, Korea, France and China – who were expected to bid in a call for tenders. However, the MOU with Russia was different in character to the others with more explicit details and by April 2016, it was still in dispute whether a deal with Russia had already been concluded. In November 2013, the South African energy minister, Tina Joemat-Pettersson, said ‘I am sure that cooperation with Russia will allow us to implement our ambitious plans for the creation by 2030 of 9.6 GW of new nuclear capacities based on modern and safe technologies.’[105] This appeared to contravene South Africa's public procurement legislation which requires it should be ‘fair, transparent and competitive’. Because of difficulties of finance and the deteriorating credit rating of the South Africa electric utility, Eskom, whose rating was ‘junk’ and even the South African government itself whose rating was little better, the common assumption was that the deal would only be possible with Russian finance. The BOO model, as proposed for Turkey was frequently mooted.

However, in April 2017, the South African High Court ruled that Intergovernment Agreement with Russia (and those with Korea and the USA) and government's decision to buy 9600 MW were illegal. The government did not appeal the decision, and this seems to set South Africa's nuclear ambitions back by years.[106]

4.3. Construction costs

Reliable outturn costs are not available for any of the AES-2006 reactors. However, most of the export projects for these reactors do have forecast costs (see Table 5). While prior cost estimates have seldom been a good indicator of outturn costs, they do give some indications. The projects are frequently reported to be ‘turnkey’ that is fixed price, for example Belarus, Iran, Vietnam, Bangladesh and Hungary. However, if unexpected costs do arise as happened in Belarus, there must be doubts whether Rosatom will absorb them.

Care must be taken in interpreting this data for several reasons.

[91] Jordanian Times ‘Russian firm set to build Jordan's first nuclear plants’ October 28, 2013.

[92] BBC Monitoring Middle East ‘Jordan's first nuclear reactor to start operating by 2025 – official’ March 20, 2016.

[93] Nuclear Intelligence Weekly ‘Briefs’ July 8, 2016, p 9.

[94] Nuclear Intelligence Weekly ‘Looking for Better Offers’ October 21, 2016, p 5–6.

[95] Rusdata ‘Moscow, Cairo to ink $26bn nuclear plant construction deal in Q1 2016′ December 30, 2015.

[96] Nuclear Intelligence Weekly ‘Egypt Approves $25 Billion Loan From Russia for Nuclear Project’ May 20, 2016, p 1.

[97] The News ‘Russia to lend Egypt $25 billion for nuclear power plant’ May 20, 2016. http://www.thenews.com.pk/print/121204-Russia-to-lend-Egypt-25-billion-for-nuclear-power-plant# (Accessed May 20, 2016).

[98] Africa News ‘Egypt; President Abdel Fattah El Sisi Addresses the Parliament’ February 14, 2016.

[99] Nuclear Intelligence Weekly ‘Closing in on an EPC Contract for Dabaa’ October 2, 2015, p 7.

[100] Nuclear Intelligence Weekly ‘Rosatom Locks in $30 Billion Nuclear Deal in Egypt’ December 15, 2017, p 3.

[101] RIA Novosti ‘Russia to Launch Construction of Nigeria's First Nuclear Plant in 2016 - Nigerian Diplomat’ August 14, 2025.

[102] http://www.world-nuclear-news.org/NN-Agreements-signed-for-Nigerian-nuclear-project-3110177.aspx (Accessed November 10, 2017).

[103] http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-africa.aspx (Accessed Apr 15, 2016).

[104] http://www.gov.za/sites/www.gov.za/files/Executive_Summary_Draft_IRP2010_2_final_20101007_0.pdf (Accessed Apr 15, 2016).

[105] Mail & Guardian ‘SA, Russia agree to $50-billion nuclear deal’ September 23, 2014. http://mg.co.za/article/2014–09-23-sa-russia-agree-to-50-billion-nuclear-deal (Accessed Apr 15, 2016).

[106] http://www.groundup.org.za/article/court-rules-controversial-nuclear-power-deals-were-unlawful-and-unconstitutional/ (Accessed June 19, 2017).

Table 5
Recent cost estimates for AES-2006 exports.
Sources: India: http://www.thehindu.com/news/national/modi-putin-to-inaugurate-kknpps-unit-3–4-civil-works/article9218690.ece

Country	Site	Cost estimate US$/reactor	Date
India	Kudankulam 3, 4	3bn (Rs19,375 crore)	10/16
Turkey	Akkuyu 1–4	5.5bn	10/14
Egypt	Dabaa	6.5bn	5/16
Bangladesh	Rooppur 1, 2	6.6bn	12/15
Hungary	Paks	6.7bn (€6.25)	6/14
Finland	Hanhikivi	7–7.5bn (€6.5–7bn)	8/15
Vietnam	Ninh Thuan 1, 2	9bn	10/16

Vietnam: http://www.dw.com/en/vietnam-ditches-nuclear-power-plans/a-36338419.
Finland: http://www.fennovoima.fi/uutiset/uutiset/vastaus-greenpeacen-avoimeen-kirjeeseen.
Bangladesh: Nucleonics Week ‘Bangladesh, Russia initial contract for construction of Rooppur’ December 17, 2015.
Turkey: http://www.hurriyetdailynews.com/construction-of-first-turkeys-nuclear-plant-to-begin-next-spring-in-akkuyu.aspx?PageID= 238&NID= 72824&NewsCatID= 348.
Egypt: Rusdata ‘Moscow, Cairo to ink $26bn nuclear plant construction deal in Q1 2016′ December 30, 2015.
Hungary: Nucleonics Week ‘Hungary approves Eur10 billion Russian funding for new Paks units’ June 26, 2014.
Notes:.

1. All internet sources accessed November 15, 2016.
2. Based on exchange rates on November 15, 2016.
3. The reactors for Kudankulam 3 & 4 are expected probably to use the AES-92 design.

Where estimates published were not in US dollars the dollar estimate is dependent on an exchange rate assumption. The figures in Table 5 are based on a dollar/Euro exchange rate of 1.07, which was the rate applying in mid-November 2016. The cost estimates do not specify their basis: for example, do they include financing costs, do they include transmission link costs?

The range of estimated costs is wide. The estimate for India, which will probably be for the AES-92 design rather than the AES-2006, is remarkably low. This may be accounted for by the fact that the estimate comes from the Indian customer, NPCIL, rather than Russian sources. NPCIL has a target of 49.5 GW of new capacity in operation by 2032, which it estimates will cost US$155bn or about US$3100/kW. Its estimate for the next two new units at Kudankulam appears consistent with that rather than being based on a Rosatom estimate. The estimate for Turkey appears low but this may be because it dates from the signing of the deal in 2010, which commits Russia to a fixed selling price. Rosatom therefore has no interest in publicly updating the cost estimate. The Egypt, Hungary and Bangladesh estimates are similar and equate to about US$6000/kW. There have been so few tenders for reactors in the past five years that it is difficult to make comparisons with other vendors. The estimates for Finland and Vietnam (US$7000/kW and US$8500/kW) are of a similar order to the cost agreed in September 2015 for the UK Hinkley Point reactor of about US$7000/kW (Thomas, 2016).[107] This evidence is limited and until outturn costs are published it will not be possible to make accurate cost comparisons with those of its competitors. Nevertheless, the cost estimates shown in Table 5 do not support an assumption that Russian reactors are cheaper than those of its competitors. In the long run, the competition for the Russian nuclear industry may come from China which has yet to bid in an open contest and from where no worthwhile cost data is yet available. It is impossible to assess the competitive position of Russia's nuclear industry against that of China.

5. Russia's capacity to fulfil its exports

Rosatom claims orders for about 35 reactors on which construction has yet to start or has just started accounting for more than half of all the world's nuclear export orders. It expects to start building about five VVER reactors for the home market by 2025. Most of the exports are only viable if Russian finance is supplied. The Russian economy was in a poor state by mid-2016 mainly due to the collapse of the world oil price and sanctions imposed on Russia resulting from Russia's annexation of Crimea. From the time of the Chernobyl disaster to 2007, Russia started construction on four new reactors and from 2007 to 17, it started construction on only 10 reactors. To fulfil the order book of about 40 reactors on current forecast timings, Russia would need to start construction on about 4–5 reactors per year.

This begs the questions: how many export reactors is Russia capable of providing the finance for; and how many reactors can Russia's reactor supply chain provide in the next decade?

5.1. Finance

In January 2016, Russia's deputy finance minister, Sergei Storchak, announced that Russia would suspend granting any new loans to foreign countries, including for nuclear projects, due to budget cuts, but all previous loan agreements would be fulfilled.[108] In June 2016, Reuters reported that there were plans to use some of the National Wealth Fund, expected to be used to finance the Hanhikivi reactor for Finland, to cover some of Russia's budget deficit. The Deputy Minister of Economic Development, Nikolai Podguzov, said in September 2016 that the National Wealth Fund, which was set up to pay pensions would not be used in future to any significant extent to fund infrastructure projects, saying ‘rational approaches now prevail’.[109] Its banking sector was in disarray with VEB, a state-owned development bank expected to finance Hungary's Paks project requiring a bail-out by the Russian government costing US$18bn. It seems unlikely Russia has the capability to provide the level of financing that fulfilling a high proportion of its order book would require.

5.2. Supply chain

It is hard to assess the strength of Rosatom's supply chain in terms of its capacity and its quality given the difficulty of getting authoritative information from Russia and the lack of progress with its order book.

[107] The cost agreed was £9bn for each 1650 MW reactor. This equates to about US $7000/kW at November 2016 exchange rates but equates to US$8200 at pre-Brexit exchange rates. https://www.gov.uk/government/news/hinkley-point-c-to-power-six-million-uk-homes (Accessed November 16, 2016).

[108] RIA Novosti ‘Russia to Suspend Granting New Foreign Loans Due to Budget Cuts - Deputy Finance Minister’ January 18, 2016.

[109] ITAR-TASS ‘New infrastructural projects hardly be financed by NWF resources - Deputy Economy Minister’ September 2, 2016.

However, some insights on quality can be gained from the preparations in Finland to build the Hanhikivi reactor. Construction is expected to start in 2020 and the Finnish nuclear regulator, STUK, a well-respected open and transparent regulatory body, has begun to inspect Rosatom's facilities to determine whether they meet the required standard.

In 2015, STUK inspected Rosatom's OKB Gidropress facility (designer of the primary circuit), its RAOS Project facility (supplier of the reactor) facility and its Atomproekt (main designer of the reactor). STUK's report[110] found shortcomings at all three facilities particularly in staffing and shortage of experts. It stated RAOS Project still has problems in their management system and their organisation despite promises made a year before to rectify these problems.

6. Conclusions and policy implications

Conclusions and policy implications fall into two areas: how far can Russia fulfil its order book; what policy issues does buying reactors from Russia raise for the importing country?

6.1. Can Russia fulfil its order book?

The appointment of Sergey Kiriyenko as CEO of Rosatom was an indicator of the priority Putin was giving the nuclear reactor industry. There is no indication that the moving of Kiriyenko from this job means that the nuclear reactor export drive will take a lower political priority (Peach, 2016). The consolidation of Russia's nuclear companies into one company, Rosatom, bringing together 400 companies and 250,000 employees, may have created an organisation that is unwieldy. The existence of two distinct reactor designs, a Moscow and a St Petersburg model, may reflect the tensions created in trying to weld together such a large array of companies with an identity they are unwilling to give up.

Given the poor state of the Russian economy, it is hard to see how Russia could finance about 35 export reactors over the next decade. Some of the markets appear to have collapsed – Vietnam, Jordan and South Africa, while others - Nigeria - are a long way from requiring concrete progress. The export projects that appear closest to construction start, those in Finland, Hungary, Bangladesh and Turkey, will be a good test of Russia's financial capability.

The capacity and the quality of the supply chain is more difficult to evaluate. The quality problems reported in India, albeit mostly from an order placed in a somewhat earlier era, are not encouraging. Again, experience in Finland will be illuminating. The Finnish state regulatory body, STUK, will have the bitter experience of overseeing a project, the Olkiluoto reactor, which has gone badly wrong fresh in its mind. It has already expressed concerns about the quality of Rosatom's equipment supply facilities and the skills available. Delays at the Hanhikivi site have been attributed to Rosatom's lack of experience of dealing with the stringent demands made by a rigorous, experienced and independent regulatory body.[111]

If there are some resources available to provide finance and components, Russia is likely to prioritise the orders with those that seem to offer the lowest commercial risk (for example, Finland), the highest prestige (Finland) and the ones that will increase Russia's political influence in areas it values (for example, Iran, Egypt, Turkey and Hungary) at the head of the queue. By mid-2017, Rosatom was saying the reactor export market was rapidly shrinking.[112]

Despite the issues of finance and supply chain, by the end of 2017, there was significant progress in Egypt, Turkey, Bangladesh and Hungary suggesting Russia is still prioritising reactor exports. Russia was involving Western companies, notably GE, in orders for Turkey, Hungary and Finland potentially adding strategic support.

6.2. Issues for importing countries

There is little recent experience of countries importing Russian nuclear reactors. There is little in the public domain about China's experience, that of India is poor and the completed project in Iran is a one-off from which little can be drawn

One issue is the extent to which the market that Russia has, was created by Russia itself through promises on prices and finance that it cannot fulfil. For example, in 2009 in Bangladesh, two Russian reactors were forecast to cost US$1.5bn but by 2015, the estimate had increased 9-fold. The outcome may be that many of the orders will be abandoned. Where firm orders have been placed and it is the customer that abandons the order, this could result in significant direct costs. For example, Bulgaria has been required to pay Rosatom about €600 m in compensation for the equipment produced for the cancelled Belene project.[113] However, the opportunity costs may be higher than the direct cost for cancelled orders. Many of the countries have rapid electricity demand growth and if plans rely on nuclear reactors that cannot be completed, resulting power shortages will have a severe impact on public welfare.

For countries that have little nuclear experience, the supplier bears a responsibility to provide expertise and back-up. It must be meticulously careful with quality control, provide training and supply the regulatory body with comprehensive, reliable data. The IAEA has a responsibility to give clear, unequivocal guidance to such countries identifying shortcomings in their national infrastructure, although it can only give advice if asked.

Especially in countries with little experience of nuclear power, the national regulatory body may find it difficult to stand up to such a powerful organisation as Rosatom, which has the full backing of the Russian government. Governments in such countries are likely to have invested a great deal of credibility in nuclear projects and will be reluctant to hear of issues that delay the project. It is important that regulators are given sufficient independence and powers that they can stand up to pressures from their own government, Russia and Rosatom.

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