Motivations for nuclear power programmes

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1. Introduction

Arguably, over its 60-year commercial history nuclear power has seldom if ever been the cheapest way to add generating capacity to an electricity system and there is little sign that nuclear power is becoming more competitive. Yet the enthusiasm of many utilities and governments for the nuclear option appears, in many cases, to be undimmed by the disappointing results of earlier programmes and some countries appear keen to launch new nuclear programmes. In this paper, we identify three key factors, weak economic regulation, availability of low-cost finance and military aspirations that may allow or motivate the ordering of economically unjustifiable nuclear power plants, focusing mainly on weak regulation. We then review the four case study countries, China, Saudi Arabia, Iran and Taiwan to determine how far these factors apply in those countries.

Nuclear power is often justified by its promoters by optimistic forecasts of costs either from the utility or from the reactor vendor and with the complicity of government. Even when it is known that nuclear is not the cheapest option, it is justified by claims that ordering now would open a stream of cost reductions from effects such as learning, technical progress and economies from mass production methods that would make nuclear power economic. A capability to offer nuclear power technology is also sometimes seen as one that can open export markets. It appears that, for example, the nuclear sectors in France, China and Russia, are supported by national government, and orders in the home market encouraged to provide a shop-window for the country's nuclear technologies.

The nuclear option is also claimed to have non-monetary strategic advantages, for example, diversifying fuel sources, reducing energy import dependence, and reducing pollution resulting from use of fossil fuels. However, while nuclear power might be seen to have advantages in these factors, it is seldom compared with other policy options that would achieve the same goals. It is consumers that almost invariably must pick up the financial consequences of investment in uneconomic plants. Despite this, any public resistance to nuclear programmes is seldom on the grounds of cost.

There would seem to be three factors that, often in combination, allow or motivate the ordering of uneconomic nuclear power plants:

- The plant buyer is insulated from the consequences of uneconomic investment decisions by weak regulation of electricity prices;
- Availability of low-cost finance; and
- The plant contributes, either overtly or covertly, to creating or maintaining a nuclear military capability either for weapons or submarines.

2. Motivating factors

The analysis in this paper focuses mainly on the first factor, weak regulation, but the other two factors are also examined.

2.1. Lack of financial responsibility

For most of its history, the electricity industry has been seen as a natural monopoly. Prices were generally set by the utilities, often publicly-owned, sometimes via some form of regulation although in most countries this regulation was neither independent of government nor rigorous. Since around 1990 there have been increasing attempts to transform the generation part of the electricity business into a competitive market, under which new power plants would have to compete in a market to repay the investment. If competition was vigorous, this would mean that investment in new power plants of all types would become very risky. This would impact particularly on capital intensive options because it would raise the cost of borrowing, and nuclear is the most capital-intensive form of generation. Because capital-intensive plants would still have to meet the high fixed costs associated with repaying the construction cost whether the plant was able to compete successfully or not.

2.1.1. Fully regulated jurisdictions

In the 1930s, the USA established and continues to operate a rigorous price-setting framework at state-level. Essentially, prices are set to allow the utility to recover operating costs and make a 'fair' return on prudent utility investsment. This requires regulators to determine when a new asset is complete and ready to enter service, whether 'the costs were prudently incurred' and whether it will be 'used, useful' before the asset is added to the portfolio of investments on which the utility can make a return. If the investment does not meet these criteria, the utility will not be allowed to recover the imprudent costs from consumers and will be required to pay for these costs from its profits.

Up till the mid-1970s, while the electricity industry was on a downward cost curve and real electricity prices were falling, this system appeared to work smoothly. In short, the decision for regulators was often seen as when to reduce prices and by how much. However, a combination of lower than expected electricity demand, rising fuel costs and a high proportion of nuclear projects being completed very late and far over-budget put a heavy strain on the system. More than 100 firm reactor orders, including some which were claimed to be nearly complete, were cancelled because they would not have been judged as 'used and useful' and the costs were not 'prudently incurred'. This abandonment of orders was often facilitated by the state regulators allowing utilities to recover some of their costs only if the projects were cancelled. This meant the costs passed on to consumers were less than they would have been if the plant had been completed. It also reduced the risk to the utility that the cost of completing the plant would continue to escalate with little hope of cost recovery from consumers.

These actions quickly brought a halt to nuclear ordering in the USA because financiers quickly saw that nuclear orders were now very risky to the utility and were unwilling to lend to them. No orders were placed after 1979 and all orders placed after 1974 were cancelled until the two projects, Summer and Vogtle, that began construction in 2013. Summer was abandoned in 2017 and it is far from certain that Vogtle will be completed.

President G W Bush announced in 2002 a programme of Federal subsidies under the Nuclear 2010 policy, for a small number of demonstration plants in the belief that these would lead to nuclear ordering without subsidy. By then several states in the USA had abandoned the fully regulated model for the electricity industry in favour of a competitive model.

Utilities in both regulated and deregulated states quickly announced plans to build more than 30 new reactors under these provisions, but in the event only the Vogtle and Summer projects, both for two reactors, went forward. Both projects are in fully regulated states and they were possible because the state regulators gave strong indications that costs would be recoverable and allowed the utilities to begin to recover their costs from the start of construction, not the completion of the plant. Both projects went wrong from the start with costs and construction times escalating alarmingly culminating in the bankruptcy in 2017 of the vendor, Westinghouse (then owned by Toshiba of Japan). Westinghouse had signed effectively fixed price deals with the utilities and, when costs escalated, it could not pass them on to the utility customers. In summer 2017, the Summer project was abandoned and Vogtle appeared at severe risk of also being abandoned, although in December 2017, the Commissioners of the Georgia Public Service Commission (PSC) agreed, against the advice of the PSC staff, for the project to continue. In the Summer case, consumers will lose much of the money already paid to the utility for construction. It is still far from certain whether the Vogtle project will be completed and if it has to be abandoned, consumers will also lose much of the money paid by them up till then.

Given this experience, there appears little prospect that regulators in other regulated US states will give utilities favourable indications on cost recovery sufficient to allow nuclear projects to go ahead. Utilities and, more importantly, financiers will see nuclear projects as far too risky to contemplate.

2.1.2. Competitive electricity markets

Outside the USA, utilities were able to build nuclear power plants in the knowledge that whatever costs were incurred could be recovered from consumers. This allowed utilities to make investment decisions for which they were insulated from the risk. It was the perception of a 'cost-plus' culture that led to the interest in competitive electricity markets under which it was assumed utilities would be forced to seek the lowest cost ways to add generating capacity. If they made uneconomic investment decisions, they would be forced to sell their power at a loss and perhaps go bankrupt. All the European Union (EU) member states are now required to operate their electricity systems on a competitive basis with wholesale power markets and full retail competition for all consumers mandatory.

This trend to competition was widely seen as being very bad for nuclear power because of its capital intensity, the high cost of nuclear generation and because the high likelihood of cost and time overruns for nuclear projects made them very risky. This expectation of a bleak outlook for nuclear power in the EU has proved well-founded with no nuclear plants ordered and completed since electricity liberalisation was required in 1997. Only four member states have reactors under construction or at an advanced stage of planning, Finland, the UK, France and Hungary. All of these except France have had to take measures to fully insulate the reactors from the market and all the projects appear problematic.

Finland has one plant under construction and expects to start construction on a second in 2018/19. As has been well documented, the first, Olkiluoto, starting construction in 2005, has gone badly wrong and is now 10 years late and about three times over-budget. The utility, TVO, thought the risk would be mitigated by two main factors: first, the plant was ordered under a fixed price (turnkey) contract for €3bn; and second, most of the output was contracted to be sold at cost to the consortium of electric-intensive industrial consumers that owned the utility. Neither measure has worked. The vendor, Areva, denied responsibility for a large part of the additional costs and this dispute is being settled in the Court of Arbitration and it seems inevitable that TVO will have to bear a significant part of the cost overruns. This will make power from the plant very expensive and, given that electric-intensive industries can only survive if they have access to cheap power it is hard to see how they can justify buying power from this plant when power from the competitive market, NordPool, is so much cheaper. If its customers are unwilling to buy power from Olkiluoto, the future of TVO will be in doubt. Despite this experience a second plant is planned, purchased from Rosatom (Russia), and is at an advanced state of planning under similar arrangements but with Rosatom taking a minority equity stake.

The UK launched a new effort to build reactors in 2006 but with a firm promise that no public subsidies would be given. This promise was essential to making the programme politically feasible and was to deal with fears that, as with previous nuclear programmes, large extra costs would accumulate and would fall on consumers and taxpayers. The clear implication of the no-subsidies policy was that new nuclear plants would compete in the

Britain's wholesale electricity market on equal terms with other generation. Under this programme, 16GW of new capacity (11 reactors at five sites) is planned. More than a year before construction on the first reactor is expected to start, power from the first reactor is at least 10 years late and the expected cost per reactor has increased five-fold. The no-subsidies promise was never credible, and a series of large public subsidies have had to be given to prevent the programme collapsing although the no-subsidies promise was not formally abandoned until 2015. Subsidies include a cap on waste disposal costs, a 35-year fixed real price take-or-pay contract to buy the output at a cost far above current wholesale prices and loan guarantees to cover all the borrowing required. Despite all these measures, construction start on the first reactor will not be before 2019 and there remains a risk none of the five projects will proceed.

Hungary is expecting to start construction of two reactors bought from Rosatom after 2019 and the output of these will be bought under long-term contract. The loan deal has already been signed and Hungary will have to start repayments to Russia in 2026 whether or not the reactors are in service.

The French electricity market is theoretically open to competition but the incumbent, Electricité de France (EDF), still has about 90 per cent of the market. This allowed it to start construction of the Flamanville plant in 2007 with no measures to insulate the plant from the market. As with its sister Olkiluoto plant, construction has gone badly wrong and it is now at least seven years late and far over budget. Plans to build follow-on plants did not materialise and in 2017, EDF stated that it could not build reactors in France without 'guaranteed income.'[1]

In the USA, nuclear projects were planned in states with competitive markets, for example, in Texas and Maryland. The Calvert Cliffs (Maryland) and the South Texas projects were short-listed for loan guarantees. The state regulatory body of Maryland was unwilling to give any guarantees and the project collapsed. The fee for the loan guarantees, reported to be as high as 11.5 per cent because of the project risk, was also a factor in the project collapse. The South Texas project collapsed before it got to the stage of negotiating loan guarantees.

2.1.3. Vendor price guarantees

Vendors very seldom sign fixed price (turnkey) contracts that would expose them to any cost overruns. Where they do, the consequences to them are often financially very serious. This was the case with the fixed price contract given by Areva for €3bn for the Olkiluoto plant in 2004. By 2018, the plant was still at least a year away from commercial operation, the costs had escalated three-fold or more and this was a significant factor in the financial collapse of the vendor Areva NP. Westinghouse became exposed to US$6bn of the cost escalation at the Vogtle and Summer projects and this was the major factor in its bankruptcy in 2017.

2.2. Availability of low cost finance

Under the old monopoly, regulated market model, the financial risk of nuclear projects was almost entirely borne by consumers rather than utilities and so lending to a utility was extremely low risk - utilities were the original 'blue chip' investment. Also, most utilities outside the USA were publicly owned and there was an element of trust in government that such companies would not engage in the profiteering that might be expected of investor-owned companies. In some cases, notably Electricité de France (EDF) until it was part-privatised in 2005, the government guaranteed all EDF's debts so effectively lending to EDF

[1] https://www.reuters.com/article/edf-nuclearpower/media-edf-says-no-new-nuclear-reactors-in-france-without-state-support-ouest-france-idUSL8N1OF3EP (Accessed December 20, 2017)

was no riskier than lending to the French government. So EDF's credit rating was as high as that of the French government, AAA, and the cost of borrowing correspondingly low. This very cheap finance was an important element in allowing EDF to finance the nuclear programme of the late 70s and early 80s when about 40 reactors were ordered in about six years.

Some countries had too low a credit rating for their utilities to obtain the finance needed and, for example, attempts to launch nuclear power programmes around 1980 in countries such as Turkey and Egypt were unsuccessful because they could not be financed.

As the real cost of nuclear power plants has continued to escalate and the pressure on utilities to make only economic investments has increased, the availability of cheap finance has increasingly become the determining factor as to whether a nuclear programme is feasible. In a few countries with large financial resources and a government policy to promote nuclear power, notably China and, for the future, Saudi Arabia, finance is likely to be available. However, in the past two decades, in most other countries, nuclear programmes are only viable if finance is offered by the vendor or a government, either that of the vendor or that of the purchaser, is willing to offer sovereign loan guarantees.

The only vendors able to offer finance are those backed by a strong government in a centrally planned economy, i.e. the Russian and Chinese vendors. Rosatom (Russia) has a large reactor export order book, almost all of which will require Russia to supply the finance at relatively low cost. The Chinese vendors (CGN, CNNC and SNPTC) have yet to win reactor export orders (except for Pakistan) but in the markets that they are targeting, finance is reported to be on offer from Chinese state-owned banks.

Sovereign loan guarantees provided in 2004 mainly by the French government were used to help finance the Finnish Olkiluoto project supplied by the French state-controlled vendor, Areva NP. These guarantees were worth €700m, about a quarter of the expected cost and their availability was enough to persuade a consortium of banks to offer the finance required. The construction problems with many of the nuclear construction projects has strengthened the financial community's perception of nuclear as a highly risky technology. This, and the increased real cost of nuclear plants has dramatically increased the scale and level of cover from loan guarantees required. For example, when the Bush Nuclear 2010 policy was conceived in 2002 to support about five new reactors, it was expected that nuclear plants would cost about US$1000/kW and that 40 per cent of the construction cost would be covered by guarantees. This would have required guarantees of about $3bn (assuming 1500MW reactors). A decade later, the expected construction cost was at least US$5000/kW and the utilities had persuaded the government that 80 per cent of the expected cost would have to be covered if fiancé was to be obtained and the scale of government guaranteed required for the same size of programme had increased 10-fold to US$30bn. Similarly, the UK policy to build 15GW of new nuclear capacity by 2030 is not likely to be feasible unless guarantees worth more than £100bn are offered.

2.3. Links to the military sector

Nuclear technology has its roots in military programmes. In many countries, a state-owned nuclear R&D organisation often with a dual civil/military remit and with significant influence in government has been an important force lobbying for the launch of reactor programmes. Such organisations included the US AEC, the French CEA and the UKAEA.

The first reactors were designed to produce plutonium for weapons via reprocessing of the spent fuel. Reprocessing was expected to be necessary for civil reactors because it was assumed that using uranium in power reactors would mean natural uranium reserves would be quickly depleted as only about 0.7 per cent of naturally occurring uranium is 'fissile' (can support a chain reaction). This was expected to mean that reactors with fuel cycles that could utilise the non-fissile uranium would be needed. So-called fast reactors use plutonium as fuel obtained via a reprocessing plant.

Uranium enrichment is also a dual-purpose technology. Weapons can be produced using Highly Enriched Uranium (HEU), while most types of civil power reactors require the fissile naturally extracted uranium to be enriched from about 0.7 per cent to about 3.5 per cent. The most widely used civil reactor design, the Pressurised Water Reactor (PWR) was developed from reactors designed for military submarine propulsion units.

The skills required to handle nuclear materials are often common to civil and military uses so a strong civil programme provides a larger pool of skilled workers that the military sector can draw on.

These strong overlaps between military and civil nuclear technology are often seen as, at a minimum, using the civil nuclear sector to bolster the military sector and at worst, covertly using civil facilities for the military sector. For example, several of the newer weapon states such as India, Israel and Pakistan acquired weapons plutonium from reprocessed fuel from reactors claimed to be civil research reactors. South Africa was able to make its nuclear weapon using an enrichment plant claimed to be for the civil sector and Iran's enrichment plants have been at the centre of concerns of weapons proliferation in Iran. Some analyses[2] claim that a key motivation of the current UK efforts to relaunch civil reactor ordering is to help retain the UK's capability in nuclear submarines. The key UK nuclear submarine company, Rolls Royce, said: 'One particular application for deployment of the talent developed through the UK SMR programme would be in the ongoing maintenance of the UK's independent nuclear deterrent. Currently, the UK Government is required to invest funding to sustain the skills and capability necessary for the maintenance of the Royal Navy's nuclear submarine programme.'[3]

3. China

3.1. Electricity sector structure

In many respects, China's nuclear sector, and its electricity sector in general are more complicated than might be expected from an economy seen as highly centralised and planned, albeit the major actors are all nationally owned. New nuclear projects must be approved by the National Energy Administration (NEA) and the safety regulator, the National Nuclear Safety Administration (NNSA) but, especially in the past few years, few of the approved plants have gone ahead.

The electricity generation sector is dominated by five large regional companies with about 45 per cent of the generation. Most of the rest of the capacity is owned by a large number of locally publicly-owned companies. The Big Five are: Huaneng Group; Datang Corporation; Guodian Corporation; Huadian Corporation; and China Power Investment Corporation

[2] P Johnstone & A Stirling 'Is Trident influencing UK energy policy' Sustainable Security. https://sustainablesecurity.org/2017/04/10/is-trident-influencing-uk-energy-policy-part-1/ and https://sustainablesecurity.org/2017/04/12/is-trident-influencing-uk-energy-policy-part-2/ (Accessed January 9, 2018.

[3] https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/nuclear/a-national-endeavour.pdf (Accessed January 3, 2018)

(CPIC). The vast majority of their capacity is coal-fired, with much of the coal coming from their own mines.

There are three reactor vendors, China National Nuclear Corporation (CNNC), China General Nuclear (CGN) and State Nuclear Power Technology Corporation (SNPTC) all of which also own and operate power plants, mostly nuclear. In 2017, CNNC announced a proposed merger with the China Nuclear Engineering Corporation (CNEC), the *de facto* monopoly nuclear construction company.[4] This merger would effectively reverse the split up in 1988 of the China Nuclear Industry group into CNNC, with the front-end and back-end fuel cycle and reactor design and supply and CNEC, with an effective monopoly in civil and military construction. In January 2018, the merger appeared was completed.[5]

While the Chinese home market has dominated the world market for nuclear power plants in the past decade, Table 1 shows its contribution to electricity supplies is tiny with only 2 per cent of capacity nuclear and about 3.5 per cent of power coming from nuclear power plants. Equally, the reactor vendors, which, along with Rosatom, are financially the most powerful in the world, are small compared to the Big Five utilities (see Table 2).

Table 1 China's generating capacity by source (2016)

Power source	Capacity (GW)
Thermal	1054
Water	332
Wind	149
Solar	77
Nuclear	34
Total	1646

Source: https://www.statista.com/statistics/302191/china-power-generation-installed-capacity-by-source/ (Accessed January 4, 2018)

The Chinese State Council has approved only CGN, CNNC and SNPTC as nuclear developers with other companies, including the Big Five, allowed to take a minority stake in nuclear projects. SNPTC, the newest and weakest of the reactor vendors, has tried to overcome this problem by merging, in 2015, with the smallest of the Big Five, CPIC to form State Power Investment Corporation (SPI).

Table 2 Main utilities in China

Utilities	Installed capacity (GW)	Total assets $bn
The Big Five	663	
Huaneng	161	150
Guodian	135	122
Huadian	135	117
Datang	127	144
SPI (CPIC)	105	119
Nuclear vendors	42	
CGN	29	67
CNNC	13	68
SPI (SNPTC)	0	n/a
CNEC	0	9
Coal company		
Shenhua	78	144

Source: Nuclear Intelligence Weekly 'Reshaping the Nuclear Industry' April 14, 2017.

[4] Nuclear Intelligence Weekly 'CNNC-CNEC Merger Marks New Era for Chinese Industry' March 24, 2017
[5] Nuclear Intelligence Weekly 'Weekly Roundup' February 2, 2018

Note: SNPTC and CPIC merged to form SPI in 2015. None of the plants supplied by SNPTC was in service at end 2017. The value of assets owned by the SNPTC part of SPI is not known.

Since then, there has been constant speculation about mergers in the power sector including between the Big Five and the other two reactor vendors, for example, CGN and Huaneng and CGN and Shenhua.[6] In June 2017, a proposed merger between Guodian and Shenhua was announced to form China Energy Investment Corp. In July 2017, a merger between Huaneng and SPI was announced, which, if completed, would reduce the Big Five to Four

How far the decline in nuclear construction starts since 2010 is down to reluctance of the Big Five to be involved in nuclear projects is hard to know. If the Big Five are reluctant, how far is this due to doubts about nuclear and how far is it due to a desire to be in control of their generating plants, not just minority shareholders?

3.2. Status of the nuclear programme

In 2018, China's nuclear capacity was 33.4GW (38 reactors), the fourth largest nuclear fleet in the world behind USA, France and Japan. It had a further 19 reactors (19.9GW) under construction, representing a third of the world's nuclear capacity under construction. Most of the operating reactors started construction in the period 2008-10 (see Table 3) when 25 of the 57 reactors in service or under construction started construction. Since the beginning of 2011, perhaps before the Fukushima disaster, only 15 construction starts have taken place with ordering very uneven.

There may be a number of reasons behind the collapse in ordering from 2011 onwards apart from the reason normally quoted, the safety concerns the Fukushima disaster raised. This pause may, in part, reflect uncertainty about reactor choice. Most reactors use an old design licensed from the French company, Areva, but, from 2007 onwards, China has been attempting to move to more modern designs. It ordered six imported reactors in 2007-08 using two of the most modern designs available (four Westinghouse AP1000s and two Areva EPRs). A new Chinese vendor, State Nuclear Power Technology Corporation (SNPTC) was set up in 2007 to import and supply AP1000 technology while CGN was the partner for the EPR project. However, cost overruns and delays have occurred, with none of these yet in service and all six are five years late. The plan to move to one of these designs now appears in doubt. The other two Chinese vendors, China National Nuclear Corporation (CNNC) and China General Nuclear (CGN) have been developing their own advanced designs since 2011 that they claim are their own intellectual property. Since 2013, there has been an attempt required by the Chinese government to merge these two designs. The result is known as Hualong One which is to be a unified design for export markets. Construction has started on eight reactors designated Hualong One. There have been difficulties in agreeing between CGN and CNNC the elements of the merged design and the reactors under construction appear to comprise two somewhat different designs.

Since 2016, the Chinese government seems to have given priority to renewables over nuclear. In 2017, demand growth was back up to 6.5 per cent and the contribution of renewables – hydro, wind, biomass and solar dwarfed that of nuclear. Solar output grew by 75 per cent, wind, by 26 per cent and biomass by 23 per cent while nuclear output only grew by 16 per cent. In response to the greater emphasis on renewables, the nuclear vendors, especially CGN, are diversifying into renewables and in 2017, CGN added 15GW of new renewable capacity and it has plans for 13GW of off-shore wind.[7]

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[6] Nuclear Intelligence Weekly 'Reshaping the Nuclear Industry' April 14, 2017
[7] Nuclear Intelligence Weekly 'Nuclear Dwarfed by Renewables in 2017' January 26, 2018

Table 3 **Reactor Construction starts in China**

Period	No of reactors
1987-2007	17
2008	6
2009	9
2010	10
2011	0
2012	4
2013	3
2014	0
2015	6
2016	2
2017	0

Source: https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CN (Accessed January 2, 2018)

Table 4 **Nuclear capacity in China (June 2016)**

Province	Capacity (MW)
Guangdong	9378
Zhejiang	6564
Fujian	5445
Liaoning	3356
Jiangsu	2120
Guangxi	1086
Hainan	650

Source: https://www.statista.com/statistics/302191/china-power-generation-installed-capacity-by-source/ (Accessed January 4, 2018)

The problems with the imported AP1000s and EPRs have continued. The two EPRs were originally scheduled for completion in 2013/14 but by 2017, this had slipped to 2018. However, an equipment problem made public in December 2017 will lead to further delays, not quantified at the time of writing.[8] The four AP1000s were claimed not to be affected by the bankruptcy of Westinghouse but none are yet in service and all are 4-5 years late.

Other factors limiting orders include the *de facto* ban on building reactors on inland sites, the reduction in electricity demand growth and the strain on human resources that starting construction on 25 reactors in the three years from 2008-10 imposed. Nuclear reactors are installed in only seven of China's 34 provinces with more than three quarters of the capacity installed in Guangdong, Zhejiang and Fujian (see Table 4). There have been frequent forecasts since 2011 that the pace of construction would pick up soon, but these have not been fulfilled. In February 2017, the National Energy Administration announced plans to approve and start construction on eight new reactors. In the event, no construction starts were made in 2017.[9]

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[8] Nuclear Intelligence Weekly 'Taishan EPR Set for Further Delays' December 15, 2017
[9] Nuclear Intelligence Weekly 'China Plans Eight Reactor Construction Starts in 2017' February 17, 2017
[10] Nuclear Intelligence Weekly 'Taishan EPR Set for Further Delays' December 15, 2017

3.3. Electricity price setting

The electricity sector has come under great strain since 2013 due to a combination of a sharp reduction in electricity demand growth leading to major over-capacity and the need to deal urgently with the air quality crisis in the cities by cleaning up and reducing coal-fired generation. Overcapacity is a particular problem in Liaoning, Fujian and Hainan provinces all of which have nuclear capacity. This strain and the reduction in profits of the Big Five is a major factor behind the merger activity in the electricity sector. The nuclear sector is a very small player in the electricity sector. The nuclear companies are small compared to the Big Five and the coal company, Shenhua. Even the most optimistic forecasts of nuclear expansion over the next decade or two made by the Chinese government would still leave nuclear supplying only a small percentage of China's power.

Nevertheless, the strains on the electricity sector have had a serious impact on the viability of the nuclear sector. The government sets the rate utilities must pay for the 'guaranteed output' of the reactors, in 2017 43 Chinese cents/kWh ($6.31c/kWh). In the past, this guaranteed output was set as the equivalent of about 7000 hours (80 per cent of the year) of operating time so nearly all the output was sold at the set rate. However, from 2015, provincial authorities have been allowed to set up regional trading markets and have the ability to set their own rules for nuclear generation including the guaranteed output, but not the price paid. First-of-a-kind reactors, such as EPR, AP1000 and Hualong One will be able to sell all their output at the guaranteed price. The Guangxi province set the guaranteed feed-in time at only 4800 hours leaving the utilities to bid the rest of their power into the market. Provincial authorities are also exerting pressure for the guaranteed price to be reduced.[11]The market price, generally set by the marginal price of coal-fired generation, is substantially below the guaranteed price. As a result, load-following for nuclear plants has had to be introduced and, in one case the start-up of a completed reactor was delayed because of low demand for the output. The utilisation rate of reactors is therefore falling significantly.[12]

3.4. Availability of low-cost finance

No details are known on how the Chinese nuclear programme is financed. Given that the companies involved are state-controlled and given the high level of currency reserves in China, it seems likely that finance was readily available and the cost low.

3.5. The military sector

In China, the exploitation of nuclear technology was originally through the Ministry of Nuclear Industry which was reorganised and became CNNC and CNEC in 1988 and the military activities are now based almost entirely in CNNC and CNEC, which were in the process of re-merging in early 2018. The weapons capability substantially pre-dates the civil nuclear programme by about 20 years to the mid-60s. In the past, CNNC's web-site has prominently claimed it was the organisation that built China's atom bomb, hydrogen bomb and nuclear submarines. It is now more discreet in its claims and only says it is 'a leading element of national strategic nuclear forces'.[13] It is difficult to know how far public opposition that halted the development of a reprocessing plant in Jiangsu province in 2016 was due to the military connection or whether it was simply down to safety concerns.[14]

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[11] Nuclear Intelligence Weekly 'Power Market Liberalization — More Challenges to Nuclear?' June 24, 2016
[12] Nuclear Intelligence Weekly 'A Reality Check for Nuclear Power — Lower Demand' June 10, 2016 and Nuclear Intelligence Weekly 'China's 13th Five-Year Plan — Mission Impossible?' November 4, 2016.
[13] http://en.cnnc.com.cn/2016-02/01/c_49164.htm (Accessed January 5, 2018)
[14] International New York Times 'Chinese city withdraws nuclear plan after protests' August 12, 2016.

3.6. Assessment

China's electricity industry appears to be an uncomfortable compromise between a centrally planned system and a market system without the control a centrally planned system or the competitive pressures a full market system would bring. Like the USA and many European utilities 40-50 years ago, Chinese utilities failed to spot the strong downturn in demand growth as demand began to saturate and the economy started to move away from energy intensive industries. As a result, China now faces increasing generation over-capacity leading to little need for new capacity to meet growth as the air quality crisis and the need to reduce greenhouse gas emissions leads to the need to build new low-carbon capacity to replace coal generation, much of which is relatively new.

In some respects, given the minimal contribution of nuclear to China's existing and almost certainly its future electricity supplies, nuclear power is a sideshow. However, from the perspective of the global nuclear industry, the future of the Chinese nuclear industry is key. In short, the world nuclear industry needs China but China does not need nuclear power. The nuclear military sector in China seems well enough established that the support of a civil programme is not essential.

There appear to be four major barriers to new nuclear orders in China: the *de facto* ban on building nuclear reactors at inland sites; generation overcapacity particularly in the regions where nuclear is feasible; problems of cost and buildability with the modern designs being developed; and the apparent lack of interest amongst the Big Five generators in nuclear power.

Central government sets the selling price for the guaranteed output of the nuclear plant. This price, US6c/kWh appears low by standards of other countries particularly for the latest designs, AP1000, EPR and Hualong One. For example, the UK is expecting to pay double this amount for the power from the proposed Hinkley Point C EPRs. It is not clear yet whether Hualong One will prove cheaper and more buildable than the imported designs. There are no reports of major construction problems yet but at this stage in the construction of the AP1000s and the EPRs in China there was no acknowledgement that things were going wrong. There is also a question mark about how much output of the old designs will be paid this price and how much will have to accept the much lower market price set in the new regional markets. The level of the guaranteed output is now in the hands of the provincial authorities rather than central government and the provincial authorities may have an incentive to reduce the guaranteed hours to reduce the prices consumers must pay.

4. Taiwan

4.1. Electricity sector structure

The electricity sector in Taiwan is dominated by Taipower, which is a fully integrated state-owned utility established in 1946.[15] Nevertheless independent power producers (IPPs) do contribute about a quarter of Taiwan's power supplies. In 2016, three quarters of Taiwan's capacity was fossil fuel, about 10 per cent nuclear and the rest renewables. Installed capacity has doubled in the past 20 years but nuclear capacity has remained static so the contribution of nuclear to total capacity has halved. Plant closures and shutdowns from 2014 onwards have meant that the contribution of nuclear to generation has fallen from 26.5 per cent in 1995 to 12 per cent in 2016.

[15] https://www.emcsg.com/f1671,123955/3_-_Dr_Chuan-Neng_Lin_Bureau_of_Energy_Taiwan.pdf (Accessed January 10, 2018)

There are plans to install 20GW of new generating capacity by 2026, two thirds of which would be renewables, mostly owned by IPPs. However, a quarter of the new capacity is expected to be coal-fired.

There are plans to unbundle Taipower, introduce a competitive wholesale electricity market, give consumers choice of supplier and introduce an Electricity Regulatory Authority (ERA) but this is all in the future.

4.2. Status of the nuclear programme

In 2018, the IAEA reported that six reactors (5.1GW) were in service in Taiwan with two (2.6GW) more under construction (see Table 5).[16] However, work on the two under construction was suspended in December 2014, 15 years after construction start, and is unlikely to recommence. In January 2016, a new government was elected with a promise to phase out nuclear power by 2025, retiring the plants after 40 years of operation.

Table 5 Reactor Construction starts in Taiwan

Year	Reactors	Commercial operation
1972	Chinshan 1	1978
1973	Chinshan 2	1979
1975	Kuosheng 1	1981
1976	Kuosheng 2	1983
1978	Maanshan 1	1984
1979	Maanshan 2	1985
1999	Lungmen 1 & 2	-, -

Source: https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=TW (Accessed January 2, 2018)

The completed reactors all started construction in the 1970s with a gap of nearly 20 years before the two uncompleted reactors started construction. Four of the six completed reactors (two at both of the Chinshan and Kuosheng sites) and the two uncompleted reactors (at Lungmen) are Boiling Water Reactors (BWRs) supplied by General Electric (GE), while the other two (at Maanshan) are Pressurised Water Reactors (PWRs) supplied by Westinghouse.

The Lungmen reactors have been delayed almost since the start of construction.[17] The original completion date when the contract was awarded was 2004 but in 2001 the project was delayed by the government for three months and the expected completion date was put back to 2006. In 2004, the schedule was delayed by a further 18-24 months and by 2005, completion was not expected till 2010. The reasons cited were escalating prices and government procurement rules. Delays in the government providing funding continued in 2006. By then, a nuclear phase-out in Taiwan was on the agenda. In 2009, completion was not expected until 2012. The problems were not confined to funding and in 2011, the Taiwan nuclear safety authority was considering suspending construction due to construction difficulties and project quality.[18] In 2014, the government decided to suspend work at the site.[19] Unit 1 was then said to be largely complete and unit 2, 90 per cent complete. It was reported that Taiwan had spent US$9.9bn on these plants.[20] In December 2015, GE began

[16] http://www.world-nuclear.org/information-library/country-profiles/others/nuclear-power-in-taiwan.aspx (Accessed January 10, 2018)
[17] Nucleonics Week 'Finish of Taiwan's Lungmen ABWRs slips again, this time to 2009/2010' May 5, 2005
[18] Nucleonics Week 'Taiwan's regulator undecided on suspending Lungmen construction' August 11, 2011
[19] Nucleonics Week 'Taiwan government suspends Lungmen work in face of protests' May 1, 2014
[20] Nuclear Engineering International 'World survey - Nuclear new-build - New-build now' June 2014

arbitration proceedings with Airpower to recover its costs.[21] Following the election of a government pledged to phase out nuclear power in 2016, there appears little chance the reactors will now be completed.[22]

The oldest reactor, Chinshan 1 has not operated since 2014, initially due to an equipment failure but subsequently due to lack of spent fuel storage capacity and this closed the other unit in 2016. Neither reactor, scheduled for closure in December 2018 and July 2019 respectively, is likely to operate again. The second unit at the second plant, Kuosheng, due to be closed in March 2024 was also closed in summer 2016 due to a fire in the turbine and may also not restart. The first Kuosheng unit is due to close in December 2022 and the Maanshan reactors are due to close in July 2024 and May 2025.[23]

4.3. Electricity price setting

There appears to be no independent and rigorous regulation of electricity prices.

4.4. Availability of low-cost finance

As a state-owned company, Taiwan Power would have had access to public funds for its nuclear programme and given its *de facto* monopoly status, it would have had access to low cost finance.

4.5. The military sector

In the 1970s and 1980s there were serious concerns about Taiwan's intentions to develop nuclear weapons through the Institute of Nuclear Energy Research (INER), which remains in operation albeit with little suggestion of any military agenda.[24] Taiwan's situation is complicated by the fact that since 1971, it has been categorised by the UN and thus the IAEA as a province of China, not a sovereign state and its signature in 1968 to the Nuclear Non-Proliferation Treaty is no longer valid. Whether statements from officials suggesting development of nuclear weapons are any more than rhetoric is hard to know.

4.6. Assessment

Taiwan's nuclear programme dates from the period before democratic rule was introduced and a centralised authoritarian government that owned and controlled the electricity sector was able to force through a nuclear programme. Public opposition has grown against nuclear power and the plans in 2018 were to phase out nuclear power by 2025. Experience in other countries that have adopted nuclear programmes suggests that while this timetable might slip, the chances of a policy reversal and new orders being placed are minimal

5. Saudi Arabia

5.1. Electricity sector structure

The dominant company in the electricity sector is the Saudi Electricity Company. It owns about 74GW of capacity, about 60 per cent of which is gas-fired and the rest oil-fired.[25] It is a *de facto* monopoly, fully integrated generation/transmission/distribution/retail company. It was established in 2000 from the merger of all Saudi electricity companies. The Saudi government owns about 80 per cent of the shares, mostly directly, with some owned by Saudi

[21] http://www.world-nuclear-news.org/C-GE-seeks-arbitration-over-Lungmen-payments-1412154.html (Accessed January 12, 2018)
[22] Nucleonics Week 'Taiwan president-elect reaffirms goal of 'nuclear-free' Taiwan by 2025' March 17, 2016
[23] Nuclear Intelligence Weekly 'Government Boosts Pace Toward 'Nuclear-Free Homeland'' September 9, 2016
[24] http://www.nti.org/analysis/articles/taiwan-and-nonproliferation/ (Accessed January 10, 2018)
[25] https://www.se.com.sa/en-us/Pages/aboutus.aspx and https://www.eia.gov/beta/international/analysis.cfm?iso=SAU (Accessed January 9, 2018)

Aramco. There are plans to functionally unbundle the company into competing generation companies, a transmission company and distribution/retail companies. There are a small number of independent power producers, allowed from 2007 onwards.

Electricity demand appears to be growing rapidly and power generated in 2016 was 7 per cent more than in 2015. The government anticipates rapid growth will continue and in 2016, the King Abdullah City for Atomic and Renewable Energy (KA-CARE) was calling for an additional 41GW of solar power, 17.6GW of nuclear and 9GW of wind power by 2032, although the nuclear target had already been downgraded by the government.

5.2. Status of the nuclear programme

The attempt to launch a nuclear power programme dates from August 2009 when the Saudi government announced that it was considering a nuclear power programme.[26] At that time, KA-CARE was set up to lead the nuclear programme. In April 2010 a royal decree was issued saying: 'The development of atomic energy is essential to meet the Kingdom's growing requirements for energy to generate electricity, produce desalinated water and reduce reliance on depleting hydrocarbon resources.'[27]

The potential size of the Saudi reactor market and its ability to provide its own finance makes Saudi Arabia a very attractive market for all the reactor vendors including small reactors for desalination purposes. A 2013 target of 17GW of nuclear capacity by 2030 had slipped to 2040 by 2015 and by 2017, it was not clear whether there was still any target. The first step would be the ordering of two reactors (2.2-3.2GW) at a site yet to be determined. In January 2018, two sites, Umm Huwayd and Khor Duweihin, were reported to have been shortlisted.[28]

Vendors who have expressed an interest in the market include GE-Hitachi, Toshiba/Westinghouse, Areva and Rosatom. In October 2017, KA-CARE submitted a request for information (RFI). Several vendors have expressed an interest in the market but those responding to the RFI were reported to be China National Nuclear Corporation, Korea Electric Power Co (KEPCO), EDF/Framatome, Rosatom and Westinghouse.[29] The financial collapse of Areva and Westinghouse mean it may be problematic for them to place bids. By end 2017, Saudi Arabia was claiming it would launch reactor tendering process within months with a view to selecting the vendor by end 2018, signing a contract in 2019 and commissioning the first unit in 2027. This timetable is very ambitious.

Suppliers mentioned for the small reactor market include: INVEP (Argentina) with its 27MWe CAREM reactor (under construction in Argentina since 2014): China Nuclear Engineering Corporation with its high temperature reactor, HTR-PM, based on the reactor under construction in China; and KAERI (Korea) with its SMART reactor (up to 100MWe), to be jointly developed with KA-CARE. KA-Care is reported to own a percentage of the Intellectual Property for the SMART design.[30]

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[26] http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/saudi-arabia.aspx (Accessed January 10, 2018)
[27] http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/saudi-arabia.aspx (Accessed December 14, 2017)
[28] https://www.meed.com/exclusive-saudi-arabia-shortlists-two-sites-first-nuclear-power-project/ (Accessed February 5, 2018)
[29] Nuclear Intelligence Weekly 'Ka-Care Hopes to Choose from Five Bids by Year's End' January 19, 2018
[30] https://www.meed.com/exclusive-saudi-arabia-shortlists-two-sites-first-nuclear-power-project/ (Accessed February 5, 2018)

5.3. Electricity price setting

A regulatory body, the Electricity and Cogeneration Regulatory Authority (ECRA) was set up in 2001.[31] Its mission is to 'insure that supplies of electricity and desalinated water products provided to consumers in the Kingdom are adequate, reliable, of high quality and reasonably priced'. Its most recently published annual report was for 2014.[32] It states that its responsibilities include:

> 'Assessment of tariffs charged for supply of the electricity and water desalination industry services, periodic review of these tariffs and when modification is needed, modifying whatever tariffs fall within its purview while for other tariffs submitting proposals to the government.'

It is difficult to determine how rigorous and independent these reviews are and how far they determine electricity tariffs.

5.4. Availability of low-cost finance

Given that SEC is state-controlled and given the vast income Saudi Arabia has from oil and gas, it seems likely that whoever was charged with owning and operating any Saudi reactors would have access to cheap capital.

5.5. The military sector

Saudi Arabia's avowed intention to build up a full fuel cycle including enrichment and reprocessing to match its reactor programme has led to serious concerns about the proliferation risk this raises. In particular, there are concerns that the US Trump government wants to come to an agreement with Saudi Arabia that does not require it to fulfil the 'Gold Standard' of a promise not to reprocess fuel and extract plutonium nor to enrich uranium.[33]

5.6. Assessment

Saudi Arabia has yet to commit to a nuclear programme and, given the wealth of the country and its ability to provide cheap finance, winning orders in Saudi Arabia would represent a major coup for a successful vendor. Despite this, perhaps only the Chinese vendors, who are only mentioned in the context supplying small reactors using their unproven high temperature gas-cooled reactor technology, are in a position to sell reactors at loss-leader prices and even they would not be able to sell at a loss for more than one or two reactors. So, unless there is a strong covert agenda to develop a military nuclear capability under the cover of a civil programme, there must be serious doubts whether Saudi Arabia will proceed with a nuclear programme when it sees the scale of costs involved. Intuitively, Saudi Arabia would appear an ideal location to develop solar power with the demand profile (notably for air conditioning) and solar supply availability appearing to match well.

6. Iran

6.1. Electricity sector structure

By 2017, the installed electricity capacity in Iran had reached 77GW.[34] Until 2000, the Iran electricity sector was dominated by the state-owned vertically integrated company,

[31] http://www.ecra.gov.sa/en-us/Pages/default.aspx (Accessed January 9, 2018)
[32] http://www.ecra.gov.sa/en-us/MediaCenter/doclib2/Pages/SubCategoryList.aspx?categoryID=4 (Accessed January 9, 2018)
[33] http://thehill.com/opinion/national-security/367838-reactors-for-saudi-arabia-are-bad-business-and-dangerous-diplomacy (Accessed January 9, 2018)
[34] http://www.iran-daily.com/News/194482.html (Accessed January 15, 2018)

TAVANIR.[35] Since then there has been a process of privatisation and introduction of competition so that by 2015, nearly half of Iran's power generation came from privately owned companies. However, TAVANIR remains the main player and its web-site states it 'manages generation, transmission and distribution of power'.[36]

About two thirds of Iran's generating capacity uses natural gas, about a quarter oil, with nuclear, coal, hydro and renewables making up the remaining 10 per cent. Demand has grown rapidly in recent years, by about 7 per cent per annum leading, at times, to shortages. However, in 2014, the government increased prices by 25 per cent and again by 20 per cent in 2015 to reduce subsidies and to dampen growth.

There are 16 Regional Electricity Companies (RECs), all wholly owned by TAVANIR, which have a management role in their region. There are 39 Distribution Companies (DCs) that are responsible for distribution and retail in their region. 40 per cent of the shares in each of these companies is owned by TAVANIR with the balance owned by a public/private company established in 2004, SABA. There are 39 Power Generation Management Companies that operate the power plants in their region. Again, 40 per cent of the shares are owned by TAVANIR, 40 per cent by the Ministry of Energy and 20 per cent by others. There are many generation companies, some owned by TAVANIR, some by private investors. There is a pool-based day-ahead wholesale power market, the Iranian Electricity Market (IEM), established in 2003. It is not clear how far this market places genuine competitive pressure on the companies given that it can be effectively bypassed with bilateral contracts.

A regulatory body, the Iran Electricity Market Regulatory Board (IEMRB) was established in 2004, but its role appears to be setting and monitoring rules rather than regulating prices.

6.2. Status of the nuclear programme

Iran had ambitious nuclear plans until 1979 under the Shah.[37] Two 1200MW PWRs were ordered from the German company, Kraftwerk Union (later known as Siemens) in 1976 to be built at the Bushehr site. Work started on the plant then and was claimed to be 77 per cent complete when work was abandoned in 1979 after the overthrow of the Shah.[38] Two PWRs were ordered from the French company, Framatome, for the Karun River site (also known as Darkhovin and Esteghlal) in 1977 but were abandoned a year later[39]. In 1991, a Swiss arbitration court awarded Framatome US$700m in compensation for cancellation of the contract.[40] Four more reactors were ordered from Kraftwerk Union but cancelled before work had started. Around this time, Iran took a stake in the Eurodif uranium enrichment plant built in France.

Plans to complete the Bushehr plants were discussed with Siemens in the 1980s but in 1987, the facility was bombed during Iran/Iraq war.[41] Despite this, discussions continued with Siemens over the completion of the reactors. However, in 1995, Iran reached an agreement with Russia to complete one of the reactors.[42] Construction restarted in 1996 but commercial operation was not until 2013. The single reactor appears to be a V-320 Rosatom reactor (the

[35] G.RezaYousefi, Sajjad Makhdoomi Kaviri, Mohammad Amin Latify, Iman Rahmati (2017) 'Electricity industry restructuring in Iran' Energy Policy, volume 108, pp212-226
[36] http://www.tavanir.org.ir/en/1.php (Accessed January 10, 2018)
[37] http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/iran.aspx (Accessed January 10, 2018)
[38] Washington Post 'Iran Set to Scrap $34 Billion Worth of Civilian Projects' May 30, 1979.
[39] Washington Post 'Iran Cuts Back Nuclear Plans To Save Money' October 23, 1978
[40] Agence France Presse 'Iran told to pay France in 700 million in damages' October 2, 1991
[41] United Press International 'Iraq bombs unfinished Iranian nuclear power plant' November 17, 1987
[42] Xinhua News Agency 'Iran, Russia sign nuclear power contract' January 8, 1995

Russian standard model from the 1980s) housed in the existing Siemens containment (Khlopkov & Lutkova, 2010). Operation of the plant has been problematic. It took 28 months from first power to commercial operation (typically this takes about three months) and in its three full years of commercial operation to end 2016, its capacity factor[43] was only 53 per cent compared to the world average of about 80 per cent.

Discussions on further orders did not take place until the Bushehr unit was in commercial operation. In 2014, Iran agreed a deal with Rosatom to build two further reactors at the Bushehr site with an option for six further reactors, two more at Bushehr and four at an undetermined site. There was optimism that construction would start soon but in November 2017, first structural was not expected before 2019 with operation in 2026 and the second unit following two years later.[44]

It also signalled its interest in building an indigenous PWR design of 360MW at the Darkhovin site and buying the ACP100 SMR from China (CNNC) for installation at the Makran site.[45] There is no schedule for either of these projects and, if they go ahead, start of construction is several years away.[46]

6.3. Electricity price setting

It is clear that it is the government, not IEMRB that sets prices and, given the dominance of the state-owned TAVANIR, this is not surprising.

6.4. Availability of low-cost finance

While Iran has huge reserves of oil and gas, international sanctions have seriously reduced its sales of oil and gas and the availability of finance is heavily dependent on the world oil price. With the relatively low oil prices of 2017/18 and sanctions still in force, it seems likely that an Iranian nuclear programme would only be possible with foreign finance.

6.5. The military sector

There has been long-running concern about Iran's uranium enrichment and reprocessing plants, even though Iran claims it is in compliance with the Non-Proliferation Treaty. The Tehran Nuclear Research Centre (TNRC) has always been at the heart of Iran's civil and military nuclear capability including the enrichment and reprocessing facilities.

6.6. Assessment

Iran has a long history going back more than four decades of trying to develop nuclear power. All it has to show for this is one rather problematic operating reactor. Proliferation concerns would make it difficult for US, European and Japanese vendors to supply plant there. Iran says it has its own reactor technology but over the last decade claims that construction would start soon on an Iranian-designed reactor have not been realised.

Iran's experience with the Russian nuclear industry, which took nearly 20 years to complete the part-built reactor at Bushehr seems poor, so it is surprising that Iran has turned to Russia for new orders. China has signalled its interest in the Iranian market, but Iran appears only interested in its unproven Small Modular Reactor design, ACP100 rather than Hualong One.

[43] Annual capacity factor is the power produced in a year as a percentage of the power that would have been produced had the plant operated at full power uninterrupted.
[44] Nuclear Intelligence Weekly 'Briefs' November 3, 2017
[45] Nuclear Intelligence Weekly 'Iran Looks to China as Well as Russia for Reactors' April 17, 2015
[46] Nuclear Intelligence Weekly 'Potential and Existing Global Nuclear Newbuild Projects (Generation III+ or Earlier)' September 8, 2017 and Nuclear Intelligence Weekly 'Limited Newbuild Ambitions Beyond Bushehr' October 14, 2016.

Construction start with Russian reactors is still reported to be at least two years off and the deal may yet collapse. Even if construction does start, the pace of ordering for follow-up orders is expected to be slow. Iran's apparent desire for technologies with dual civil/military applications may be a factor that will force an uneconomic nuclear programme through.

7. Conclusions

The four case study countries are at very different phases in their nuclear reactor programmes. Saudi Arabia has yet to make a firm commitment to nuclear power and while its wealth and the potential size of the market make it an attractive proposition to reactor vendors, it seems likely that the lower cost of other low-carbon options may yet stop the nuclear programme. Iran has a long history in nuclear power but with little to show in terms of generating capacity. International sanctions make it difficult for many of the reactor vendors to operate in Iran and low oil and gas prices and sanctions put its ability to finance a reactor programme in doubt. The programmes of Saudi Arabia and Iran are both predicated on continued rapid electricity demand growth. If, as has happened in many other countries, the forecast rate of growth is not sustained, at best, the nuclear programme will not happen or will be scaled back and, at worst, will place heavy costs on consumers to pay for facilities that are not needed.

Over the past decade, the Chinese nuclear industry has become one of the main hopes in the nuclear industry for a future for new reactors. However, China' nuclear programme appears at a turning point with generation over-capacity, high costs, technology issues and opposition to inland sites putting the future of the new nuclear orders in doubt. There appears little prospect of any future for nuclear power in Taiwan other than a relatively rapid decline.

Nevertheless, the four countries have a number of factors in common, which, in other countries, have been seen as important factors in allowing nuclear power programmes to be implemented:

- The nuclear programmes were conceived and driven by rather centralised authoritarian regimes;
- The electricity sector is largely owned publicly-owned, mostly by central government, companies; and
- Independent and rigorous economic regulation of the electricity sector is largely absent.

Despite this, the Taiwan programme appears to have little future, the Chinese nuclear power programme is at a crisis point and the proposed programmes in Iran and Saudi Arabia are in doubt.