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Nuclear power: 2018 in review

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Here are the key nuclear power numbers for calendar year 2018:

Nine power reactor grid connections, seven in China and two in Russia, all of them conventional large PWR reactors.[1,2] Those reactors added 10.4 gigawatts (GW) of capacity (compared to 178 GW of new renewable capacity added in 2017[3] and probably a similar amount in 2018).

Six permanent power reactor shut-downs (3.8 GW)[4]: Chinshan-1 and 2 in Taiwan, Oyster Creek in the US, Leningrad-1 in Russia, and Ikata-2 and Onagawa-1 in Japan.

Four power reactor construction starts (or five if Hinkley Point C in the UK is included): one each in Turkey, Russia, Bangladesh and South Korea.[2]

49 reactors under construction – the first time the number has fallen below 50 in a decade, down four from the end of 2017, down 19 since 2013, and the number has decreased for five years in a row.[5]

2009–2018 grid connections, construction starts and permanent reactor closures:

YEAR	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	10-year total
Reactor grid connections	2	5	7	3	4	5	10	10	4	9	59
Construction starts	12	16	4	7	10	3	8	3	4	4	71
Permanent shutdowns	3	1	13	5	6	1	7	3	5	6	50

Main source: IAEA, PRIS database, https://pris.iaea.org/pris/

According to the World Nuclear Association, 41 reactors will enter commercial operation in the four years from 2019–22 (15 in 2019, 11 in 2020, 6 in 2021, and 9 in 2022).[6] Then the pre-Fukushima mini-renaissance (38 construction starts from 2008–2010) slows dramatically with an estimated total of just nine reactor start-ups in the four years from 2023–26.[6] The 49 reactor construction starts in the five years from 2009–13 more than doubled the 22 construction starts from 2014–18.[7]

Currently, nuclear power reflects two contradictory dynamics: the mini-renaissance is in full swing but will subside by the mid-2020s, and the Era of Nuclear Decommissioning[8] has begun and will be in sharp focus by the mid-2020s.

Over the past decade – and over the past two decades – the number of operable reactors has increased marginally or decreased marginally depending on whether reactors in long-term outage (almost all of them in Japan) are included in the tally:

YEAR	NUMBER OF OPERABLE REACTORS	CAPACITY (GW)
31 Dec. 1998[9]	430	345
31 Dec. 2008[9]	438	372
31 Dec. 2018		
WNA (including reactors in long-term outage)[10]	450	399
WNISR (excluding reactors in long-term outage)[5]	417	

Mycle Schneider, coordinator of the World Nuclear Industry Status Reports, notes that the total of 417 reactors (excluding reactors in long-term outage) is up 12 from a year ago (including both reactor grid-connections and restarts of some reactors in long-term outage) but still below pre-Fukushima levels and 21 reactors lower than the historic peak of 438 in 2002.[5]

No country generated nuclear power for the first time in 2018 while one country – Turkey – began construction of a power reactor for the first time. Four newcomer countries are building reactors – Bangladesh, Belarus, Turkey and the UAE. The World Nuclear Industry Status Report noted in September 2018 that new-build plans had recently been cancelled in Jordan, Malaysia and the US or postponed in Argentina, Indonesia, and Kazakhstan.[11] In November 2018, State Secretary for Energy José Dominguez announced that Spain's seven operable reactors will be permanently shut down when they reach their 40-year lifespan and thus Spain will be nuclear free by 2030.[12]

Aging reactor fleet

The industry faces severe problems, not least the aging of the global reactor fleet. The average age of the fleet continues to rise and reached 30 years in mid-2018 according to the latest World Nuclear Industry Status Report.[11]

There will likely be an average of 8-11 permanent reactor shut-downs annually over the next few decades:

- The International Energy Agency expects a "wave of retirements of ageing nuclear reactors" and an "unprecedented rate of decommissioning" – almost 200 reactor shut-downs between 2014 and 2040.[13]

- The International Atomic Energy Agency (IAEA) anticipates 320 GW of retirements from 2017 to 2050.[14]
- Another IAEA report estimates up to 139 GW of permanent shut-downs from 2018–2030 and up to 186 GW of further shut-downs from 2030-2050.[15]
- The reference scenario in the 2017 edition of the World Nuclear Association's *Nuclear Fuel Report* has 140 reactors closing by 2035.[16]
- A 2017 *Nuclear Energy Insider* article estimates up to 200 permanent shut-downs over the next two decades.[17]

So an average of 8–11 construction starts and grid connections will be required to maintain current nuclear output. Yet construction starts have averaged just 4.5 over the past five years.

Grim prospects

For the first time in many years, perhaps ever, the IAEA was up-front about the grim prospects for nuclear power in a September 2018 report.[18] The IAEA said:[19]

"Nuclear power's electricity generating capacity risks shrinking in the coming decades as ageing reactors are retired and the industry struggles with reduced competitiveness … Over the short term, the low price of natural gas, the impact of renewable energy sources on electricity prices, and national nuclear policies in several countries following the accident at Japan's Fukushima Daiichi Nuclear Power Plant in 2011 are expected to continue weighing on nuclear power's growth prospects ... In addition, the nuclear power industry faces increased construction times and costs due to heightened safety requirements, challenges in deploying advanced technologies and other factors."

The IAEA's low and high projections for global nuclear power capacity in 2030 are both 36% lower than the same projections in 2010, the year before the Fukushima disaster.[20]

Former World Nuclear Association executive Steve Kidd noted in an August 2018 article:[21]

"The current upward spike in reactor commissioning certainly looks impressive (at least compared with the recent past) but there are few signs that here will be a further uplift in the 2020s. What we see today is largely the result of rapid growth in the Chinese industry, which has now seemingly ended. ... In Asia, the sharp downturn in Chinese interest in nuclear is unlikely to be replaced by India or by a combination of the other populous counties there. It is clear that without a strong lead from the established nuclear countries, a worldwide uplift in reactor construction is not going to happen."

And therein lies a fundamental problem for the nuclear industry: it is in a frightful mess[11] in the three countries that accounted for 56% of global nuclear capacity just before the Fukushima disaster: the US, France and Japan.[22]

Spin

2018 was a "positive year for nuclear power" according to the World Nuclear Association.[1] And indeed it was – compared to 2017, which was one of the industry's worst-ever years.[8] The Association cited nuclear power's net gain in 2018 (9 grid connections, 6 permanent shut-downs).

Bright New World, an Australian pro-nuclear lobby group (that accepts secret corporate donations) listed these gains in 2018:[23]

1. Taiwanese voters voiced support for overturning legislation to eliminate nuclear power.
2. Poland announced plans for a 6–9 GW nuclear sector.
3. China connected the world's first AP1000 and EPR reactors to the electrical grid.
4. Some progress with Generation IV R&D projects (Terrestrial Energy, NuScale, Moltex), and the passing of the US Nuclear Energy Innovation Capabilities Act which aims to speed up the development of advanced reactors.

Those are modest and pyrrhic wins. To take each in turn:

1. Taiwan's government remains committed to phasing out nuclear power although the 2025 deadline has been abandoned following a referendum in November 2018.[24]
2. Poland might join the club of countries producing nuclear power – or it might not. Currently it is a member of a group of countries that failed to complete partially-built power reactors and have never generated nuclear power, along with Austria, Cuba, the Philippines, and North Korea.[25]
3. China's nuclear power program has stalled – the country has not opened any new construction site for a commercial reactor since December 2016.[1]
4. Generation IV fantasies are as fantastical as ever. David Elliot – author of the 2017 book *Nuclear Power: Past, Present and Future* – notes that many Generation IV concepts "are in fact old ideas that were looked at in the early days and mostly abandoned. There were certainly problems with some of these early experimental reactors, some of them quite dramatic."[26]

One example of the gap between Generation IV rhetoric and reality was Transatomic Power's decision to give up on its molten salt reactor R&D project in the US in September 2018[27] – just weeks before the public release of the *New Fire* propaganda film that heavily promotes the young entrepreneurs who founded Transatomic.[28] The company tried but failed to raise a modest US$15 million for the next phase of its R&D project.

An article by four current and former researchers from Carnegie Mellon University's Department of Engineering and Public Policy, published in the *Proceedings of the National Academy of Science* in July 2018, argues that

no US advanced reactor design will be commercialized before mid-century. Further, the authors systematically investigated how a domestic market could develop to support a small modular reactor industry in the US over the next few decades – including using them to back up wind and solar, desalinate water, produce heat for industrial processes, or serve military bases – and were unable to make a convincing case.[29]

Long-time energy journalist Kennedy Maize recently argued in *POWER* magazine that Generation IV R&D projects are "longshots" and that the "highest profile of the LWR apostates is TerraPower ... backed by Microsoft founder and multi-billionaire Bill Gates. Founded in 2006, TerraPower is working on a liquid-sodium-cooled breeder-burner machine that can run on uranium waste, while it generates power and plutonium, with the plutonium used to generate more power, all in a continuous process."[30] TerraPower recently abandoned its plan for a prototype reactor in China due to new restrictions placed on nuclear trade with China by the Trump administration.[31]

Bright New World might have cited some other pyrrhic wins in 2018. The French government abandoned previous plans to reduce nuclear power to 50% of total electricity generation by 2035 ... but still plans to shut 14 reactors by 2035.[32] The Vogtle project in the US state of Georgia came close to being abandoned but it was rescued despite monumental cost overruns (the estimate for two AP1000 reactors has risen from US$14 billion to US$28 billion) and multi-year delays.[33]

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China to the rescue?

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China's nuclear power program grew rapidly before the Fukushima disaster … then slowed for a few years as the implications of the disaster were assessed … then picked up pace … then slowed once again. Currently, China has 45 operable power reactors (43 gigawatts (GW) capacity) and 13 under construction (12.8 GW).

The most likely outcome over the next 5–10 years is that a small number of new reactor projects will be approved each year, well short of previous projections and not nearly enough to match the decline in the rest of the world.

China's National Energy Administration said in March 2018 that by the end of the year, announcements would be made about sites for the construction of 6–8 new nuclear reactors, ending a two-year freeze on new starts.[1] That didn't eventuate. Perhaps announcements will be made this year.

Mycle Schneider, coordinator of the World Nuclear Industry Status Reports, noted in a January 2019 article:[2]

"While China has accounted for 35 of 59 units started up in the world over the past decade and has another dozen reactors under construction, the country has not opened any new construction site for a commercial reactor since December 2016 (a demonstration fast breeder reactor not comparable to a commercial project was launched in December 2017). The nuclear industry is awaiting a central government decision over future technology choices and project siting. Construction is expected to be relaunched during the year 2019. However, there is no official government statement as to timing and ambition of future nuclear planning."

Former World Nuclear Association executive Steve Kidd noted in an August 2018 article that the growth of renewables in China "dwarf the nuclear expansion".[3] Kidd wrote:

"Many of the negative factors which have affected nuclear programmes elsewhere in the world are now also equally applicable in China. Despite many new reactors starting up, it is clear that the programme has continued to slow. The most obvious sign of this is the lack of approvals for new construction starts. There have been no new approvals for approaching three years, so the number of reactors under construction has been falling sharply. Other indications of trouble are uncertainties about the type of reactor to be utilised in the future, the position of the power market, the structure of the industry with its large state-owned enterprises (SOEs), the degree of support from state planners and the level of public opposition to nuclear plans. ...

"Perhaps surprisingly, a big issue today affecting the Chinese nuclear programme is its economic viability. With nuclear power only currently representing 3-4% of China's electricity supply, one would think that there is still plenty of room for dramatic growth. However, the slowing of the Chinese economy and the switch to less energy-intensive activities, together with over-investment in power generation capacity, means that there is now more than can be carried in the grids in some provinces. It cannot therefore be assumed that new nuclear units will run at the 80-90% capacity factors necessary to pay back the funds invested in their construction.

"Tariffs that producers receive when they sell power to the grid are also under threat. The central government wishes to liberalise the Chinese power sector and make it more responsive to economic criteria and this may not help nuclear. The rising costs of building Gen III units are also a factor. Reactors may have to load-follow, which is not ideal in the technical or economic sense. Nuclear has to compete against other generation options. ...

The threat in China is that nuclear may become no more than a niche, bridging technology, as a route to something better in the future."

Peter Fairley, an *MIT Technology Review* contributing editor, noted in a December 2018 article:[4]

"Officially China still sees nuclear power as a must-have. But unofficially, the technology is on a death watch. Experts, including some with links to the government,

see China's nuclear sector succumbing to the same problems affecting the West: the technology is too expensive, and the public doesn't want it.

"The 2011 meltdown at Japan's Fukushima Daiichi plant shocked Chinese officials and made a strong impression on many Chinese citizens. A government survey in August 2017 found that only 40% of the public supported nuclear power development.

"The bigger problem is financial. Reactors built with extra safety features and more robust cooling systems to avoid a Fukushima-like disaster are expensive, while the costs of wind and solar power continue to plummet: they are now 20% cheaper than electricity from new nuclear plants in China, according to Bloomberg New Energy Finance. Moreover, high construction costs make nuclear a risky investment.

"And gone are the days when nuclear power was desperately needed to meet China's soaring demand for electricity. In the early 2000s, power consumption was growing at more than 10% annually as the economy boomed and manufacturing, a heavy user of electricity, expanded rapidly. Over the past few years, as growth has slowed and the economy has diversified, power demand has been growing, on average, at less than 4%. …

"The government has lately said little about nuclear policy. Its official target, last updated in 2016, calls for 58 gigawatts of nuclear generating capacity to be installed by 2020 and for another 30 GW to be under construction. All experts agree China won't reach its 2020 goal until 2022 or later, and pre-Fukushima projections of 400 GW or more by midcentury now look fanciful."

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Taishan EPR nuclear power plant.

UK nuclear new-build program collapsing

Author: Jim Green – Nuclear Monitor editor

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A nuclear industry lobbyist said in early 2017 that the UK's nuclear power program faces "something of a crisis".[1] Since then, several plans for new reactors have collapsed and thus the nuclear new build program is in a full-blown crisis. In November 2018, Toshiba announced its withdrawal from the planned Moorside nuclear power project near Sellafield. And on 17 January 2019, Horizon Nuclear Power, a subsidiary of Japanese company Hitachi, suspended plans to build two Hitachi-GE Advanced Boiling Water Reactors (ABWR) at Wylfa in Anglesey, Wales. Hitachi's less-developed plan to build two ABWRs at Oldbury in Gloucestershire has also been suspended.

The reason for the Wylfa suspension is that Hitachi has been unable to find investors to reduce its costs and risks to an acceptable level. Horizon sought the support of South Korea's KHNP[2], just as Toshiba sought South Korean support to rescue the Moorside project – but in both cases South Korean utilities decided not to invest. Many other potential investors have been approached in Japan, the UK and elsewhere to get Wylfa off the ground, but to no avail.

The UK Nuclear Free Local Authorities noted that Hitachi joins a growing list of companies and utilities backing out of the UK nuclear new-build program:[3]

"Let's not forget that Hitachi are not the first energy utility to come to the conclusion that new nuclear build in the UK is not a particularly viable prospect. The German utilities RWE Npower and E-on previously tried to develop the site before they sold it on Hitachi in order to protect their own vulnerable energy market share in the UK and Germany. British Gas owner Centrica pulled out of supporting Hinkley Point C, as did GDF Suez and Iberdrola at Moorside, before Toshiba almost collapsed after unwise new nuclear investments in the United States forced it to pull out of the Sellafield Moorside development just a couple of months ago. If these 'titans' of the energy world cannot get new nuclear to work, then this growing trend should be telling the Government that the time for real change in energy policy has to now come, and indeed it is most overdue."

Greg Clark, Minister for Business, Energy and Industrial Strategy, put Hitachi's decision in context: "Across the world, a combination of factors including tighter safety regulations, have seen the cost of most new nuclear projects increase, as the cost of alternatives has fallen and the cost of construction has risen. This has made the challenge of attracting private finance into projects more difficult than ever, with investors favouring other technologies that are less capital-intensive upfront, quicker to build, and less exposed to cost overruns."[4]

An artist's image of the suspended Wylfa project.

The Wylfa project could be resumed "providing the right conditions are in place and the finance is there," said Hitachi's Director of Corporate Affairs Leon Flexman. But he wasn't enthusiastic: "I can't comment on the future when we don't know if those conditions will be met."[5]

Hitachi's CEO Toshiaki Higashihara listed three conditions that would have to be met in order for Hitachi to restart the Wylfa project: the project would have to be financed off the corporation's balance sheet; Hitachi would only commit relatively limited additional capital to the project; and even this modest incremental investment would have to offer the corporation prospects of an adequate profit.[6]

Horizon's chief executive Duncan Hawthorne said Hitachi would prefer to return to the UK as a supplier rather than a developer taking on large upfront risks.[7]

Flexman said the Wylfa project was costing £1m a day and "you just can't keep doing that forever as a responsible private company."[5] Hitachi – which purchased Horizon from E.ON and RWE npower for £696 million in 2012 – has invested about £2 billion in the Wylfa project, including site preparation costs and completion of the UK's Generic Design Assessment for ABWRs.[5]

Hitachi said that it plans to post an impairment loss of about ¥300 billion (£2.1 billion; US$2.74 billion) and other expenses on consolidated financial results for fiscal 2018 (ending March 31, 2019). It also plans to post an extraordinary loss on unconsolidated financial results for fiscal 2018.[8]

The estimated cost of the twin-reactor Wylfa project had risen from ¥2 trillion (US$18.3 billion) to ¥3 trillion (US$27.4 billion).[9]

Staggering government support on offer

Neither the Wylfa decision or Toshiba's decision to scrap the Moorside project came as a surprise. Perhaps the most striking feature of the Wylfa obituaries was the address to Parliament by Minister Greg Clark, in which he disclosed details about the staggering level of government support on offer:[4]

"Mr. Speaker, while negotiations were ongoing, I am sure the House will understand that the details were commercially sensitive, but following Hitachi's announcement I can set out in more candid terms the support that the government was willing to offer in support of the project. Firstly, the government was willing to consider taking a one third equity stake in the project, alongside investment from Hitachi and Government of Japan agencies and other strategic partners. Secondly, the government was willing to consider providing all of the required debt financing to complete construction. Thirdly, the government agreed to consider providing a Contract for Difference to the project with a strike price expected to be no more £75 per megawatt hour.

"I hope the House would agree that this is a significant and generous package of potential support that goes beyond what any government has been willing to consider in the past. Despite this potential investment, and strong support from the government of Japan, Hitachi have reached the view that the project still posed too great a commercial challenge, particularly given their desire to deconsolidate the project from their balance sheet and the likely level of return on their investment. ...

"I believe the package of support that we were prepared to consider was the limit of what could be justified in this instance. I was not prepared to ask the taxpayer to take on a larger share of the equity, as that would have meant taxpayers taking on the majority of construction risk and the government becoming the largest shareholder with responsibility for the delivery of a nuclear project. I also could not justify a strike price above £75 per megawatt hour for this financing structure, given the declining costs of alternative technologies and the financial support and risk sharing already on offer from the government which was not available for Hinkley Point C."

Bleak prospects

The World Nuclear Association described the UK government's financial terms for Wylfa as "unprecedented".[10] The Japanese government was also offering significant support[11], the details of which have not been publicly disclosed.

If a project with so much government largesse on offer can't get off the ground, the prospects for the nuclear industry in the UK are clearly bleak. Labour's Shadow Energy and Climate Change Minister Dr Alan Whitehead said the government's nuclear power strategy is now in "complete meltdown" and "has gone up in smoke".[12] Dame Sue Ion, chair of the UK's Nuclear Innovation and Research Advisory Board, said the Wylfa suspension is "a devastating blow for North Wales and for the nuclear sector generally and leaves the Government's Nuclear Industry Strategy in tatters and companies across the whole sector unwilling to invest further."[13]

An artist's image of Toshiba's abandoned Moorside project.

In 2017, the Department for Business, Energy and Industrial Strategy (BEIS) downwardly revised its nuclear power projection from 17 GW to 14 GW in 2035, compared to current capacity of 8.9 GW.[14,15]

That 14 GW would comprise the Sizewell B reactor and 13 GW of new capacity (with all other operable reactors permanently shut down by 2035). If Hinkley Point C (3.2 GW) is completed, almost 10 GW of new capacity would still be required. It's anyone's guess where that might come from. EDF is hoping to build 3.2 GW of nuclear capacity at Sizewell, and China's CGN hopes to build an estimated 2.3 GW at Bradwell, but both projects face obstacles and all other projects have collapsed or been suspended. (Chinese utilities currently hold a one-third share in Hinkley Point C, a 20% share in Sizewell C and a two-thirds share in Bradwell. China sees the UK as a bridgehead into the rest of Europe, where it intends to build its own reactors.[16] One wonders how long China's enthusiasm will last with the UK new-build program falling apart and several European countries phasing out nuclear power over the next 10–15 years: Germany, Switzerland, Spain and Belgium.)

It seems likely that BEIS will be mugged by reality and will once again downwardly revise its projections for nuclear power.

In its infrastructure assessment released in July 2018, the UK government's National Infrastructure Commission argued that the government should take a slower, step-by-step approach to new nuclear projects and should not agree to support more than one new nuclear power station beyond Hinkley Point C before 2025.[17] The Commission estimated that an electricity system powered mainly by renewables would cost no more than relying on new nuclear power plants; indeed it estimates slightly lower average costs for a scenario with 90% renewable and less than 10% nuclear compared to a scenario with 40% renewables and around 40% nuclear. The Commission said the economic analysis factored in the cost of balancing intermittent renewables through storage, smart grids and interconnectors.

Sir John Armitt, chair of the Commission, said: “When it comes to energy, then we see a future of renewables. ... I think where I have been accused of a change of mind is on nuclear. Where, in the past, I’ve been a strong supporter of nuclear, this work that we have done in the national infrastructure assessment – and the evidence base that we have got for it – I think that we are in a different world today. We don’t have to be as dependent on a nuclear solution as maybe we thought we needed to be 10 years ago.”[18]

The government will release its formal response to the National Infrastructure Commission report in the coming months. The government will also release details of a new nuclear financing model which aims to foist an even greater share of costs and risks onto British taxpayers and electricity ratepayers.

The Energy and Climate Intelligence Unit (ECIU) has analyzed the potential for renewables to fill the gap (9.2 GW or 73 TWh/year) left by the failure of the Moorside, Wylfa and Oldbury projects. The ECIU concluded: “Filling the ‘nuclear gap’ with alternative low-carbon power sources would keep bills down, maintain secure energy supply and allow the UK to maintain progress towards legally binding climate targets.”[19]

Just because the rationale for the new build program is fading, that doesn’t mean it won’t go ahead. It might still be pursued because of ideological pig-headedness and stupidity. Hinkley Point C is a case in point. In 2017, the UK National Audit Office said Hinkley Point is “a risky and expensive project with uncertain strategic and economic benefits”[20] and the UK Parliament’s Public Accounts Committee said Hinkley Point amounts to a “bad hand” and “the poorest consumers will be hit hardest”.[21]

The new build program might also be pursued in the belief that a strong civil nuclear industry is an important or necessary underpinning to the UK’s nuclear weapons program.[22]

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Japan's nuclear export industry collapsing

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Japan Times reported in February 2017 that Japanese firms have attempted "with little success" to sell their nuclear technologies to countries as diverse as France, Vietnam, India, Turkey, Hungary, Poland, Slovakia, the Czech Republic and the United Arab Emirates.[1]

Since then, the prospects for Japan's nuclear export industry have gone from bad to worse. Hitachi's recent suspension of the Wylfa and Oldbury reactor projects in the UK is another nail in the coffin of Japan's nuclear export industry.

Last November, Toshiba announced its decision to liquidate its NuGen subsidiary, which was planning to build Westinghouse AP1000 reactors at Moorside in the UK.[2] As recently as June 2016, Toshiba said its goal was to win orders for at least 45 AP1000 nuclear reactors overseas by 2030.[1] But Toshiba subsidiary Westinghouse filed for bankruptcy in March 2017 – nearly bankrupting its parent company in the process – and was later sold to Canadian investment company Brookfield Business Partners for about US$4.6 billion (considerably less than US$5.4 billion Toshiba paid for Westinghouse in 2006).[3] Toshiba has exited the reactor construction business.

Pro-nuclear commentator Dan Yurman wrote in May 2018: "The biggest black eye that Japan has gotten in recent years isn't from cleanup troubles at Fukushima, but from the multi-billion dollar cost overruns at the V C Summer site [in South Carolina] where Toshiba's Westinghouse ran the project into the ground with self-inflicted management failures."[4]

It seems very likely that Mitsubishi Heavy Industries' (MHI) plan to take a lead role in the building of four reactors at Sinop in Turkey will be formally abandoned in the near future.[5] In 2018, MHI told the Turkish government that the cost of the project would total around ¥5 trillion (US$45.6 billion), more than double the original estimate of about ¥2.1 trillion (US$19.2 billion).[6] "We cannot accept this" cost increase, a Turkish government official reportedly told MHI representatives.[7] Itochu Trading House, a Japanese company, exited the Sinop project consortium in 2018 due to the escalating costs and unrealistic timeframe.[4,9]

A dozen Japanese companies were involved in the JINED consortium that hoped to build reactors in Vietnam. Japan's Ministry of Economy, Trade and Industry was to provide significant financing and insurance, but Vietnam cancelled its nuclear power plans in 2016.[10] *Reuters* reported following the cancellation: "Though it has sought contracts for years, Japan has never led a nuclear project to completion overseas and Abe has lent his office's prestige to attempts to win contracts ... The dented ambitions for exports come at a time when Japan is struggling to restart dozens of reactors shut down in the wake of Fukushima."[11]

Japan has concluded a nuclear cooperation agreement with India, but it's doubtful that it will lead to any work for Japanese companies. Tom Corben noted in *The Diplomat* in December 2017 that Japan's willingness to supply India's nuclear power program is problematic: "Meanwhile, as a non-signatory to the Nuclear Non-Proliferation Treaty, the ambiguous nature of assurances from the Indian government that Japanese technology will not be used to produce nuclear weapons is worrying, as is the lack of legal definition around the circumstances in which Japan may justifiably abandon the deal."[12]

In October 2018, Toshiba and IHI decided to dissolve a joint venture formed in 2011 to manufacture and supply nuclear plant equipment.[8] IHI will keep its nuclear business alive but is shifting energy operations towards renewables as well as hydrogen and other non-fossil-fuel options.[13]

Toshiba has exited the reactor construction business (but continues to work on maintaining, repairing and decommissioning existing plants), sold Westinghouse, and exited the joint venture with IHI. Other Japanese utilities are also shifting from reactor construction to decommissioning. TEPCO, Chubu Electric Power, Hitachi and Toshiba are negotiating a partnership in areas including reactor decommissioning and maintenance.[8]

Government support for nuclear exports

A December 2018 editorial in *The Mainichi* questioned the Japanese government's continuing promotion of nuclear exports:[14]

"Projects to export nuclear power plants, a pillar of the "growth strategy" promoted by the administration of Prime Minister Shinzo Abe, appear to be crumbling.

"Factors behind the failures include ballooning construction costs due to strengthened safety standards after the triple core meltdowns at Tokyo Electric Power Co.'s (TEPCO) Fukushima Daiichi Nuclear Power Station in March 2011, and growing anti-nuclear sentiments around the world.

"Nothing else can be said but that the export projects have effectively failed. The prime minister's office and the Ministry of Economy, Trade and Industry must bear the responsibility of continuing to promote these exports despite a massive change in the attitude toward nuclear power plants. …

"In 2012, a national referendum in Lithuania voted down a project to build a Hitachi nuclear power plant, and then in 2016, Vietnam scrubbed a similar construction plan. The same year, Japan signed a nuclear cooperation agreement with India, eyeing exports of nuclear power plants despite concerns about the proliferation of nuclear materials to the nuclear weapon state outside of the

Nuclear Non-proliferation Treaty. Still, the export plan has yet to materialize. It is clear that the export of nuclear power plants has been backed into a corner for quite some time already. …

"Continuing to focus on nuclear power export, however, will lead Japan nowhere. The government should take another look at global trends, and review the basis of its nuclear power policy to rid Japan of nuclear power as soon as possible."

Loss of skills

Japan's nuclear export ambitions are crumbling and there is little chance of new reactors being built in Japan. Thus Japan is fast losing the capacity to build reactors at home or abroad. The *Nikkei Asian Review* reported in December 2018:[8]

"The biggest challenge for Japanese manufacturers losing nuclear orders will be retaining and passing on skills. Around 3,000 people were engaged in nuclear-power-related work in 2016, down sharply from the 2010 peak of 13,700, while the number of technical workers in the field has tumbled 40%, according to the Japan Electrical Manufacturers' Association. This has raised concerns about whether the industry will have enough engineers to handle decommissioning work, demand for which is set to rise as power companies scrap old reactors. 'In the U.S., technical know-how at Westinghouse Electric and General Electric sharply declined during a long stretch of time without new nuclear construction,' said an executive at a heavy industry group, adding that the same loss of skills 'is sure to happen in Japan.'"

The Japanese nuclear export industry did have one small win in 2018: Idaho National Laboratory subcontracted GE Hitachi to work with Bechtel to advance design and cost estimates for an experimental fast neutron reactor based on GE Hitachi's PRISM technology. The US

Where Japanese companies have been forced to give up or suspend nuclear power projects

U.K.	
Hitachi	•Construction project suspended *(2019)*
Toshiba	•Liquidation of nuclear power subsidiary announced *(2018)*
Lithuania	
Hitachi	•Order received but project now under suspension *(2016)*
Turkey	
Mitsubishi Heavy Industries, Framatome	•Project dropped after costs ran excessively high *(2018)*
United Arab Emirates	
Hitachi, General Electric	•Outbid by South Korean competition *(2009)*
Vietnam	
Mitsubishi Heavy Industries, Tokyo Electric Power	•Project terminated due to Vietnamese government's deteriorated budget *(2016)*

Department of Energy plans to decide in 2020 whether or not to proceed with the project. If built, the reactor will be operated as a national test facility – a source of fast neutrons to help researchers develop fuels and materials for fast reactors.[15] Dr Ed Lyman from the Union of Concerned Scientists questioned the wisdom of the project, noting that compared to conventional light-water reactors, fast reactors are less safe, more expensive, and more difficult to operate and repair.[16]

That one, small win does nothing to change what Tadashi Narabayashi, a professor at the Tokyo Institute of Technology, recently described as a "critical situation" for Japan's nuclear power industry.[17] "Japan would lose its own atomic power industry, and would have to import Chinese-made nuclear plants 20 years from now," he said.

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The economic viability of nuclear power is only going down

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Last year the Trump administration's Energy Department announced the launch of a media campaign to counter what an official called "misinformation" about nuclear power.[1] We haven't noticed an upsurge in pro-nuclear news – because there is none to report.

On the first day of 2019, the energy industry trade journal *Power* asked whether new technology can save nuclear power by making new reactors economically feasible – not only to replace coal and natural gas but also to compete with the rapidly dropping cost of renewable energy.[2] The verdict from Peter Bradford, a former member of the federal Nuclear Regulatory Commission: "[N]ew nuclear is so far outside the competitive range. ... Not only can nuclear power not stop global warming, it is probably not even an essential part of the solution to global warming."

His bleak outlook is shared by the authors of a recent article in the *Proceedings of the National Academy of Sciences*.[3] The authors – an engineer, an economist and a national security analyst – reviewed the prospects for so-called advanced designs for large nuclear reactors, and for much smaller modular reactors that could avoid the billions in construction costs and overruns that have plagued the nuclear energy industry since the beginning.

They concluded that no new designs can possibly reach the market before the middle of the century. They cite the breeder reactor that, according to the Bulletin of Atomic Scientists, received US$100 billion in public development funds worldwide over six decades and still did not get off the ground.[4]

The authors say there may be an opening for small modular reactors but that it will be very difficult to find a market for these reactors without – as is always the case with nuclear power – a massive infusion of taxpayer dollars. "For that to happen," they argue, "several hundred billion dollars of direct and indirect subsidies would be needed to support their development and deployment over the next several decades, since present competitive energy markets will not induce their development and adoption."

Despite the past failure and poor future outlook, support for more nuclear funding persists. In a recent study, the Energy Department pointed to the US$50 billion in federal incentives provided to renewables like solar and wind power between 2005 and 2015, implying that such policies can have a similar impact on modular nuclear reactors.[5] But unlike nuclear power, the costs of wind and solar have dropped dramatically, to the point where the cost of new, unsubsidized utility-scale wind and solar power investment can now compete with that of existing coal and nuclear power plants.[6]

The bigger question is whether nuclear power is needed at all. Nuclear advocates' claims that nuclear power is required to fight climate change falls short. California met its climate goal of reducing greenhouse gas emissions to 1990 levels by 2020 four years early by turning off its nuclear plants and setting policies that prioritize renewables, energy efficiency and energy storage investments over natural gas plant additions.[7]

An argument advanced in the Energy Department report is that, to ensure that power can be delivered 24/7, large coal and nuclear power plants designed to run day and night – also known as baseload plants – need to be replaced by small nuclear units that run day and night. However, mounting, real-world evidence refutes this assertion.

Recent studies from New York and California show that it is cheaper to invest in renewables, energy efficiency and energy storage in order to replace aging nuclear plants than it is to keep the existing plants running.[8] Savings range from hundreds of millions to billions of dollars – achieved without any impact on electric system reliability.

Nuclear power belongs in a museum. We shouldn't continue to squander public dollars on a technology that will never make economic sense. We should divert resources into improving and deploying wind, solar, energy efficiency and energy storage technology that we know will keep the lights on, effectively reduce carbon emissions and cost what we can afford to pay.

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