Nuclear power plants 'under construction' - Part II

(This document is based on data available in June 2021.)

Having discussed the European nuclear power plant projects in Part I of the more than 50 nuclear power plants officially under construction in the world, the question may be raised: can the Australians, the Americans, China and India all be right if the first ones find the idea of building a nuclear power plant alarming, while the latter two actually welcome the notion? How about the appearance of Bill Gates on the scene?

The bi-annual fuel report of the World Nuclear Association (World Nuclear Association, WNA) which celebrated its 20th anniversary this year was last published in autumn 2019. The reasons supporting its vision outlined to 2040, includes which countries and economies find constructing a nuclear power plant attractive and why according to the WNA. The reasoning included that the Association believes nuclear power plants emit zero greenhouse gases and other pollutants, they are a reliable and safe source of electricity, nuclear power is competitive in the long term and nuclear energy can contribute to the development of industry, economy and humans alike. However, rather than pondering or clarifying the truth of these claims, it would be worth focusing on the following statement: according to the WNA, the power generation size and concentration of nuclear power plants makes them 'especially attractive to industrialising countries and those which do not possess energy resources'.

Therefore, a dedicated subpage was created on the Association's website, and the data and information compiled there indicate that the majority of the countries interested in building nuclear power plants are indeed so-called developing countries, where governments usually do not only participate in the planning process, but also act as financial contributors. However, this approach explains why Australia has not considered nuclear power as a potential attractive solution to replace the substantial capacity provided by its coal-fired power plants. A report presented to the Australian Parliament detailed the reasons why builders failed during nuclear power plant construction projects around the world. They have narrowed down the scope of the report to five projects; three in Europe (Olkiluoto 3 in Finland, Flamanville-3 in France and the Hinkley Point C in the UK) and two in the U.S. (Vogtle 3&4 and VC Summer 2&3). In addition to uncontrollable costs and the inability to meet deadlines, the most common issues highlighted were the confusion around the investment, which together could lead to a result that is contrary to market expectations. They found that if a nuclear project is analysed in its entirety - i.e. taking into consideration both up-front and downstream costs - it is 'quite possible' that a nuclear project could cost more per unit than a modern solar photovoltaic system.

In addition, the lens applied by WNA allow us to take a fresh look at nuclear power plant constructions through a study disclosed by Science Direct in May (but published only in the August 2021 issue) that sought to clarify the association between nuclear power plants and climate change mitigation. A study conducted by researchers of the Institute of Safety and Risk Sciences, University of Natural Resources and Life Sciences, Vienna (BOKU): *Nuclear energy - The solution to climate change?* argues that nuclear energy growth scenarios have overestimated both the rate of nuclear generating capacity growth and the spread of nuclear power plants around the world.

Studying a number of projections, including the reports compiled by the IAEA, OECD-NEA and WNA, the researchers found that projections made in the 1980s (such as the IAEA's 1986 'low' scenario) expected a significantly (up to ten times) higher, 5,000 GW of installed capacity by 2000. Actual construction proportions were regularly overestimated and overrated even after the Chernobyl accident, when optimism declined. This approach, albeit with less intensity, was sustained even after the Fukushima disaster, so while the IAEA's 'high' scenario projected 400 to 500 new reactors to be built by 2040, a total of 3,000 to 4,000 units would be needed to replace fossil fuel power plants if only nuclear power plants were used.

Bribes, corruption and lies

However, through the prism of the WNA, the piece of the puzzle of the U.S. nuclear industry may also 'fall into place' based on the document that was written on the U.S. nuclear power industry last August by the Environmental Working Group (USA) (Environmental Working Group, EWG). It states that nuclear industry policy has three characteristics: bribes, corruption and lies.

The U.S. nuclear industry knows that it cannot compete fairly in the open market with safe, clean, cost-effective renewable energy sources like solar power, wind power and batteries, therefore, it employs illegal and inconvenient tactics, stated the EWG. Recent examples were cited to prove the claim:

1) In July 2020, the FBI prosecuted Larry Householder, Speaker of the Ohio House of Representatives for accepting more than USD 60 million from FirstEnergy Corporation to secure benefits and federal government subsidies for the company's nuclear and coal power plant plans until 2026.

Although the company has not been sued to date, several people have been arrested in the case. Like the Southern Ohio prosecutor, David DeVillers called it 'likely the largest bribery and money laundering scheme ever perpetrated against the population of Ohio'.

2) Exxon's subsidiary (Commonwealth Edison Company, ComEd) quickly paid a USD 200 million fine in a similar bribery case that broke out a few days after the one in Ohio: they had planned to ensure the adoption of laws in Illinois that would allow the company to operate two nuclear power plants and to maintain its monopolistic position in the energy market. Former ComEd Vice-President Fidel Marquez was the first to be charged for illegal lobbying on 4 September. According to a calculation, the shabby deal cost Illinois residents USD 2.4 billion.
3) Back in February, the United States Securities and Exchange Commission (SEC) filed a complaint against South Carolina Electric & Gas Company (SCE&G) for lying to both regulators and investors about the progress of the construction of the nuclear power plant VC Summer. This project was cancelled due to the estimated cost of USD 13 billion and an enormous overspending in 2017. As The Intercept revealed: South Carolina spent USD 9 billion to dig a hole in the ground and then fill it back in.

David Pomerantz, Executive Director of the Energy and Policy Institute, which investigates corruption cases of utility companies, said Illinois and Ohio Bribery Scandals Show the Perils of Mixing Utilities and Politics and the power of utility companies is the source of all problems, as they exert their financial power to influence political decision-making. Especially if those contribute to strengthening their monopolistic position and increasing their profits, which has nothing to do with climate change policy or efforts. According to Pomerantz, curbing the political power of large energy and utility companies would benefit both the expansion of renewable energies, and climate protection in the long run.

Stronger politics is required

Interestingly, Pomerantz's conclusion reflects the views of perhaps the most influential energy expert in the United States, S. David Freeman, who passed away in May 2020, and summarized in one of his last interviews why politics, not industry and economics, should dictate the direction and pace of the energy transition. Freeman said the market operates much too slowly in the very capital-intensive field of energy, and therefore, we need to use the force of the law to make these monopoly-type companies go in the direction climatologists say. However, putting this into practice is not that easy, but that is why politics has to change. 'I think the problem is that we're not smart politically. We have a beautiful, simple message to sell. We've invented a better mousetrap, and the goddamn fossil fuel industry and the nuclear industry has got enough clout, and the marketplace is too slow, and they're stopping it' explained Freeman. The sector doyen nicknamed the Green Cowboy added: We need to overcome all that with the force of law and plans need to be implemented.

'We're going to save money over time, and we're also going to save the planet.'

But what if all these doubts, counter-examples and reasons are only secondary or even lag behind for the government of a country, because it turns to nuclear energy because of its political connections, the demographic explosion or the need for energy resulting from urbanisation and economic development, or even because of the scarce availability of its own energy raw materials?

Bill Gates opened a new window

We only heard about it a few weeks ago in Hungary, but the nuclear industry has actually been talking about Bill Gates's sodium-cooled reactor for years. TerraPower founded by Gates promised to develop and build these reactors and show the way forward in nuclear power plant construction and nuclear power generation before 2030. The idea of using heat generated by nuclear fission not to directly spin a turbine, but to store it in a tank of molten salt, is not new under the sun. The topic came up again when the Nuclear Energy Institute (NEI) hosted a virtual event ***(Nuclear Energy Assembly)*** in early June, where Bill Gates explained: 'nuclear power must play a role in getting the world to net zero'. Since Gates's appearance can be well communicated as a positive message in any fields, be it healthcare or charity, Canadian railways or John Deere and tractor manufacturing (the philanthropist has interests in them all), no wonder that World Nuclear News published the full text of the speech.

None of the people reporting on the internet forum really noticed that U.S. Secretary of Energy Jennifer Granholm also turned up there, and said 'The future of nuclear energy is here. It's got a simpler design that will hopefully result in faster construction at lower cost.' Even though her train of thought might be appealing to many, there is a huge problem. The fact is that small nuclear power plants have not been able to satisfy the requirements mentioned by the Secretary since the 1960s. It's a vicious circle like the production of mini cars: just because the car is smaller, it will not be proportionately cheaper, because safety costs, technological and construction compromises, unexpected challenges, material costs and know-how will not cost less just because a Mini or a Fiat 500 rolls off the production line instead of a standard car.

However, sodium-cooled technology also appealed to the military industry: the U.S. Navy tested the technology live in the 1950s, after a mini nuclear power plant built by GE's nuclear lab was installed in nuclear submarine USS Seawolf (SSN-575). Unfortunately the system has not passed initial tests, since it often failed at full load and the reduced power sea tests were only attributed to the success of the improvised repairs, therefore, the submarine was eventually fitted with a traditional water-cooled reactor. The Environmental Working Group published an article in March on small modular nuclear reactors (Small modular reactor, SMR), and detailed why they do not help counter the climate crisis, stating that despite about a hundred billion dollars spent worldwide, sodium cooled reactors have been commercial failures globally.

Even though Bill Gates' new reactor does not actually fit into the SMR category (which is limited to 300 MW) because of its power (345 MW), it has other weaknesses. The Bulletin published an article by Frank N. von Hippel in March. According to the professor engaged in fissile materials policy issues for 30 years, Bill Gates' plan is not only costly, but also entails huge safety risks, since this technology produces plutonium, which is considered to be a treasure trove for the defence industry. Von Hippel has spent his entire life in these plutonium producing reactors, and thinks it is no coincidence that the United States, Germany, the United Kingdom, France, and Japan all abandoned their breeder-reactor efforts after spending the equivalent of USD 10 billion or more each. In addition, currently only two sodium-cooled (fast neutron) breeder reactor prototypes are operating - both in Russia. Officially India is building one, and China is building two with Russian help. In von Hippel's opinion, it is not clear India and China are looking only to generate electricity with their breeders; they may also be motivated in part by the fact that breeder reactors produce copious amounts of weapon-grade plutonium. This is why the proliferation of such projects in fact harbours many threats - wrote the physicist. It was demonstrated in 1974, when India carried out its first explosive test of a nuclear-weapon design with plutonium that had been produced with US Atoms for Peace Program assistance for India's ostensibly 'peaceful breeder reactor program'. The United States, thus alerted, was able to stop Brazil, Pakistan, South Korea, and Taiwan from going down the same track and get access to plutonium.

In 1977, the U.S. concluded that plutonium breeder reactors would not be economic and not only was it not worth building and developing new ones, or experimenting with them since they were not profitable, but even existing ones should be decommissioned. However, von Hippel also pointed out that although the last U.S. unit of this kind was abandoned and shut down during the Clinton administration, during the Trump administration, the department agreed to back the construction of a plutonium-fuelled, sodium-cooled reactor. The 'Versatile Test Reactor', designed to have a capacity of 300 MW in Idaho (Versatile Test Reactor, VTR) is officially scheduled for completion in 2026, the estimated cost of the project is currently USD 5.6 billion. GE-Hitachi Nuclear Energy and Bill Gates' Terrapower also joined the VTR project in January 2020, which can produce more than 300 kg of plutonium per year - writes von Hippel. This amount is 50 times higher than the amount carried by Fat Man bombs detonated by the U.S. Air Force over Nagasaki on 9 August 1945.

Former Nuclear Regulatory Commission (NRC) head Gregory Jaczko has a totally different approach, but he also talked about the issue of security, in an interview in 2019, when he said that although he started his career as a scientist, he didn't think there's anything wrong with trying to come up with better nuclear fission technology.

'In the short term, we could work on better nuclear, but if it comes to spending money on nuclear or other renewable energy sources, it would make more sense to invest in the other' he explained. He also mentioned the example of Japan to highlight what happens when an economy hinges on its fleet of nuclear reactors. A country of the Kyoto Protocol with very aggressive climate goals before 2011, faced after the Fukushima accident that it is unable to follow the course planned previously. All nuclear power plants were shut down because of a single accident and they had to (re)turn to fossil fuels.

Nuclear power plants under construction - Countries II.

1) **Argentina**

CAREM25 – 8 February 2014 – 25 MW

The name CAREM25 is an acronym for the Spanish Central ARgentina de Elementos Modulares and refers to the net power output capacity of 25 MW. Construction of the mini nuclear power plant has officially been underway for more than 7 years, but since the first concrete was poured on 8 February 2014, several suspensions have been ordered. The construction company decided to do so last year because the government did not pay its share of the bills, but there were also problems with the technical documentation.

CAREM25 is being built next to Atucha (110 km northwest of Buenos Aires, near Lima), which is home to two of Argentina's three operating nuclear power plants, with a combined capacity of 1,033 MW. Argentinean contractors are paying over two-thirds of the construction costs of the domestically developed small modular reactor (SRM), however, given its size, its main significance is not contribution to the national grid but potential technology exports. At least, that is the view of the Argentinean government, which asked shareholders to vote in order to go ahead with the project in April. The problem is that even though the Argentinean modular reactor design was first presented in 1984, the whole project was relaunched in 2006, however, the prototype was not ready until 2017. One year later, the estimated cost of the SMR project was somewhere between USD 446 to 700 million, the launch was scheduled for 2020 and last year's halt was not included in the plans.

However, when we talk about SMRs, it is worth considering electricity 'prices' per kWh in Europe, where household consumers typically pay EUR 0.1 to 0.2 , while based on the costs incurred to date, Argentina's CAREM25 produces electricity at a price of USD 22,000 (EUR 18,260 at current exchange rates) per kWh, as reported by the EWG in its astonishing March article.

2) Bangladesh

ROOPPUR-1 – 30 November 2017 – 1,200 MW

ROOPPUR-2 – 14 July 2018 – 1,200 MW

Bangladesh and its historic predecessor, Eastern Pakistan has wanted to build a nuclear power plant for 60 years. The first installation plan (1961) aimed at 200 MW, which was gradually increased (1987: 300-50 MW, 1998: 600 MW, 2013: 1,000 MW) - but strictly on paper. Then, in late 2015, due to the obsolescence of the VVER-1000 type originally recommended by the Russians, the VVER-1200 type was opted for and Bangladesh ordered two. The nuclear power plant is being built by Rosatom based on its own plans about 160 kilometres from Dakka. The initial cost estimate of the project amounted to USD 13 billion, but it was finally agreed during the preparatory work, when the parties fixed the division of responsibilities that 90 percent of the USD 12.65 billion contract would be financed by a Russian loan and the rest by the government of Bangladesh from domestic funding.

Rosatom, being responsible for the design, construction and delivery of all major equipment, promised to commission Rooppur-1 in 2023, and Unit 2 a year later. There have been no official reports of delays or problems in the works and the project has not even been slowed down by Covid-19, with over 12,500 people working at the construction site at its peak. In November 2020, the 14,000-kilometre, two-and-a-half-month journey of the reactor pressure vessel of Unit 1 to its future operating site on the eastern bank of the Ganges ended in November as reported by the

World Nuclear News, the 7-tonne steam collector of the power plant also arrived within the month. The internals of the power plant ready for shipment from the Volgodonsk site include an 11-metre long inner shaft, a divider plate and a protective tube unit, a total of more than 210 tonnes of components are awaiting land and sea freight.

Officially, in February 2021 the project schedule reflected that Rooppur 1 is to be commissioned in 2023 and the second unit was expected to be completed in 2024. Rosatom committed to deliver a turn-key construction in Bangladesh and to train local personnel during the first year of operation of Unit 1. The Russians take this role seriously, they have been training local personnel for years and expect to train over 1,500 trainees in the Russian Novovoronezh Nuclear Power Plant II by 2022.

3) Brazil

ANGRA-3 – 1 June 2010 – 1,405 MW

Angra-3 is a worst case scenario of nuclear power plant construction. The first chapter of the project, which began in 1984, lasted only for two years, and from 1986 the reactor built in cooperation with Siemens was delivered only as equipment (more than two-thirds of it), however, they are now being stored and becoming obsolete in a warehouse. The project, which was relaunched more than 20 years later in the summer of 2007, was contracted to France's Areva, and when actual construction began in the summer of 2010, the parties estimated that the 1,350 MW reactor could be connected to the Argentinean power grid by 2018. This did not happen since the government stopped construction in 2014 and tried to sell the entire project. Hoping (in vain) to attract a large amount of money and committed private investors through auction, in March 2021, Leonardo Mendes Cabral, the privatisation director of Brazil's National Bank for Economic and Social Development (BNDES), said a financial package for the power plant unit could be ready within the next 18 months. Resuming works has already been rumoured since last summer, because the meeting was attended by President Jair Bolsonaro, but even more revealing is the report published in The Bulletin in February 2021 on the association between the nuclear power plant construction and political corruption in Brazil. The statement on systematic corruption, money laundering, bribes paid to government officials, fraud and embezzlement illustrates that the construction of Angra 3 is rather a series of political decisions associated with money and politics, which have little to do with better care or the provision of common good.

Rising technology costs and higher safety requirements in the nuclear industry have officially increased investment costs by 'only' 2.7 billion dollars between 2008 and 2018, but it has been calculated recently that based on the amount of money spent on the future plant so far, its cost per megawatt hour has doubled and now equals to USD 90. However, the construction is not over yet, the government now expects it can be completed by 2023 or 2024.

4) **South Korea**

SHIN-HANUL-1 – 10 July 2012 – 1,400 MW

SHIN-HANUL-2 – 19 June 2013 – 1,400 MW

SHIN-KORI-5 – 1 April 2017 – 1,400 MW

SHIN-KORI-6 – 20 September 2018 – 1,400 MW

In June 2021 a study was published on the Research Gate portal, which examined the functioning of the trust-acceptability models in South Korea, especially in the context of loss of trust in government and nuclear energy. The timeliness of the issue is perfectly illustrated by the fact that South Korea, which has been showcasing one of the world's most intense nuclear power plant construction and expansion efforts in the world for a decade, still suffers the consequences of corruption, safety concerns and scandals which broke out in 2013. The researchers found that an individual's trust in the government today has a negative effect on perceived benefits and a positive effect on perceived risks. This basically means that people don't fully believe what is officially communicated to them about nuclear power.

The country that was so confident in the flawlessness of its own technology that it has not shut down any of its nuclear power plant units after the Fukushima disaster, and in 2012, it still expected to start up 11 new reactors by 2021, and by 2035 it planned to have increased the existing 23.9 percent share of nuclear power in the energy mix to 60 percent, now organises the construction of its last nuclear reactors. Nowadays the news claim that Hanul-1 and -2 units had to suspend production in both March and April since the influx of marine organisms in the tube system disrupted water pump operation, and officials at Korea Hydro & Nuclear Power (KHNP) have no idea when they will be able to resume operation or if the problem will be solved permanently.

SHIN HANUL-1, 2

The six Hanul reactors with a capacity of 1,000 megawatts each built in the south-eastern part of the country between 1983 and 2005, were originally planned to be replaced by four 1,400 MW reactors built in the vicinity under the name 'new Hanul', i.e. Shin Hanul. The first concrete was poured for Units 1 and 2 on 10 July 2012 and 19 June 2013, however, they still suffer the repeated delays in construction attributed to various reasons. Units 3 and 4 have been cancelled. The originally planned two pressurised water KEPCO Generation III reactor units, with a capacity of 1,340 MW each (type APR-1400), should have been connected to the grid in 2017 and 2018 respectively, but neither this deadline, nor the originally estimated budget of USD 6 billion could be met.

When Unit 2 was due to be handed over, Asian Power wrote that KHNP had announced an additional 8-month delay in the construction of Unit 1, as there had been two major earthquakes in its vicinity in 2017 and in such cases increased monitoring is required during the new construction. At that time the plan was to complete Shin Hanul 1 by 2019, however, in January 2021 KHNP requested the approval of period extensions, and promised to complete construction by the end of 2022 and the end of 2023 respectively. Meanwhile, it applied for an extension of the expiring construction permits for Shin Hanul Units 3 and 4, which, despite earlier government promises that the country would not start building more nuclear power plant units after 2017, were approved in 2016, and the Ministry of Energy in South Korea renewed them at the end of February to expire by the end of 2023.

SHIN-KORI-5, 6

While the latest energy plan of South Korea mentions its goal is to shut down 11 of the country's 25 nuclear power plants by 2030 and increase the amount of renewable energy resources to 20 percent of total energy production and to 30 percent by 2040, without building either a nuclear power plant or a coal-fired power station, the construction of Shin Kori units 5 and 6 'started' alongside the two units at Shin Hanul ahead of the 2017 start date. Work started in 2017 and 2018 and achieved a progress in the first two years, and Nuclear Engineering International reported that work on the two units was 51 percent complete when the pressure vessel was installed in Unit 5 in December 2019. The two units are built around APR-1400s, in accordance with South Korean nuclear power plant construction practice, with Unit 5 scheduled to be commercially operational by March 2023 and Unit 6 a little over a year later, by June 2024.

However, in February this year it was in the news that the project would be delayed due to amendments to legal regulations. KHNP's President Jung Jae-hoon announced that night-time work would no longer be allowed because, even though the deadlines are tight, the Severe Disaster Punishment Act (it strengthens criminal penalties for business owners in the event of an industrial accident that caused serious human damage) no longer allows it. No decision has been taken yet on how much delay this might cause to the original schedule, the CEO added.

5) United Arab Emirates

BARAKAH-2 – 16 April 2013 – 1,400 MW

BARAKAH-3 – 24 September 2014 – 1,400 MW

BARAKAH-4 – 30 July 2015 – 1,400 MW

The UAE could have been a testing site for the international expansion of nuclear power generation systems by South Korea, and even though the project was one of the few nuclear power plants that were completed on time and within the planned budget, the results are mixed. The first nuclear power plant in the Arabian Peninsula was designed to have four units and was launched with the hope of providing a quarter of the country's power needs. In a USD 23.5 billion deal signed in 2009, KEPCo committed to build all four units as a 'turnkey' project by 2020. In 2011, Bloomberg reported the program was said to cost USD 30 billion.

Barakah 1 with a capacity of 1,345 MW was originally due to be connected to the power grid by the end of 2017, however, it was first postponed to 2018 at the request of Korean companies - officially 'as a reinforcement of operational proficiency for plant personnel' (unofficially it meant that Emirati professionals trained at Shin-Kori 3 in South Korea were not trusted to be able to operate Barakah 1). However, even though the construction of Unit 1 was completed in March 2021 and it was ready for testing in May, the UAE's Federal Authority for Nuclear Regulation (FANR) ruined South Korean success. After the FANR 400 found failures, it did not authorise the startup of the unit until such failures were corrected. It did not happen until 2020 and commercial operation started only in April 2021 due to additional finetuning. Khaldoon Khalifa Al Mubarak, Chairman of the Emirates Nuclear Energy Corporation (ENEC), said that they have a clear schedule and will ensure that the highest international safety and quality standards are met. (Mohamed Al Hammadi, Chief Executive Officer of the Emirates Nuclear Energy Corporation said in an interview in December 2020 that 'The Barakah plant is not just a power plant, it is an engine of growth for the nation.')

ENEC announced that the construction of Unit 2 had been completed in June 2020, and in March 2021 the FANR issued the operating licence for Unit 2. When Unit 1 was connected to the power grid a month later, Barakah 3 was 94 percent while Barakah 4 was 87 percent completed, and applications for operating licences for both units had been submitted.

6) United States of America

VOGTLE-3 – 12 March 2013 – 1,250 MW

VOGTLE-4 – 19 November 2013 – 1,250 MW

The United States, considered the world's largest nuclear power, has been performing a crazy magic show over the past decades to cover up the problems with its nuclear power plants. The most revealing diagram was made by the EIA, which shows that while the system has been fluctuating around 100,000 MW of production volume since 1986, the amount generated has almost doubled (from 414 TWh to 800 TWh). This is a truly magic, because fewer and fewer new power plants are being built.

In 1986, 7 new nuclear units were connected to the grid, another 8 in 1988, and over the next decade a total of 4, while since February 1996 (when Watts Bar-1 was connected to the grid) a total of 1 (Watts Bar-2 in 2016). In the meantime, 40 units have shut down, including some that still had a valid operating licence for further operation, however, whose operation was no longer profitable. Although there are 42 projects in the history of US nuclear power plants that have never been fully completed, there is currently only one plant (two units) 'under construction'. Furthermore, even sources within the sector are not overly optimistic about Vogtle 3 and 4.

The power plant expansion, which had been underway since 2009, would have guaranteed the energy security of the state of Georgia. It also aimed to enable Georgia Power, which supplies 2.6 million customers through its nuclear, coal-fired and wind turbine power plants (as a subsidiary of Southern Company, America's leading energy company), to supply 500,000 consumers and allow it to approach its carbon neutral operation undertaken to be achieved by 2050. However, nobody mentioned that the project's original estimated investment cost doubled and this will be clearly visible in electricity bills rates.

Construction of Units 3 and 4 also started in 2013, however, the project, originally promised to be completed by 2016, was almost immediately delayed: billions of dollars of government loan guarantees had to be requested both under the Obama and the Trump administrations. The construction of the new Vogtle power plant units has not officially stopped despite the subsidies, and the bankruptcy of nuclear power plant unit builder, Westinghouse (mainly caused by cost overruns seen in new U.S. power plant constructions), however, the promised aggressive project schedule failed and the company was even late with the status reports to be submitted every six month in return for the loan guarantee. Finally Vogtle 3 could not even meet the 2020 completion deadline.

It was announced earlier that once Georgia Power delivered the first batch of nuclear fuel to Vogtle 3 by 10 December 2020, initial fuel loading could take place in April and preparations for hot functional testing could begin, however, eventually this scenario did not work out. In 2021 new deadlines were announced in March (Georgia Power indicated in its submission to the Securities and Exchange Commission that the start of commercial operations for Unit 3 could be delayed by a month or more, costing the company an additional USD 25 million per month), CEO Tom Fanning, who presented the company's figures during the first quarter earnings call in April said that the company was aiming the end of 2021 for placing Unit 3 in service (while the most recent power plant startup dates approved by the authorities were November 2021 and November 2022). Finally, less than a month after Georgia Power announced that it would begin the last major test series on Unit 3 without fuel (the so-called hot functional testing), and also the last big module in Unit 4, a giant 750,000 litre water tank will be installed, Nuclear News announced a further delay on 11 June. Another delay, because Unit 3 is unlikely to start before summer 2022, and the start of Unit 4 only seems realistic a year later. This was based on the fact that the project supervisors and construction safety analysts said there were still a number of important things to be done (important components had failed and had to be replaced, and important system software updates were also overdue). In response to the news, the company stated that the construction of Vogtle 3 was officially due to be completed in January 2022, and Unit 4 would be commissioned in November 2022. The latest delay was translated into numbers: this increased the already overly expensive USD 27 billion investment cost by another USD 48 million.

7) India

KAKRAPAR-4 – 22 November 2010 – 700 MW

KUDANKULAM-3 – 29 June 2017 – 1,000 MW

KUDANKULAM-4 – 23 October 2017 – 1,000 MW

PFBR – 23 October 2004 – 500 MW

RAJASTHAN-7 – 18 July 2011 – 700 MW

RAJASTHAN-8 – 30 September 2011 – 700 MW

KAKRAPAR-4

In June 2020, a long and complex writing was published in The Indian Express. The article mixed elements of a description, pamphlet and interview, and the reason behind it was that the country's first 700 MW self-developed nuclear power plant unit, Kakrapar-3 (KAPP-3) was connected to the grid. The point of the 'landmark event' for the plant which has been under construction on the west coast of India near the Surat and Tapi rivers since 2010, as well as for India's civil nuclear programme, is the replacement of the 540 MW PHWR units mainly used so far by a larger, more advanced PHWR that operates based on the same principles as CANDU reactors. India expects the 700 MW reactors to be put into service in such quantities that they will soon become the mainstay of India's nuclear reactor fleet. The idea is that higher capacity per unit will make it easier to achieve the quantitative target set in 2007 for more than tripling the current nuclear power plant capacity of less than 7 GW to 22,480 MW by 2031. Even though the targets have already been broken down to units and construction sites, the Department of Atomic Energy in India (DAE) announced in January 2019 that India plans to commission 21 new power plants by 2031, including ten self-developed PHWRs with a total production capacity of 153,100 MW, however, this leap is now likely to be unsuccessful, even though Russia has become a very important supplier of technology and nuclear fuel in the last two decades, and gradually replaced the former strong Canadian and French relations established in previous decades. The main problem lies in delayed constructions.

New Delhi-based Jagranjosh summarised facts and dreams about nuclear power plants in India in April 2021. According to this, the country currently has 22 operating nuclear reactors with an installed capacity of 7,780 MW in 7 nuclear power plants. In 2021, almost the same number of power plant fleet with a capacity of 7,480 MW was under construction, while a total of 33 GW are planned in 10 sites. The Jaitapuri nuclear power plant is among the latter, which, if it were built, would be the largest power plant in the world today, with a capacity of 9,900 MW. The main problem is that although the idea of building a power plant has been present since 2010 (with French cooperation), in 2021 not only France was positioned differently on the world nuclear map, but the only progress achieved is that EDF submitted a technical and commercial bid, which does not commit either party to announce or start the project.

When first concrete was poured at KAPP-3 (November 2010), it seemed certain that the reactor would be connected to the grid in 2015, but it only happened five years later due to delays. While this first new reactor, and the associated infrastructure and essential equipment such as steam generators, diesel generators and other reactor components, will delay usual completion deadlines due to time-intensive design, production and testing, and, as the Financial Express reported in October 2019 - compared to Russia, China or South Korea, India has a limited number of manufacturers certified by the nuclear industry - therefore, the same delay is expected for Kakrapar-4. Minister of State Jitendra Singh stated in a written reply to the upper house of the Indian Parliament in early March 2020 that its commissioning was expected in September 2021.

KUDANKULAM-3, 4

Kudankulam is one of the largest nuclear power projects under construction in India, which, when completed, will use six VVER-1000 reactors built in Russia to generate electricity for the grid in one of the most densely populated states in the southern tip of the country (Tamilnadu). The first two units of the Kudankulam power plant (based on the India-Russia agreement concluded originally in 1988 and renewed in 1998) are already in operation (since December 2014 and April 201), while the second two units are officially under construction since February 2016 and June 2017 respectively, while Kudankulam Units 5 and 6 only exist on paper.

Since first concrete was poured, construction of the units was uninterrupted, just like the manufacturing and gradual delivery of various equipment and components. Official documentation declares that the main buildings are in place, most of the equipment has been manufactured and delivered to the site and the installation of the core catcher has been completed. (The documentation does not elaborate on the fact that various technological changes, inflation, and additional insurances taken out by the parties for the investment have already doubled the cost of the first two units, but this was eventually accepted by the Indian government.)

The plant was subject to a cyber attack in 2019. The only fact published was that traces of malware was found in the IT system, but the attacks only affected the system's administrative network. The hackers, identified as North Koreans, allegedly did not gain access to the internal network that controls the plant. However, Economic Times published in India revealed that based on the incident report 'hackers remained unnoticed in the victim's network for a long time' and malware had indeed spread across Kudankulam's IT network. The hackers' interest in Indian nuclear technology is likely to be triggered, they wrote, by the fact that India is developing thorium-based reactors, which could be the new energy resource in the world (and India has more of it than anyone else in the world).

Nevertheless, construction has not been affected. Last summer *we read it in the news that t*he vessel with the equipment for Units 3 and 4 of Kudankulam nuclear power plant left the port of Saint-Petersburg, because, despite the restrictions imposed as a result of the Covid-19 pandemic, the collection, shipment and delivery of 4,200 cubic metres of cargo, which was the 17th shipment, could be completed in more than a third of the time previously required, thanks mainly to bilateral diplomatic efforts. Another 'interesting' news appeared in December 2020 when the feed pumps for the turbine hall manufactured by Russia's TsKBM have arrived at the construction site. According to official documentation, the reactors' start-up dates are currently March 2023 and November 2023 respectively, however, in March 2021 it was published on Projects Today that construction work on Units 5 and 6 of the nuclear power plant was about to start soon. More precise dates are not available, but the portal claims that the two units, each with a capacity of 1,000 MW, are planned to be built in the course of 66 and 75 months respectively from the first concrete pour.

PFBR

In 2021 the fast breeder reactor prototype built by Bharatiya Nabhikiya Vidyut Nigam Ltd. (BHAVINI) in Kalpakkam (**Prototype Fast**Breeder**Reactor**, PFBR) had been officially delayed for more than a decade. *Is it time to abandon the programme?* asks the title of an article published in February 2020 on The India Forum, which tries to recall not only the reasons for failure near Chennai (formerly Madras), India's 4th largest city, but also why the strategic importance of the 500 MW power plant (i.e. its importance for India's nuclear weapon arsenal), which was also designed to use plutonium as fuel, has become obsolete.

The article was written because the announcement on expected commissioning of PFBR by 2022 made on September 2020 was not sustainable. The timeline of statements and reasons for the delays have also been summarised by Florish Studio, but it is not surprising that the science column of The Wire in India had already taken a thorough look at the situation before the Indian Forum article, following promises made last autumn. After all, this project was initiated by the Indian government in the 1970s, and even though the project was in the planning phase for three decades, it was set aside in 2003, saying that the project had an enormously high investment cost, however, construction has been going on since 2004. It was promised to be completed by 2010 and was almost completed, despite rising costs over the years. In 2014, when the project was officially tested, it was found that 76% of the high-value orders from previous years were not delivered on time (the average delay was 158 days, but the record was 1,092 days), and the entire project was also characterised by systematic cost overruns and a lack of required documentation. Not much changed - in 2015, when the government admitted during another due diligence that there were 'no financial restrictions' for the PFBR, so it is not surprising that a study was published in the journal *Progress in Nuclear Energy* under the title 'India's fast reactor programme - A review and critical assessment' in 2020, which concluded that the reactor could not be operated as it was designed. It is particularly significant that the study was conducted by R.D. Kale, who used to be a key figure in the development of sodium coolant technology in India.

The start-up and commissioning deadlines, which have been regularly revised since 2010, were initially related to plutonium manufacturing and production and in recent years to issues with sodium pumps, while it is estimated that the initial cost of Rs 35 billion amounted to Rs 70 billion based on the posts of Fissile Materials, an international body engaged in fissile materials. Nobody can say that they did not predict this, the organisation's explanation in 2010 on why breeder reactors are expensive and problematic can be retrieved from the same source.

In May 2020, the Minister of Atomic Energy in India specified that commissioning would take place and operation would start by December 2021.

RAJASTHAN-7, 8

Probably the best illustration of the evolution of nuclear power generation in India is the Rajasthan nuclear power plant; how it started as an imported technology-based 100 MW unit and evolved into self-developed 700 MW units. The nuclear power plant in northern India has been under construction and expansion for over 50 years, and even though the first Canadian Candu reactor started up in 1973 was shut down in 2004, the total capacity of 1,180 MW of the five generating RAPS units supplied to the grid is still significant. This will be more than doubled when Units 7 and

8 are completed, as the two new PHWR units will have a capacity of 700 MW each.

The two new units have been 'under construction' since 2011, and they were planned to be operational by 2016. However, the works are still not completed and even though the latest official date was December 2020 and December 2021 respectively, these deadlines will not be met. An article of the World Nuclear News on the power plant stated in 2019 that according to the World Nuclear Association, the completion of Unit 7 will definitely have to wait until March 2022 and that of Unit 8 until 2023.

8) Iran

BUSHEHR-2 – 27 September 2019 – 1,057 MW

Russian Minister of Foreign Affairs Sergey Lavrov announced in January 2021 that Russia was ready to help Iran expand the capacity of the existing Bushehr nuclear power plant through the construction of new units. Bushehr 1 has been operating for 10 years, construction of Unit 2 started last November, therefore, Unit 3-related preparatory work can be started. According to the contracts, both new reactors will be supplied to Iran by Rosatom with VVER-1000, Generation III+ technology and the latest safety features, however, Russia will also provide the Bushehr power plant with fuel.

The ceremony to mark the pouring of first concrete for Bushehr Unit 2, which is classified as 'under construction' had a Russian style: President of the Atomic Energy Organisation of Iran (AEIO), Ali Akbar Salehi highlighting the huge size of the project entertained the audience with a lengthy list of figures.

He stated that each reactor built, in addition to providing reliable electricity, saves Iran 11 million barrels of oil, or USD 660 million per annum and when pouring first concrete for Unit 2 is completed, it marks more than 30% of the project's schedule at a cost of 3 million cubic meters of earthworks, 3,000 tonnes of reinforced concrete and 350,000 tonnes of cement.

Phase 2 of the construction of the nuclear power plant at the Bushehr site, located 17 kilometres southeast of the city of Bushehr on the coast of the Persian Gulf, is scheduled to be completed by 2024. This could be disrupted by the fact that was announced at the end of March in a Bloomberg article, stating that the Bushehr nuclear power plant is facing the risk of shutdown because U.S. banking restrictions have made it difficult for Iran to transfer money and procure necessary equipment and make payments to Russian contractors. At the same time, another fire was photographed and a massive fire was reported in early May near the nuclear power plant and the cause of the fire remains unknown.

9) Japan

OHMA – 7 May 2010 – 1,328 MW

SHIMANE-3 – 24 October 2006 – 1,325 MW

Shunsuke Kondo, Chairman of the Atomic Energy Commission of Japan held a lecture just months before the Fukushima nuclear power plant accident. He outlined a bright future for the island country's nuclear industry, which would be achieved through key concepts such as safety, cost-effectiveness, high quality and the enforcement of climate protection aspects. Based on Kondo's calculations the share of nuclear power plants in Japan's energy mix could amount to 49 percent by 2030. Now it is clear that he will not be right; of the 33 reactor units currently in operation, 27 are in 'permanent shutdown' - i.e. in a long period of inactivity in Japan. Among the 27 are the 10 Fukushima units (the 6 reactors at Daichi hit by the disaster and 4 units at Daini) whose operation will almost certainly not be resumed, as according to official estimates, the aftermath of the 2011 disaster will require a clean-up in the region for up to 40 years. TEPCo, whose executives were found not guilty in the Fukushima accident, received government approval in April this year to discharge more than 1.3 million tonnes of pre-filtered, but still radiologically contaminated water into the ocean. The company claims this is not dangerous, however, there have been doubts about TEPCo's credibility in the past. Another item has just been added to this list, as it was revealed that the company failed to perform the safety review at the Kashiwazaki-Kariwa nuclear power plant. Asahi published an article stating that even though the company announced in January that it had completed its safety measures-related construction work the previous day and was awaiting regulatory approval to resume operation in Unit 7, in fact some of the required work (in at least 76 locations) had not been completed. Even though a former inspection already identified negligence in the area, and the Nuclear Regulatory Authority (NRA) then cancelled the reactor's resume schedule.

Japan currently relies mainly on hydrocarbons for its energy supply (coal: 25 percent, natural gas: 23 percent, oil: 39 per cent), but while the government's original plan was for the island state to reach 64 GW capacity in solar energy by 2030, this limit was already approached in 2018 (55GW), however, the use of wind power is still considered 'innovative' (3.6 GW in 2018). According to data published by the Institute for Sustainable Energy Policies, ISEP, the share of renewable energy in energy production reached 18.5 percent in 2019. As far as nuclear energy is concerned: The rate was zero until 2015, but has since recovered to 6.5 percent as a results of authorised restarts. The government now hopes nuclear could provide 20 percent of the nation's power by 2030 and also supports that the economy and society count largely on renewables. However, it does not need to primarily rely on newly build nuclear power plants. It seems that even though the database shows that two new power plants are under construction, their permits were issued before 2011.

The Tsuruga-3 & 4 and Higashidori 1 projects were in the final stages of the official review of the building permit application in 2010, but today these ideas are non-existent. 15 years ago the first ones were scheduled to start up in spring 2016 and 2017 respectively, the latter was already delayed before the Fukushima disaster: TEPCo reported a one-year delay attributed to the construction plans in January 2008, followed by an additional delay after the earthquake at Kashiwazaki-Kariwa NPP in December 2008 forced the construction of a new electricity project to meet stricter safety requirements. So when the construction permit was obtained in January 2011, work was halted in March like the operation of all power plants. Therefore, neither the original 2015 nor the revised start-up plan for 2017 worked out. TEPCo currently discloses on its website that construction work is halted and has not been resumed yet.

The Japan Times published an on-site report about the Higashidori area in December 2020. The depressing article highlighted how a small town of barely 6,000 people went from heaven to hell. The nuclear power plant built by Tohoku Electric Power and not TEPCo was started up in the outskirts of Higashidori in 2005, but the substantial amount of local tax paid to the municipality dried up after Higashidori-1 (Tohoku) was not allowed to resume operation after a general shutdown in March 2011, when it was discovered that two dangerous fault lines were located under the 1,000 megawatt reactor building.

Now, back to the nuclear power plants officially ‘under construction’ in Japan!

OHMA

The Ohma nuclear power plant located in Aomori Prefecture, northern Japan suffers the consequences of repeated changes to deadlines that have never been met. In fact, construction of a GE Hitachi Nuclear Energy Generation III ABWR nuclear reactor began in Ohma in the spring of 2008 with the aim of providing the country with an earthquake-resistant nuclear power plant constructed on the basis of a new standard, and will be operational for 60 years.

The construction of Unit 1 if Ohma was scheduled to be completed by March 2012, but work was only about 40 percent complete by March 2011. Following the general shutdown after the Fukushima accident, construction was resumed in October 2012, and was planned to be completed by November 2014, and the builder, Japan Electric Power Development (J-Power) promised: 'It will strive to build a safe power plant', reinforce the safety of the power plant and take into consideration the lessons learned from the Fukushima disaster. This included the construction of the main power plant structures (reactor, turbine buildings, etc.) at a height of 12 metres above ground level to manage tsunami risks, and the installation of two 500 kV and one 66 kV cables to guarantee power supply to emergency facilities.

In September 2015, the company announced that the project would not be completed until 2021 due to delays in the production of safety equipment, and a year later, due to the delayed safety due diligence and the NRA review protocol, it was announced that Ohma would not be completed until the second half of 2023. This target date has also changed: J-Power announced another two-year delay in autumn 2018 to comply with stricter safety protocols, but that's not the end of the story, as in September 2020 the company announced further delays, as new NRA regulations, for example, require compliance with more stringent seismic safety and tsunami protection standards than before. The new regulations, however, will push the investment into a forced path, and the construction company claimed that safety enhancement measures construction work required can realistically be completed by the second half of 2027. This is followed by an examination and licensing period, therefore 'the startup date of Ohma-1 is not specified yet' stated J-Power.

SHINAME 3

Owned and operated by Chugoku Electric Power, this project is even less lucky than the Ohma construction. The unit was originally expected to be commissioned in December 2011, but the construction work was suspended at 94 percent completion under the general shutdown following the Fukushima disaster. Actually the purpose of the entire plant construction undertaken by Hitachi-GE Nuclear Energy was not to increase generating capacity, but, as Power Technology wrote: the new unit would have replaced Unit 1 at the Shimane nuclear power plant. Unit 1 has been operational since 1974 and was slowly approaching decommissioning, which finally took place on 30 April 2015.

However, due to inability to comply with safety review protocols the construction of Unit 3 ceased after March 2011. Chugoku Electric Power submitted an application to Japan's Nuclear Regulation Authority for review of the NPP's compliance with the new safety standards in August 2018, hoping that the project could be completed.

The optimism that Shimane 3 could be the first new nuclear power plant built in Japan after the Fukushima accident has so far resulted in the possibility that Shimane 3 could be started up before Ohma-1. However, it is unknown when this will take place. In February 2020, S&P Global claimed that the plant was completed and was one of 16 units that meet NRA requirements, yet only 9 units have been green-lighted for commercial operation. This information hasn't been confirmed from other sources, however, it is certain that Shiname 3 is not among the operating reactors, and is officially still 'under construction'.

10) China

SANAOCUN-1 – 31 December 2020 – 1,117 MW

CHANGJIANG-3 – 31 March 2021 – 610 MW

XIAPU-1 – 29 December 2017 – 642 MW

FANGCHENGGANG-3 – 24 December 2015 – 1,000 MW

FANGCHENGGANG-4 – 23 December 2016 -1,000 MW

FUQING-6 – 22 December 2015 – 1,000 MW

HONGYANHE-5 – 29 March 2015 – 1,061 MW

HONGYANHE-6 – 24 July 2015 – 1,061 MW

SHIDAO BAY-1 – 9 December 2012 – 200 MW

TAIPINGLING-1 – 26 December 2019 – 1,116 MW

TAIPINGLING-2 – 15 October 2020 – 1,116 MW

TIANWAN-6 – 7 September 2016 – 1,000 MW – (9 June 2021 - put into commercial operation)

ZHANGZHOU-1 – 16 October 2019 – 1,126 MW

ZHANGZHOU-2 – 4 September 2020 – 1,126 MW

The importance and pace of China in nuclear energy is best illustrated by large numbers and lengthy lists. While NS Energy Business counted 48 reactors in operation and 9 under construction in February 2020, 16 months later, the International Atomic Energy Agency had 50 power plants in operation and 14 under construction in its register, provided that WNISR, whose data are always embarrassingly precise is right, as it indicates a 51:19 ratio. In terms of total nuclear power generation in 2020, China preceded France, even though it still produced less than half the amount of nuclear power produced by the largest producer, the United States. However, they have no problem with the age of the reactors: the current world average of 30.8 years would only be reached in more than 22 years if no reactors were connected to the grid as of tomorrow.

While the perception of nuclear power in China is changing (in 2015, they planned to build at least 110 nuclear reactors by 2030, but that number is no longer realistic), the nuclear industry is strongly supported, and even though they have seven giant power plants they still plan to build further nuclear power plants. The combined capacity of the seven largest nuclear power plants is 31,472 MW, which was just slightly behind Japan in 2019 (31,680 MW), but already exceeded Russia's total capacity (28,437 MW).

The Top7: Yangjiang Nuclear Power Plant - 6x1,000 MW, Tianwan Nuclear Power Plant - 5 different units, total: 5,100 MW, Qinshan Nuclear Power Plant - 7 units, total 4,142 MW, Hongyanhe Nuclear Power Plant - 4x1,061 MW, Ningde Nuclear Power Plant - 4x1,018 MW, Fuqing Nuclear Power Plant - 4x1,000 MW, Ling Ao Nuclear Power Plant - 4 units, total: 3,914 MW. China's nuclear power plant network had a total capacity of 46,520 MW in 2019, which increased by a few thousand MWs since then. An additional 19,735 MW is under construction, provided that China sticks to its current schedule and does not leave any construction work unfinished.

SANAOCUN-1

Site measurements started in Shanghai's southern neighbour, Zhejiang in 2007, and 5 years after the National Energy Commission approved the project (2015), the State Council Executive Meeting approved the construction of Units 1 and 2 last December, the building permit was issued by the National Nuclear Safety Administration on 30 December, and as a result, the Chinese Communist Party Provincial Standing Committee Secretary ordered the start of construction at 9.30 a.m. the following day. That is the way it goes in China. Work had begun by pouring first concrete for Unit 1 and the aim is to complete Unit 1 of the Sanaocun nuclear power plant, which will be powered by 6 self-developed Hualong One reactors, by 2025. The state-owned China General Nuclear Power Group (CGN), which currently has seven nuclear reactors under construction beside the existing 24, also stated that this investment is the first in China to involve private capital 'creating a new model for mixed reform of nuclear power plants'. In addition to CGN, the project is financed by five other companies. One of them is a non-state-owned company: Geely Technology Group, maybe best known in Europe as the manufacturer of Volvo and Lotus cars. They hold a 2 percent share in the power plant.

CHANGJIANG-3

Even newer than the Sanaocun project is the new nuclear power plant construction project in Hainan Province, an island off the southern coast of the country, south-west of Hong Kong. The first concrete for Unit 1 in the smallest province of the People's Republic of China was poured on 31 March and the same is scheduled for Unit 4 for February 2022. The two projects will be built around two Hualong One units with 1,000 MW capacity respectively. The main expectation for the JPY 40 billion investment has not changed compared to previous years: both reactors should be operational by the end of 2026. This project is a joint investment by the owners of two existing reactors (China National Nuclear Corporation, China Huaneng Group), each with a capacity of only 600 MW. The official press release announcing the start of construction of Changjiang-3 highlighted that this is the first nuclear power plant project to be started during the 14th five-year-plan period.

XIAPU-1

Following the successful completion of the test of China's first sodium-cooled mini power plant in 2010, CEFR, capable of generating 20 MW of electricity and 65 MW of heat, China started the development of a larger, 600 MW fast reactor. (Interestingly, and unusually, China has not provided any data on CEFR since it was connected, so it is uncertain whether the mini power plant produces power and/or is operational.) Construction of the CFR600 sodium-cooled pool-type fast reactor, designed by the China Institute of Atomic Energy, has started in Fu Chien province, on the coast opposite Taiwan, and has now grown to 642 MW net power and 1,882 MW heat capacity. The official goal for the construction of the reactor is to reach 40 percent thermal efficiency, however, World Nuclear News also reminds us that Chinese fast neuron reactor research and development is Russian-based (the unit was built by OKBM Afrikantov in collaboration with the Kurchatov Institute, among others), and that the CEFR core already contained 150 kilograms of plutonium. It is also important to note that almost two thirds of the latter (98 kg) is the same material (plutonium-239) used by the defence industry to make plutonium bombs.

13 months after the start of construction of Xiapu-1, Rosatom also contracted for the refuelling of CFR600 and the supply of fuel for 7 years after commissioning through its subsidiary (TVEL). The launch date of Xiapu-1, which is planned to operate for 40 years, is specified by CNLY for 2023 (CNLY is a subsidiary of the state-owned China National Nuclear Corporation (CNNC), which originates from the Ministry of Nuclear Industry and by definition 'oversees all aspects of China's civilian and military nuclear programmes').

It has to be completed by 2023, because the plans already foresee the development of CFR-1000 reactors with a capacity of 1,000 to 1,200 MW by 2030.

Nuclear Engineering International announced in the beginning of January 2021 that China began the construction of the second CFR-600 a few days earlier. The news is based on a corporate press release, however, it is unclear whether it means that first concrete has actually been poured for Xiapu-2. The Chinese press release also elaborates that the earthworks, which began a year earlier, have been completed, and according to CNNC, all adverse conditions are 'overcome' therefore construction could have started in 2020 as scheduled. However, Xiapu-2 has not appeared in any international registers yet indicated as 'under construction'. WNISR states that the start of construction of the second CFR600 is surprising because China does not yet have industrial facilities suitable for reprocessing spent nuclear fuel (i.e., plutonium separation) and breeder fuel production.

FANGCHENGGANG-3, 4

The first reactor was commissioned a few days after the construction of Unit 3 of the nuclear power plant was started on the Qisha peninsula, which juts into the South China Sea near the Vietnamese border. Unit 2 started generating electricity in summer 2016, and the foundation of Unit 4 was poured in December. A total of six reactors are planned to operate at the

Fangchenggang site: the existing units are powered by CPR-1000 reactors, the new units under construction will be powered by Hualong One units, which is the upgraded version of CPR-1000, and in May 2018, when the dome was installed on the containment building in Unit 3, Fangchenggang 5 and 6 were still planned to be built around Westinghouse AP1000s.

In 2010, when the first construction was announced, China Daily reported that the cost of constructing phase I was CNY 25 billion, and investors were not willing to spend more than CNY 70 billion on the total investment of the project by the end of phase III. However, no information was disclosed on money and budget later.

It was predicted in 2018 that as a result of the joint investment of nuclear power plant operator Guangxi Fangchenggang Nuclear Power Group, provincial real estate development company Guangxi Investment Group and nuclear power plant company China Guangdong Nuclear Power Co Fangchenggang 3 will be put into service in 2020, however, it has not happened to date. The reason for the delay has not been announced officially, the only clue is that the plant's Wikipedia page, without explanation or indicating the source claims that Unit 3 will not be completed until 2022.

FUQING-6

The construction of Fuqing Nuclear Power Plant with six reactors planned for 2008 is about to be completed in Fu Chien province, home to the construction of Xiapu's plutonium-fuelled reactor. Cold functional testing has been completed in Unit 5 was commissioned in February, and just over two weeks earlier the cold functional testing of Unit 6 was completed. The four previous units were equipped with CNP-1000 reactors, the first one was commissioned in November 2014, the second in October 2015, the third in October 2016 and the fourth in September 2017. Fuqing 5 and 6 are equipped with upgraded CNP-1000 type, Hualong One reactors, which have become the standard in China. They have a net capacity of 1,000 MW respectively, but the newer reactor (also known as HPR1000) is designed to operate for 60 years and produce 10,000 GWh of electricity per annum, while refuelling is required only every 18 months.

Planned to be commissioned in 2021 by China National Nuclear Corporation (CNNC), the last unit may be completed in time. It is highly uncommon for Chinese nuclear power plant constructions, that the connection of Unit 5 to the grid was two months behind the original schedule for 2020. The first four units have been delayed more than this, as the project was halted and underwent a safety review between March 2011 and November 2012 following the Fukushima nuclear disaster.

HONGYANHE-5, 6

China General Nuclear (CGN) announced at the beginning of last year that the commissioning of Hongyanhe 5 under construction since March 2015 will be delayed. Therefore, the official completion of construction in Liaoning province is expected to be one year later than planned, in the second half of 2021. This also means that the announcement of completion of Unit 6 will also be delayed, even though CGN promised that the unit, which has been under construction since June 2015, will be commissioned in the first half of 2022, so it will be put back by six months compared to the original date.

The construction plan for the plant, built around two reactors with a capacity of 1,061 MW each, 'required adjustment', claimed the operator Liaoning Hongyanhe Nuclear Power Company (LHNP), after completing a risk assessment of the construction. The company decided to do so 'after due consideration', however, what that entailed remains a mystery. It was not common in the case of the first nuclear power plant in Northeast China: the previously built units designed to provide a capacity of 4x1,000 MW were all completed on time and no problems were encountered during the preliminary tests. The four CPR-1000 reactors were commissioned after one another without any issues (in 2013, 2014, 2015 and 2016).

What was found during the inspection of Unit 5 already running cold functional tests in October 2018, remains unknow. A more thorough inspection is suggested by the fact that more detailed information was shared on the cold functional tests carried out earlier when CGN announced that the construction of Unit 6 entered the commissioning phase in November 2020. This reveals that the pressure vessel was placed under 228 bar pressure and the main circulating tubes have been cleaned in addition to making sure that the tubes and valves are leak-proof, and a total of 68 commissioning tests have been carried out. There is nothing strange about it, however, the implementation of a newer, independently developed cyber security system in Unit 5 of Hogyanhe reported by CGNPC in the beginning of March 2021 was a telltale sign. Since then, there has been no new information on the two construction sites, even though the first half of the year has already passed.

SHIDAO BAY-1

In the eastern Chinese city of Weihai (Shandong Province), overlooking South Korea on the Yellow

Sea, a prototype for a Generation IV small power plant has been under development for almost a decade. The Shidao Bay nuclear power plant is the joint project of one of the country's largest state-owned power generating companies, China Huaneng, Peking University and Tsinghua University. The troika started the construction of an HTR-PM unit, which uses high temperature gas-cooled reactor technology in December 2012. The system is powered by two small reactors driving a single 200 MW steam turbine, is fuelled by thousands of graphite pellets containing six centimetres of uranium, and the graphite core of the reactor is cooled by inert helium gas. But since the entire construction project, which is expected to make Shidao Bay China's largest nuclear project, is scheduled to take 20 years and cost CNY 100 billion, it is hard to say how much of a delay the project has suffered as it will require testing and on-going development. CNNC already reported last spring that the main components of the second reactor (such as the reactor pressure vessel, steam generator, hot gas duct, etc.) had been installed. The primary side of the hot helium flow system has been tested at 750 degrees Celsius, on the secondary side, where the steam that is eventually released to the turbines circulates, at 570 degrees Celsius, and 100 and 500-hour full-speed simulations have been carried out (in a hot state and nitrogen environment) for more than 7 years. According to World Nuclear News, the representative of CNNC claimed in October 2020 that the results 'show that all indicators of the first reactor of the demonstration project meet the design requirements'. Hot functional testing of reactors started in January 2021, and commissioning is planned for the end of 2021.

Even so, the laboratory-reactor is still officially 'under construction'. In addition, the project started with the notion that Shidao Bay would have a set of 10 of these double reactor HTR-PM systems, i.e. 18 mini reactor units still have to be built after the completion of Unit 1.

TAIPINGLING-1 and 2

Li Fulong, head of the Development and Planning Office of the National Energy Administration of China,(NEA) convened an international press conference in the summer of 2019 to brief the media that it will soon start building three new nuclear power plants.

This marks the end of a moratorium on construction in China since 2017. It means that between 2017 and 2019 Beijing has not approved a single new nuclear power plant construction plans. However, as Chief Strategist Michael Barnard of The Future is Electric Strategy Inc. (TFIE) based in Vancouver wrote in February 2019, maybe the focus of future energy investment in China's energy strategy has shifted within this short period of time. Forecasts in 2015 included up to 110 nuclear power plants in operation by 2030 and a government investment of up to USD 1 trillion to bring 250 GW of nuclear capacity into the system by 2050, but based on Barnard's calculations the two-year suspension made these targets vanish into thin air and the primary focus is shifting to wind and solar.

The same shift was indicated earlier by the Cleveland-based Institute for Energy Economics and Financial Analysis (IEEFA) stating: China has been increasing its renewable energy capacity at double the global average for a decade now, and is slowly getting ready to be a global leader in green energy development. One of the new power plants announced in summer 2019 is a nuclear power plant to be built in the city of Taipingling in Guangdong province. Even though the building permit has been issued for the project in February, the concrete for Taipinglingling-1 was not poured until 10 months later, the end of the year. The facility plans included a total of six units, and the unusually long delay in the start of construction in China was attributed to the fact that the reactor type was also changed here. The plant's owner, China General Nuclear Power Corporation (CGN), originally planned to install Westinghouse AP1000 light water reactors in the Taipingling power plant, however, later replaced them with Hualong One Generation III reactors developed in China.

No information has been released about the construction to the specialised press yet, but the plan seems to be sustainable: Unit 1 is expected to be operational in 2024. Meanwhile, construction of Taiplingling 2 has also started: the IAEA's information system has officially confirmed that the new unit has been under construction since 15 October 2020.

TIANWAN-6 (7)

Lianyungang situated on the shores of the Yellow Sea has become one of the world's largest power plants in the past 15 years, and serves as an example of Russian-Chinese nuclear industrial relations. When concrete was poured for Unit 1 (October 1999), perhaps neither the Rosatom subsidiary (nuclear equipment exporter Atomstroyexport (ASE)) nor China National Nuclear Corporation (CNNC) thought that they could build six reactors continuously without major disruptions. This is exactly what happened, after the commissioning of the first two VVER-1000 units (2007), due to the delaying impact of the Fukushima disaster, Units 3 and 4 were built over a decade later (2018), and even the construction of the third reactor pair was started. The first concrete of Tianwan-6 was poured at the beginning of September 2016, and it was equipped with the same ACPR-1000 type reactor as Unit 5. Construction was completed almost routinely, without any issues or disruptions reported, and the biggest change was the restructuring of the project's ownership to include a local, but still Chinese, state actor. CNNC has been replaced by Jiangsu Nuclear Power Corporation, which operates the Tianwan power plant, but is still 50 per cent owned by CNNC, but there is additional local power is represented by the involvement of Jiangsu Guoxin Group, an investment group in Jiangsu (20 percent), while state attention is reinforced by the 30 percent share of China Power Investment Corporation.

The rapid functional testing of Unit 6 started in November 2020, decision on the fuel loading process was made in mid-April, and on the connection to the grid a month later. The project was completed so successfully that CNNC even demonstrated its ability to improve its marketing communications when Tianwan Phase III neared completion. Not only did the company report on the additional electricity generated by the new units per annum, but also on the environmental impact when Unit 6 completed its full power test in early June 2021 and was ready to enter commercial operation. World Nuclear News claimed that the operation of the two new units (Unit 5 was connected to the power grid in September 2020) will allow China to cut back its carbon emissions by 13.6 million tonnes, and reduce sulphur dioxide emissions by 44,100 tonnes. Furthermore, the environmental impact of the new nuclear power plant units has been compared to tree planting: the pollutant savings from Tianwan 5 and 6 are calculated to be equivalent to planting 34,000 hectares of trees to clean the air.

CNNC and ASE will jointly build the next two nuclear power plant units in Lianyungang under a Sino-Russian agreement signed in 2019 and a specific contract signed in March 2020. However, Tianwan Phase IV will already include the installation of VVER-1200 reactors. World Nuclear News reported on 19 May that the construction of Tianwan 7 has started. Databases do not reflect the completion of Unit 6 and the termination of its ‘under construction’ status, or the start of construction of Unit 7. However, this ‘exchange of seats’ will not mean a numerical change in global statistics, one unit in, one unit out, nor in local activity, since Lianyungang continues to build nuclear power plants. It appears that the first concrete can be poured for Unit 7 reactor pairs next March. The two units will increase the power plant's capacity to 8,000 MW, and are scheduled to start commercial operation in 2026 and 2027 respectively.

ZHANGZHOU-1, 2

It’s been less than two years ago that the construction of Unit 1 has begun in the area by the city of **Zhangzhou** in Fu Chien province, China. China National Nuclear Corporation (CNNC), the majority (51%) owner of the nuclear power plant started pouring concrete a week after the construction licence valid for 10 years was issued. By then the power plant had already gone through a major delay and a drastic redesign.

Five years earlier, in 2015, the idea was to install Westinghouse AP1000 reactors at the power plant located by the city, and the National Nuclear Safety Administration granted the power plant a relevant licence in December. However, after also getting the green light to choose the site, they 'switched to domestic products' in mid-2017. That means HPR-1000 (Hualong One) was chosen, and CNNC explained that the reason beyond the replacement was to maximise design, development and optimisation and 'improved safety and economic features'. In reality, the reason beyond the replacement was that the supply chain for the U.S. reactor type had been torn apart, U.S. reactor construction costs skyrocketed and Westinghouse was only saved by Toshiba's USD 9 million self-destructive kamikaze action from a tragic demise. From this point of view, the fact that Zhangzhou 1 eventually became the fifth unit built around the Hualong One reactor is not only logical, but also a fortunate change. Even though the National Energy Administration of China (NEA) only approved the construction of the first two units in Zhangzhou in June 2019.

Construction of Unit 2 was reported by World Nuclear News in September 2020, CNNC also disclosed that construction of the entire project is 'progressing smoothly' and all major steps are being completed in time and the quality required. The actual target date for the completion of Unit 1, originally planned to be completed by 2017 is unknown, not because of the fact that the reactor replacement delayed construction by about 3 years, but because more than five years after the first concrete was poured, several domestic reactor units have already been commissioned in China, with the first Zhangzhou-1 expected to be completed around 2023-2024 and its counterpart within a year.

Originally, the plan was to add two new pairs of reactors to the Zhangzhou plant after the first phase was completed, but whether these are put on the drawing board will depend on the pace at which nuclear-packed CNNC can move forward with the rest of its constructions.

11) Pakistan

KANUPP-3 – 31 May 2016 – 1,100 MW

When fuel loading was commenced at Chinese HRP-1000 Kanupp-2 (also known as Karachi-2 or simply K2) reactor units last December, and was connected to the power grid in mid-March this year, it was confirmed that Chinese-developed nuclear power generation technology can be built on schedule in a foreign country. Therefore, both China and Pakistan may be proud of the 1,000 MW unit built and commissioned in less than 6 years after the first concrete was poured. The first exported Hualong One was built next to an 'ancient' small power plant which was operational since 1971 and had a capacity of 125 MW, and Kanupp 1, which experienced several shutdowns in 2019, is actually just waiting for its successors to be commissioned. This will be allowed by the completion of the third Chinese Hualong One Generation III reactor equipped with improved safety systems and enhanced emergency response capability. Pakistani Prime Minister Imran Khan inaugurated K2 in May, from Islamabad that coincided with the celebration of the 70th anniversary of the establishment of diplomatic ties between the all-weather allies. 'The project will produce 1,100 megawatts of clean energy, which is particularly important for us as Pakistan is one of the 10 countries most affected by climate change' Khan said at the ceremony. It was not mentioned in the news that 80 percent of the construction costs of the new unit, like Kanupp 3, was financed by Chinese state bank loans. K3's main contractor, China National Nuclear Corporation (CNNC), had previously announced at the end of April that it had successfully completed a cold hydrostatic test of the primary circuit on the reactor units, which marks the start of the commissioning phase. It is expected that the unit can be connected to the grid by the end of this year, but no later than in Q1 2022, and, like K2, it will generate electricity for at least 60 years.