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REPORT

Altered designs, budgets and schedules: nuclear power plants under construction

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According to official statistics, there are currently 52 nuclear reactor units under construction in the world. In other words, 52 projects have reached the stage where construction permits were issued for a nuclear power plant's power generating units. It also means that, concrete pouring underneath the reactor building began subsequently, and that 52 projects under construction are not yet finished. i.e. the facilities are not connected to the grid and do not generate electricity, simply because they are not ready. The figure, however, does not reveal that not all of these 52 projects will be completed. Indeed, at this stage, it is not possible to say how many will fail to reach completion.

Seemingly, little have happened to the projects under construction in the world since Energiaklub published its first global report on the subject in July 2021. Nevertheless a lot has changed over the one and a half years since the publication of Time has become the biggest enemy of nuclear power plant construction. This is why we consider it important to update this knowledge base at least once a year from now on. The world is also facing radical changes in this field, therefore we believe it is important to offer a factual, up-to-date document on the subject, based on professional sources.

Of the more than 200 countries around the world, 17 are officially engaged in a project of constructing one or more nuclear power plants classified as "under construction". A closer look, however, reveals that, of these 17 countries, in Argentina, Bangladesh, Brazil, Iran, Japan, South Korea, Slovakia, Ukraine and the United States of America, the construction processes do not seem to lead to rapid and significant results. The only project in France is more a disgrace to the constructor company, EDF, than a credit to it, and EDF should also, to say the least, be ashamed of its other construction project, a British two-reactor project.

Furthermore, Turkey, waiting for three reactor units to be finished, and Belarus, waiting for another nuclear unit, are relying on Rosatom, which (even before Russia's war in Ukraine) made faster progress on its joint construction projects in China than in its home country. Moreover, it seems likely that Rosatom will face challenges in terms of future projects, given that Finland has pulled out of the joint construction project, the project in Hungary is hanging by a thread, while Poland, the Czech Republic, the Netherlands and everyone else in Europe no longer wants Russian technology. At the same time, US nuclear investors and lobbyists, so influential in Poland, are also stumbling around in their home country, which looks similar to Japan and South Korea, where there are ongoing reactor investments, but the realistic question about them is whether those construction projects are in fact underway or serve statistical purposes only.

Minus ten, plus six

According to WNISR, which has been systematically collecting and collating data on the global nuclear industry for more than 20 years, currently there are 414 nuclear power units in operation, 25 are out of operation (typically under repair), 203 are shut down, 52 are under construction and 93 are abandoned by investors. This data series acquires historical significance once we add that in 2021, ten nuclear reactors around the world were shut down and closed, leading to largest loss of nuclear capacity in the decade since the Fukushima disaster. Moreover, Europe is leading the way in the phaseout: three units in Germany and three in the UK have been permanently switched off the grid, although the German ones (Gundremmingen, Brokdorf and Grohnde) were operating throughout 2021. But among the reactor units closed in the UK, there are two (Dungeness B) that have not actually been in

production since 2018. Reactor units were shut down in Pakistan (Kannup 1), Russia (Kursk 1), Taiwan (Kousheng 1) and the United States (Indian Point 3).

While ten reactor units were shut down in 2021, only six were connected to the grid (three in China, and the rest in Pakistan, India and United Arab Emirates). No new reactors started operation in Europe, only Finland's Olkiluoto 3 unit (which received its start-up license in December) reached 30% of its full capacity by the end of March 2022. Still, the state of the nuclear industry is reflected by the fact that while 16 units were promised to be built by early 2021, less than half of them have been actually completed.

Of the six units ticked off on the list in 2021, even the Chinese (who are the most active in the field) connected only three units of which one unit adds virtually nothing to China's power generation, being a small SMR pilot reactor unit of not more than 200 MW, built on an experimental basis since 2012 and now completed after a series of delays and corrections. One must consider these facts when assessing the feasibility of the promises discussed by the global nuclear portal World Nuclear at the end of March 2022, namely, that in 2022 Belarus, Finland, Pakistan, Russia, South Korea and Slovakia would complete the construction of one reactor unit each and connect them to the grid, while both India and China are planning to connect three reactor units to the grid. Connection to the grid indeed took place in Pakistan (Karachi 3, 8 March) and in Finland (Olkiluoto 3, 14 March), but as for the rest, it is too early to be sure.

As per official agenda, besides the above 12 reactor units, in 2023 the construction of one unit each in Argentina, Bangladesh, China, France, Russia, Slovakia and Turkey would be completed, while two reactor units each in the United Arab Emirates, the United States and South Korea and a further three in India would start power generation. In 2024, Bangladesh, Iran, South Korea and Turkey plans to complete the construction of one reactor unit each, while China plans to finish two. In 2025, three Chinese reactor units are scheduled to start power generation alongside the next Turkish unit, to be followed in 2026 by a British reactor unit (which is still under construction), six Chinese, one Russian and the next Turkish reactor units. In 2027, one Indian, one British and four Chinese reactor units are planned to be connected to the national grids. This is the promise, and this is the expectation of constructors and clients. Yet, almost certainly, it is not going to happen. Industry experts with a more realistic approach opine that of the 56,258 MW of nominal capacity (indicated by statistical data) only around 30,000 MW will be available according to the optimistic scenario and even that not necessarily on schedule.

Milestones and Rosatom

Yet there is still no shortage of industrial visions. For example, in mid-March, Yves Desbazeille, Director General of the Brussels-based European nuclear lobby Foratom, in his classic speech on *"nuclear energy being the key to cheap electricity"* went as far as to say that nuclear energy can contribute to reducing energy costs. The reason for that, he said, is that production costs in the nuclear industry remain stable despite the energy price boom, given the low operating costs and the fact that the price of uranium accounts for only five per cent of such costs. (Desbazeille refrains from mentioning that the costs involved in failure to meet the deadlines and budget of nuclear power plant construction modify this rosy picture, to say the least.)

Jeremy Gordon, who considers the "humanisation" of the nuclear issue to be his main task, presents a similarly greedy view. Gordon opines that 2021 already was a milestone and adds that 2022 will be a year of major decisions in Europe, and that the nuclear industry will show such a "positive, serious, confident and competent" face that he expects apoplexy from its opponents. And, as he puts it, "being anti-nuclear has actually become a minority position. They would be best ignored as far as possible."

But this will certainly not be the case after Russia launched a war against Ukraine. Today, no one can predict to what extent economic sanctions on Russia will limit the nuclear industry. Yet it must be borne in mind that it is not only Paks II and Finland's Hanhikivi 1 that are

affected by the Rosatom influence. Russia's state nuclear company is the constructor of the Akkuyu units in Turkey (the main components were installed in the first reactor building in early March, yet the project involves three reactor units) which could become unfeasible for many years. Rosatom is also behind the technology envisaged for the development of the Mochovce nuclear power plant in Slovakia (Mochovce 3 and 4), the Belarusian Ostrovets 2, the Bangladeshi Roopur 1 and 2, the Indian Kudankulam 3, 4, 5 and 6, the technical part of the Iranian Bushehr 2 project, as well as China's Tianwan 7 and 8, Xiapu 2 and Xudabao 3. In other words: of the nuclear power projects currently in the construction phase around the world, up to 18 items may be dumped due to further and stricter sanctions against Russia for its war against Ukraine.

As usual, there is no shortage of promises
Additionally, it is unclear where new nuclear power plants would be built after 2027. Albeit South Korea's new government has indeed re-introduced the idea of building nuclear power plants, the impressive vision promises only half the capacity (30 GW) of what was previously defined as a necessary means for South Korea to achieve self-sufficiency. Meanwhile, ongoing investments tend to go beyond deadlines or financial constraints.

The United States will indeed refrain from starting the construction of another nuclear power plant. In France, which has the highest hopes in Europe, the grandiose plan of the incumbent president, Emmanuel Macron, pertains to no more than the construction of six reactor units of "normal size" (and, similarly to the US, Britain, Canada, Russia and China, pledges about numerous SMRs, but the technology for a modular mini-nuclear power plant is not yet complete or ready; mass production is just another promise, yet the nuclear lobby worldwide is already using it for misleading the public). But Macron, like Rolls Royce, promises results only for the post-2035 period, which, to say the least, raises some doubts concerning the dominance of the technology itself.

Even the 2021 World Energy Outlook of IEA is questionable. It estimates that installed nuclear capacity will increase by more than 26% between 2020 and 2050, and that the current generation capacity (approximately 390 GW, including all units that will be decommissioned) could be increased up to a nominal capacity of 525 GW. Yet it remains unclear how this could be achieved.

Nuclear power plants under construction (by country)

United States of America -
VOGTLE 3 – 12 March 2013 – 1250 MW
VOGTLE 4 – 19 November 2013 – 1250 MW

The United States, being the world's largest nuclear power, has been forced to make immense efforts in recent decades to conceal the problems related to its nuclear power plants. A most revealing graph was prepared by EIA. It shows that since 1986 there has been essentially around 100,000 MW of generation capacity ready for operation in the system, while the amount of electricity generated by US nuclear plants has almost doubled, increasing from 414 TWh to 800 TWh. This is a big feat, all the more so as in the last 35 years the number of new nuclear power plants constructed in the United States has been decreasing. Back in 1986 and 1987, seven and eight nuclear units were connected to the grid, respectively, while in the subsequent decade only four in total. Since February 1996 (when Watts Bar 1 was connected to the grid), only one has been connected (2016, Watts Bar 2), while more than 40 units were shut down, including some that could have continued to generate power as per their operating licence, but they were no longer profitable.

Indian Point 3, shut down in April 2021, is no exception. Although it had been generating power since 1976 and holds the world record for continuous energy production, it was not financially feasible to renovate it, that is, to ensure that it is in a state where it could safely continue operation for years to come. Meanwhile yet another scandal is taking shape with regard to decommissioning. The ownership change initiated during the decommissioning process raises concerns that Holtec (the new owner) does not have the financial resources to perform dismantling and recultivation.

Meanwhile, in the history of US nuclear power plants, there are 42 projects where construction started but was never finished, and only two reactor units of one plant fall currently into the "under construction" category. It must be added that even industry players are pessimistic about Vogtle 3 and 4. The power plant expansion process, initiated in 2009, was intended to guarantee the energy security of the state of Georgia and also to ensure that Georgia Power (a subsidiary of Southern Company, America's leading energy company in the field of energy from nuclear through coal to wind turbines) serves 500,000 customers and thus contributes to the achievement of the 2050 carbon neutrality objective.

When the construction plans were approved in 2012, the construction costs of the two AP1000 reactor units were estimated at $14 billion, and Vogtle 3 was scheduled to be connected to the grid by 2016. The investors held back the information that the price will be double the original investment costs, and that the extra expenses will be considerable for consumers in the electricity bills. The construction of Units 3 and 4 started in 2013, but fell behind schedule almost immediately. To keep the project afloat, government loan guarantees of billions of dollars were requested (and granted) under the Obama and then Trump administrations. In 2018, even The Wall Street Journal reported on the series of price and deadline corrections of the Vogtle project. The result of the subsidies and of the fact that the construction of the new US nuclear power plant units was not halted in spite of the bankruptcy of the builder Westinghouse (the main reason for the bankruptcy being the cost overruns of new US power plant constructions) was simply that the company was late even with the submission of the mandatory six-monthly status reports (a precondition for the loan guarantee) although the original promise was to finish the project at a very fast pace. Eventually, the Vogtle 3 project was unable to meet its 2020 deadline.

Previously, it had been planned that Georgia Power would deliver the first batch of nuclear fuel to Vogtle 3 by 10 December 2020, then the loading of the cassettes would take place in April and preparations for hot functional tests would begin. Eventually, this did not materialise. Even at the end of March 2021, the option of further deadline modification was mentioned (Georgia Power informed the Securities and Exchange Commission that the launch of the commercial operation of Unit 3 could be delayed by a month or more, which would entail an extra cost to the company of $25 million per month). In April, CEO Tom Fanning, presenting the company's first quarterly report, said that the target date for Unit 3 could be the end of 2021. But completion had not happened by then either. Barely a month after Georgia Power announced that it would begin on Unit 3 the last major test series prior to fuel loading (hot functional testing) and that the last large module (a huge water tank of 750,000 litres) would be put in place in Unit 4, the usual announcement was made on 11 June: relying on its own sources, Nuclear Newswire reported that Unit 3 was unlikely to start operation before summer 2022, and, therefore, Unit 4 will most probably miss the scheduled start date, too, by a year. Nuclear Newswire concluded this on the basis of the fact that project supervisors and construction safety analysts opined that there were still a number of key tasks to be performed, given that major components had malfunctioned and needed to be replaced, and important software updates were also overdue. Responding to the news, the company said that the completion of Voglte 3 has been officially set for January 2022 and the commissioning of Unit 4 for November 2022. This is yet another delay which meant that the investment cost, now $27 billion was increased with an additional $48 million. But that is not the end of it. Last October Georgia Power announced another three-month delay, that is, it promised that Vogtle 3 and Vogtle 4 would be operational in the third quarter of 2022 and in the second quarter of 2023, respectively. But in February 2022, NucNet discovered that the latest modifications mean that even Vogtle 3 will start electricity generation in March 2023 at

the earliest. At this point, Fanning, CEO of Georgia Power said that the latest inspection of Unit 3 had revealed major deficiencies with regard to the materials and equipment installed, and, therefore, a further delay of 3 to 6 months was expected. Fanning also noted that last year the poor quality of construction and documentation had also added to the costs. By the time Voglte 3 and then Voglte 4 start operation (which will require approval from US nuclear regulatory authority), the total cost of the project could reach $33 billion.

Argentina
CAREM25 – 25 August 2015 – 25 (32) MW

"CAREM25" is made up of an acronym for the Spanish Central ARgentina de Elementos Modulares and a reference to the net capacity of 25 MW. The construction of the nuclear module (or small modular reactor), which measures not more than 14,000 square metres, has officially been ongoing for more than 8 years now, given that the first concrete pouring did not take place in 2015, as the statistical data show, but on 8 February 2014. Since then, the project has been put on hold several times. Most recently, it was the construction company which decided to halt the project, because the government had failed to pay its share of the bills. There have been problems with technical documentation as well.

Atucha (located 110 km northwest of Buenos Aires) is best known for its nuclear power plant, which includes two of Argentina's three nuclear power plant units. Although the two Atucha units have a combined capacity of 1033 MW and are already operational, CAREM25 is not insignificant either. Argentinean contractors pay over two-thirds of the construction costs of this domestically developed small modular reactor (SRM), which, due to its small size and its function, has a role to play in potential technology export rather than in Argentina's energy sector as a unit connected to the grid – or at least this is what Argentina's leaders think, who in April 2021 made shareholders vote for the continuation of the project.

The problem is that the Argentine design of the modular reactor was presented as early as in 1984, then in 2006 the whole project was re-launched, and the prototype was not ready until 2017. In 2018, the price of the SMR project was projected to fall in the range between $446 million and $700 million, but then the launch was still scheduled for 2020.

CAREM25 had proven to be expensive even before the global energy price explosion: while in Europe the price of 1 kWh was still 10-20 euro cents, the amount spent on the Argentinian mini nuclear power plant until the summer of 2021 exceeded $22,000 (at the exchange rate at the time, €18,260). This amount was calculated by EWG for a study which presents economic evidence that small modular reactors will not help counter the climate crisis.

The latest news, namely that the construction is indeed going ahead and employs at least 250 people, was reported by the press after the Argentinian government published an announcement on its website on 4 November 2021 that the national nuclear operator Nucleoeléctrica Argentina, Argentina's nuclear energy agency (CNEA) and Argentinian-Brazilian industrial designer and constructor Henisa had concluded a 20-month contract as part of the reactivation of the CAREM25 project. The subject of the contract is the construction of the concrete structure of the CAREM reactor building. CNEA added that "at least 70% of components and related services are being be supplied by domestic companies and will fully meet international standards."

Bangladesh
ROOPPUR 1 – 30 November 2017 – 1200 MW
ROOPPUR 2 – 14 July 2018 – 1200 MW

Bangladesh (and its historic predecessor East Pakistan) has intended to have a nuclear power plant built for more than 60 years now. The first installation plan in 1961 was for a 200-MW facility. The planned capacity then gradually increased from 300–500 MW in 1987 to 600 MW

in 1998 and then 1000 MW in 2013 – but only on paper. When at the end of 2015 the VVER 1000 type, originally proposed by Russia, became obsolete, the option of a newer type, VVER 1200 of Generation III+, was raised. Bangladesh ordered two of them. Bangladesh's first nuclear power plant will be built by Rosatom, at a location about 160 km from Dakka.

Rooppur Nuclear Power Plant will be equipped with two reactor units similar to those in operation at the Novovoronezh Nuclear Power Plant and which were originally planned to be installed in Finland and Paks. The initial cost estimate for the construction in Bangladesh was $13 billion. In the preparatory phase, when the parties agreed on the division of responsibilities, it was finally decided that 90% the contractual amount of $12.65 billion would be financed from a Russian loan and the rest by the Bangladeshi government. Rosatom, which designs, builds and delivers all the major equipment, promised that Rooppur 1 would be commissioned in 2023 and Unit 2 in 2024. No official announcements or reports of delays or problems have been reported. Even Covid19 did not slow down the project progress. In the peak period, more than 12,500 people worked on the construction site.

In November 2020, World Nuclear News reported that, after a 14,000-kilometre journey that took two and a half months, the pressure vessel of Unit arrived at its future operating site, on the eastern bank of the Ganges. A month later the 7-tonne steam generator of the Unit arrived, too. The Russian project in Bangladesh involves turnkey construction and training local staff in the first year of operation of the first reactor unit. The Russians seem to be thorough in that. They have been training local staff for years now, and they expect to train more than 1,500 trainees at Russian nuclear power plant Novovoronezh II by 2022.

Last November, Rosatom completed the installation of four steam generators for Unit 1. As reported by NucNet in March, Rosatom reported that the welding of the main circulation pipeline for Unit 1 (the most challenging skilled work to date, launched in December) had been completed in 72 days.

There are still no reports of any problems with construction, finance or organisation, yet it is true that at the end of March The Financial Express mentioned that the economic sanctions against Russia could make financing the construction in Bangladesh difficult. According to the analysis, blocking Russia from the SWIFT international payments system, along with restrictions concerning Russia's central bank and other Russian commercial banks may have consequences that hamper the completion of the project. All the more so because – in addition to the Russian loan and state funding from Bangladesh – India provided a loan of approximately $1 billion for infrastructure construction. But the plan remains to have all the physical and mechanical equipment for the plant installed by June 2022.

Belarus

BELARUS 2 (Ostrovets-2) – 27 April 2014 – 1194 MW

Albeit the Ostrovets Power Plant of Belarus had been promised to start up in early 2020, the historical moment of the launch of Belarus' first nuclear power plant did not arrive until November. The plant had originally been scheduled to start operation in 2017. But, as usual with nuclear power plant construction, the project (launched in 2009) was hampered by problems and obstacles. Atomstroyexport (a Rosatom company) and Belarus' nuclear power company concluded a contract in 2011 for two reactor units, each with a capacity of 1200 MW, originally planned to be constructed with a loan of $9 billion granted by Russia. The finalised contract, however, stipulated that Russia would provide a loan of up to $10 billion for the construction, and the amount cannot exceed 90% of the project expenses. The same arrangement applies to the Russian-Hungarian contract for Paks II, but Belarus was granted the loan for a period of only 25 years.
The town of Ostrovets, located less than 40 kilometres from Vilnius, Lithuania's capital, was chosen as plant site; therefore, international technical literature often refers to Belarus' nuclear power plant as "Ostrovets". The construction of the first reactor unit (designed for 60 years of operation) commenced in November 2013, after Gosatomnadzor (the Nuclear and

Radiation Safety Department of the Belarusian Emergencies Ministry, acting as the highest-level local regulator) issued the construction permit in October 2013, ignoring various problems.

The construction of Ostrovets 2 started six months later (before the date originally scheduled), albeit the full construction permit was not issued until the end of December 2014. But the construction did not stay ahead of schedule for long. In December 2015, a ministerial order was issued to ensure that the competent authorities in Minsk provide more specialists and skilled labour so that the project could keep to schedule. In the summer of 2016, during the installation of the pressure vessel of Belarus 1, the cast item fell to the ground. Eventually, Rosatom decided to replace the special unit by moving the pressure vessel originally intended for Unit 2 into Unit 1, and build a new item for Unit 2. This resulted in a delay of more than six months for Belarus 2, but did not entail extra cost for the customer. (Still, it says a lot about the real expenses as well as Rosatom's financial, technological and industrial room for manoeuvring that in the end Unit 2 did not receive a completely new, tailor-made pressure vessel, but a unit originally intended for Baltic 1.)

The commissioning of Belarus 1 started in April 2019, after addressing the concerns voiced by the European Union and the use of a protocol in line with IAEA criteria. A year later, Rosatom started to deliver fuel to the reactor unit. In November 2020, Unit 1 was connected to the grid and six months later, in June 2021, it was granted the operating licence. In the meantime, the Belarusian government proposed extending the repayment period of the $10 billion Russian loan (originally due from April 2021 onwards), by 10 years, that is, to 35 years. By this time, the construction of Belarus 2 had also been completed.

In September last year, World Nuclear News reported that the power plant unit was 90% ready for production – or at least this was the information given by Belarusian energy minister Viktor Karankevich to IAEA when he and Rafael Grossi, head of IAEA signed a five-year agreement for the IAEA oversight of the plant. Hot functional tests were completed in October. In the second half of December, fuel loading took place: the process of loading the reactor core with 163 fuel assemblies took five days, and finished on 27 December 2021. Since then, various tests have been performed to bring the reactor capacity to the minimum controlled level and then gradually increase it.

Ostrovets 1 produces 22% of the power generated in Belarus; the second will double this rate. In January, Sergey Bobovich, deputy director of state-owned utility Belenergo, told the state news agency that the second unit of the power plant was expected to be connected to the grid in the summer of 2022.

Brazil
ANGRA 3 – 1 June 2010 – 1405 MW

Angra 3 is the South American "basket case" of nuclear power plant construction. The first phase of the investment, which started in 1984, lasted only two years. The reactor unit, built in cooperation with Siemens, was being delivered in the form of pieces of equipment for some time from 1986. More than two-thirds of them was delivered, but has since been stored in warehouses, in deteriorating condition. 640-MW Angra 1 and 1350-MW Angra 2 has been in operation since 1982 and 2000, respectively, but Unit 3 had not gotten beyond the phase of relaunched construction by summer 2007. That phase was undertook by France's Areva. When construction proper commenced in the summer of 2010, the parties expected the 1350-MW reactor unit to be connected to Argentina's electricity grid by 2018. Then, in 2014, the government halted the public construction process, and made attempts to sell the project instead. Neither the auction nor the hunt for private investors proved to be successful; therefore, the Angra 3 project was stopped once again.

Until February 2021, nothing much happened with the Angra 3 project other than being subject to political visions. Then in February 2021, The Bulletin published a report on how

nuclear power plant construction in Brazil interlinked with political corruption. The report on systemic corruption, unlimited spending, the bribes paid to public officials, fraud and embezzlement shows that the construction of Angra 3 is a result of a series of decisions of party policy, linked to money and politics, and has little to do with better service provision or serving the common good. Between 2008 and 2018, the stalled power plant construction project cost $2.7 billion more than the originally estimated amount. The project was barely making any progress, while the expected unit price of power generation had risen to $90/MWh, well before the energy prices exploded. The scandal, however, did not have an impact. Quite the contrary, the government reactivated Angra 3. In July 2021, the results were published for the tender where a Brazilian consortium won the contract for the completion of Angra 3 with a bid of just $56.1 million. Having closed the appeals submitted after the announcement of the results, state energy company Eletrobras approved the contract at the end of January 2022. Given that its nuclear subsidiary Eletronuclear signed a memorandum of understanding with Russia's Rosatom in September on increased cooperation, in January the project was expected to be completed possibly by 2024.

However, at the end of March, Powermag reported that Brazil hoped for a 2027 commissioning.

South Korea
SHIN HANUL 1 – 10 July 2012 – 1400 MW
SHIN HANUL 2 – 19 June 2013 – 1400 MW
SHIN KORI 5 – 01 April 2017 – 1400 MW
SHIN KORI 6 – 20 September 2018 – 1400 MW

In mid-March, Bloomberg published a lengthy analysis of Yoon Suk-yeol's vision of the energy sector. Yoon, who won the 2022 South Korean general elections by just 1%, made it clear quickly that, unlike his predecessor, he had no concerns about the nuclear power industry of South Korea. The Bloomberg analysis discussed, above all, how much sense it makes for South Korea to return to the path it had left behind mor than a decade ago. The trajectory change (which is very difficult not to attribute to the fact that Yoon Suk-yeol's supporters include nuclear industry players such as Bosung Power and Kepco) primarily involves plans to reactivate nuclear power in South Korea in order to achieve net zero emissions.

But a deeper look reveals a very different story. Albeit the South Korean government used to expect that by 2035 up to 60% of electricity would be generated by nuclear power plants by 2035, Yoon Suk-yeol's objective is to reach 30% by 2030 and then upkeep the ratio. Given that currently this indicator is fluctuating between 20% and 25%, the commitment of the new government does not seem to be particularly bold. The previous administration, led by Lee Jun-seok, pledged that once the nuclear power plants under construction are completed, no more nuclear power plants would be built in South Korea and the export of technology for commercial purposes (which, at the time, had started only in the United Arab Emirates) would be stopped. This fact makes it evident that the nuclear issue, albeit of major importance for South Korea, is more an arena for political battles than an energy policy issue. Currently, four reactors are under construction in South Korea (with a nominal capacity of 4 x 1400 MW), which can be nearly sufficient to reach the 30% target.

NucNet reported at the end of March that the new government first of all was preparing to reactivate the construction of Sin-Hanul 3 and 4 units (suspended in 2017). However, the issue is not yet settled (especially after Russia's acts of war against Chernobyl and Zaporizhzhia), given that five years ago in South Korea the construction was halted because the site is too close to the North Korean border and there is an increased risk of military attacks. And there is yet another problem. The Korea Times called attention to the risk of earthquakes and nearby forest fires which are becoming more frequent due to climate change. Kwanghee Yeom, senior associate for South Korea at Agora Energiewende also believes that starting new nuclear power plant construction projects would entail difficulties because "local communities tend to prefer renewable projects over them." Instead, he

expects that the operating lives of nuclear power plants Kori 2, 3 and 4 and Hanbit 1 (whose permits are due to expire during the newly elected president's term) will be extended. Moreover, President Yoon announced that, besides the reactivation of the construction process (which was halted 5 years ago), South Korea will renew its research on small modular reactors and intends to sell and build in foreign countries at least 10 reactors by 2030. One of these projects can be the envisaged expansion of Dukovany in the Czech Republic: in mid-March, Czech state energy company CEZ invited KHNP (along with France's EDF and the US Westinghouse Electric) to submit a formal bid for the future tender. (CEZ envisages the construction of a new nuclear unit between 2029 and 2036. For reasons of national security, Russia's Rosatom was not invited to the tender, and in April 2021, it was excluded.)

SHIN-HANUL 1 and 2

As per the original plans, four new 1400-MW reactors units, called "Shin-Hanul" ("new Hanul") would have been built in the vicinity of the six 1000-MW Hanul reactors, constructed in Southeast Korea between 1983 and 2005. Concrete was first poured in Unit 1 and 2 on 10 July 2012 and 19 June 2013, respectively, which meant that the project barely escaped the new vision developed for South Korea in the past decade. Units 3 and 4 did not, and, at least until now, it has seemed that they would not be built.

The first two units of the new nuclear power plant (Generation III pressurised-water APR-1400 KEPCO reactor units of 1,340 MW capacity each) were initially scheduled for being connected to the national grid in 2018 and 2019, but neither the deadline nor the originally estimated budget of $6 billion were met. When the second unit was due to be handed over, Asian Power reported that Korea Hydro & Nuclear Power (KHNP) had announced a further 8-month delay in the construction of Unit 1, because of the two major earthquakes that had taken place in its vicinity in 2017, and an essential requirement for new construction was increased monitoring. At the time, Shin-Hanul 1 was scheduled to be completed by 2019. As of January 2021, KHNP was still seeking approval for further delays, and promised the construction process to be completed by the end of 2022 and the end of 2023.

Shin Hanul 1, located 330 kilometres from Seoul, was completed in April 2020, after more than five years of delays. However, its (conditional) licence was not issued by the South Korean Nuclear Safety and Security Commission (NSSC) until 2021 summer. Further safety measures, inspections and requests for modifications also contributed to the fact that, albeit fuel loading officially started in July 2021, the process of loading 241 fuel assemblies was not completed place until October 2021.

On 8 March 2022, Korea's Joong Ang Daily, in collaboration with The New York Times, published a news item citing an announcement of the Ministry of Trade, Industry and Energy that errors had been found during the test runs, which would delay the commissioning and commercial launch of Shin-Hanul 1. According to the article, the delays were justified by a software glitch, a nearby earthquake and risks related to building materials. Consequently, the next inspection that can give green light for the power plant unit (declared to be completed in April 2020) was postponed to March 2023. The other unit is planned to be connected to the grid by 2025.

SHIN-KORI 5 and 6

Two new units of the Shin-Kori nuclear power plant are being built near the city of Busan in the south-eastern region of South Korea. At the time of starting construction works in the spring of 2017, it seemed feasible to commission the two reactor units in March 2021 and March 2022. However, as early as in the autumn, the project delayed six months and nuclear operator KHNP pledged to pay local contractors one hundred billions of Korean won in compensation for the suspension of construction. The construction work then continued, and, for two years, the schedule was kept. In December 2019, when the pressure vessel was lifted into place in the building of Unit 5, Nuclear Engineering International reported the two units to be 51% complete. In conformity with South Korean practice, the two reactor units are APR-1400 units. According to the original schedule, Unit 5 and Unit 6 would have started commercial operation by March 2023 and in June 2024, respectively.

However, according to news published in February 2021, the project will be delayed again due to changes in the legislative environment: KHNP President Jung Jae-hoon announced that night-time work had to be suspended even if time was pressing, given that it is prohibited by

the Severe Accident Business Penalty Act, which imposes strict penalties on company owners for industrial accidents that cause serious harm to human health.
Nevertheless, six months later the Korean press reported that South Korea's Supreme Court confirmed the dismissal of a request to cancel construction permits for Shin-Kori 5 and 6 (meaning that the construction was not stopped). At the time, the plan was still to launch commercial operation in the two units in 2023 and 2024, but in March 2022 the Ministry of Trade, Industry and Energy announced that the new target dates for Shin-Kori 5 (still under construction) and for Unit 6 are March 2024 and March 2025, respectively.

United Arab Emirates
BARAKAH 3 – 24 September 2014 – 1400 MW
BARAKAH 4 – 30 July 2015 – 1400 MW

The United Arab Emirates could have been a test country for South Korea for exporting its nuclear power generation systems, however, that nuclear power plant construction project (which indeed met the deadline and did not exceed the original cost estimates) was only partly successful. The first nuclear power plant in the Arabian Peninsula was designed to have four units and was expected to satisfy a quarter of domestic energy needs. In a $23.5 billion deal, signed in 2009, KEPCo undertook to build all four units "turnkey" by 2020. According to Bloomberg's estimations, the total value of the deal was $30 billion in 2011.

The connection of 1,345-MW Barakah 1 (originally scheduled to be connected to the grid by the end of 2017) was postponed until 2018 at the request of the Korean companies to allow "a reinforcement of operational proficiency for plant personnel" ("unofficially, it was reported that Emirati experts trained at Shin-Kori 3 in South Korea were not trusted to operate Barakah-1"). However, although the construction of the first unit was indeed completed in March 2018, and preparations for testing were underway in May, the nuclear regulatory authority of the United Arab Emirates (FANR) prevented South Korea's success: 400 faults were found and the approval for switching on the unit was not issued until they were corrected. This did not happen until 2020. The launch of commercial operation took place in April 2021, after further fine-tuning.

Afterwards, however, there seemed to be no further delays or stoppages in the project. FANR issued the operating licence for Barakah 2 in March 2021; then fuel loading and testing began. In August, it was reported that Unit 2 started up, grid-connected generation began in September, and at the end of March 2022, ENEC announced that Barakah 2 had entered the phase of commercial operation. At the same time, UAE's nuclear power provider also announced that the two remaining units of the South Korean construction process were in the final stages of commissioning. The construction of Barakah 3 was completed in November 2021 and it is in preparation for operational readiness. Baraka 4 is undergoing finalisation. If the connection process takes place as usual, the two units can be connected to the grid in autumn 2022 and autumn 2023.

United Kingdom
HINKLEY POINT C 1 - 11 December 2018 – 1630 MW
HINKLEY POINT C 2 – 12 December 2019 – 1630 MW

The Hinkley Point C Nuclear Power Plant Project (Somerset, south-west England) entails the construction of two French 1600-MW EPR reactor units. Years ago, The Guardian labelled it the most expensive power plant in the world, despite the fact that nuclear technology has been in use to generate electricity in the windy and barren location since 1965. The third Hinkley plant (which obtained planning permission in 1990 yet its construction did not start until 11 December 2018, or December 2019 for Unit 2) has a long history dating back to Margaret Thatcher's premiership. The Iron Lady saw the construction of ten new British nuclear power plants as a way out of the problems posed by coal-fired power plants and coal mining. However, of the ten plants only Hinkley Point C finally got to the construction phase

even though in 2006 Tony Blair regarded it as a means to end dependence on natural gas. There are many strange stories surrounding the third Hinkley Nuclear Power Plant, such as the story how the French EDF got a central role to play or how Chinese investors were ultimately denied access to the stalled project due to national security risks. The British and American press investigated the project in minute detail throughout the years.

As for the construction of the first reactor unit (originally planned to be completed by 2025), the planned costs of the investment, £16 billion in 2016, were estimated in December 2017 to reach £20.3 billion, which is the upper limit of the previously estimated construction cost calculated for the planned operational lifetime of 60 years. Currently, EDF is envisaging the start-up of the first reactor unit for 2027 and the estimated construction costs is £22.5 billion. The price will be paid by consumers as the government and the constructor/operator concluded a fixed-price power purchase agreement binding for the first 35 years of operation. Official government communication still maintains that £92.5/MWh, the price specified in the agreement with EDF, is a result of a competitive bidding process, however, due to the emergence of green power generation, electricity price before the energy price boom and the European gas supply difficulties was much lower, between £55 and £70/MWh. It was a parliamentary committee report that concluded that the government ignored the interests of consumers.

At the end of May 2021, the BBC gave another account of the problems surrounding the construction: (1) the Covid19 outbreak, although did not halt the work, slowed it down; (2) the costs are approaching the £23 billion mark; and (3) labour shortage puts further pressure on the start-up deadline, currently delayed until June 2026. To demonstrate the government's support, in January the House of Commons voted by a large majority in favour of the new Nuclear Energy Financing Bill. The Bill, which provides for a new financial support scheme for additional nuclear power plants (including those designed by Rolls Royce) was forwarded to the House of Lords.

In November 2021, the first ring of the reactor building C-2 was lifted into position. In March 2022, EDF announced that Unit C-1 reactor was finally "taking shape", having reached a heigh of 32 metres. This happened just days after the UK's Office for Nuclear Regulation (ONR) gave the green light for the start of mechanical, electrical, ventilation and heating works. However, at the end of March, EDF indicated that it would review the costs and schedules it had published in January 2021 for Hinkley Point C Nuclear Power Plant: it was rescheduled to June 2026, and its costs were increased by another half a billion pounds, reaching almost to £23 billion. The decision was justified with the fact that new challenges, such as the conflict in Ukraine, could cause price increases and delays. While updating costs and schedules, EDF also announced that it was elaborating plans to mitigate delays, but did not specify if the 2026 target date for the start-up of Unit 1 was in jeopardy or not.

France
FLAMANVILLE 3 – 03 December 2007 – 1630 MW

In France, there are 56 active nuclear reactors and 14 decommissioned ones, and only one unit under construction, which, however, is a disgrace for the French nuclear industry as a whole. Most probably, not only the French, but the entire nuclear industry would be happy to forget Normandy's Flamanville 3, a model for the new generation of EPR2 reactors, which has been under construction since December 2007. The planned development of a single reactor unit (designed to produce 1650 MW), which has exhibited almost all conceivable technological, financial, safety and quality problems from the history of nuclear power plant construction, had an original budget of €3,3 billion and was intended to showcase the new generation of France's nuclear power plants in 2013. However, the project, had not been completed by 2019 either, when the expenses reached €10.9 billion. A year later, after further delays, the costs reached the €12.4 billion mark, while promises were made to switch the nuclear power plant on in 2022. With regard to the construction project, which from 2017 onwards (after 75.5% of Areva, the bankrupt original constructor was acquired by state energy

giant EDF) has been kept afloat as a public investment, EDf announced in February that commercial operation would start by mid-2023. But in March yet another design fault was identified, when three nozzles of the EPR2 reactor unit were found to have a design anomaly. The problem had been known since 2013, and redesign and correction had been performed at the time, which, however, failed to bring the expected result. This was one of the reasons why the government made an official announcement at the end of March about postponing the launch of Flamanville 3 until 2024. Obviously, this will postpone the concept development of the construction of the six new reactor units requested by the government in 2020, since the concept development process was planned to start after the commissioning of Flamanville 3.

In his speech given in Belfort, Emmanuel Macron mentioned the idea of six new units, making a speech, intended to be inspirational, that promised a nuclear renaissance. In addition to the EPR2 units, Macron promised 7 or 8 small modular power plants (SMRs), which could increase the capacity of France's nuclear facilities by around 12 GW. At present, the nominal capacity of nuclear power plants becoming obsolete is 62 GW. Last December, so many of them were under repair or maintenance that France had to import electricity. The state of the fleet is deteriorating to such an extent that EDF decreased its electricity generation expectations for 2022 from 330–360 TWh to 295–315 TWh; then, after Macron's speech, EDF announced that it had decided to lower its power generation forecast for 2023, too, from 340–370 TWh to 300–330 TWh.

With regard to the situation of Flamanville 3, it is to be noted that in January, EDF announced yet another delay, because welding defects had been found, which they will try to correct by August. In addition to the six-month delay (which was partially attributed to the Covid19 pandemic), a project cost increase of €300 million was announced by EDF. This means that the total cost will be €12.7 billion, four times the original estimated amount.

India
KAKRAPAR 4 – 22 November 2010 – 700 MW
KUDANKULAM 3 – 29 June 2017 – 1000 MW
KUDANKULAM 4 – 23 October 2017 – 1000 MW
PFBR – 23 October 2004 – 500 MW
RAJASTHAN 7 – 18 July 2011 – 700 MW
RAJASTHAN 8 – 30 September 2011 – 700 MW

In June 2020, The Indian Express published a long piece of complex genre, a mixture of description, pamphlet and interview on connecting to the grid India's first 700-MW domestically developed nuclear power plant unit, Kakrapar (KAPP-3). The "milestone event" in India's nuclear programme was that in the plant (under construction since 2010, near the Surat and Tapi rivers) the 540-MW PHWR units, which had been mainly used until then, were replaced with a bigger and more advanced heavy-water system, which, however, is still based on the principle of the CANDU reactor units. Continent-sized India expects the 700-MW reactors to start operating in large numbers and to become soon pillars of the Indian nuclear reactor fleet. This is worth recalling because in March 2022, Swarajya reported that KAPP 3, connected to the grid in January 2021, had not started commercial operation yet.

Currently, India has 21 (+1) nuclear power generation units in operation, with a combined capacity of 6,780 MW, which accounts for 3.3% of its electricity mix. The idea is to increase the per-unit capacity to make the target set in 2007 easier to reach, more specifically, to increase the current 7-GW nuclear capacity more than three times, to 22,480 MW by 2031. Although the projected numbers have already been broken down by units and construction projects, and in January 2019, India's Department of Atomic Energy (DAE) announced that India plans to commission 21 new power plants by 2031, this major leap is more likely to prove unsuccessful. This holds true even if in the last two decades or so, Russia has become a key supplier of technology and nuclear fuel to India, complementing (and later, substituting) the strong Canadian and then French relations of the early decades.

The greatest problem is delayed construction. The actual and planned figures for India's nuclear power plants were last summarised in January 2022, by Jagranjosh, a New Delhi-based company. As shown by the data, India currently has 22 operating nuclear units in seven nuclear power plants, with an installed capacity of 7780 MW. In 2022, 8 GW of nuclear capacity is under construction, and a further 32.4 GW is under preparation or planning. The latter includes the Jaitapuri Nuclear Power Plant, which, if built, would be the largest in the world today (with a capacity of 9900 MW). The problem is that the concept of building a power plant has been around since 2010, and, although originally planned to be implemented by the Indians in cooperation with France (and in 2018, Alexandre Ziegler, the then Indian ambassador, referred to it as a deal that could be closed by the end of 2018), it has never materialised. Now, three years later, EDF has not got beyond the stage of submitting a technical and commercial offer, which, however, does not oblige either party to start the project.

Instead of concentrating on the completion of existing projects, India is looking to the distant future. At the end of March 2022, the government announced that from 2023 onwards India will build its nuclear power plants in "fleet mode". This means that in three years 10 additional nuclear units will be built, and the identical units (each with a capacity of 700 MW) will be switched on within 5 years of the first concrete pour. At least that is the promise at the moment.

KAKRAPAR 4

At the time of the first concrete pour of KAPP 3 (November 2010), it seemed quite certain that the unit would be connected to the grid in 2015. Connection, however, did not take place until five years later. It is possible that since this was the first new unit, the associated infrastructure and key equipment (such as steam generators, diesel generators and other reactor components) caused delays due to the design, building and testing process. It is also highly likely that (as the Financial Express reported in October 2019), compared to Russia, China or South Korea, India has a limited number of qualified manufacturers of nuclear grade reactor equipment and component. The same delay is expected for Kakrapar 4, which also has been under construction since November 2010. In early March 2020, in a written answer to India's Upper House, Minister of State Jitendra Singh specified that commissioning is expected to take place in September 2021. This, however, did not happen. The reasons have not been reported, but official data now indicate that commissioning will take place in 2022.

KUDANKULAM 3 and 4

This is one of the largest ongoing nuclear power projects in India. It is located in the southern tip of the country, and is connected to the grid of Tamilnadu, one of the most populous states. Upon completion, a total of six Russian-built VVER-1000 reactor units will operate. The first two units of the Kudankulam Power Plant, being built under an agreement between India and Russia (originally concluded in 1988 and then renewed in 1998) have been operational since December 2014 and April 2017. The second two units have been officially under construction since February 2016 and June 2017, respectively. Kudankulam 5 and 6 (about which The Economic Times reported in 2021 July and late December 2021, respectively, that work with the Russians had commenced) have not yet reached the "under construction" category.

Construction work on Units 3 and 4 (currently falling into the "under construction" category) has progressed basically without any interruption since the first concrete pour, as has the manufacturing and delivery of the equipment and components. The main buildings are standing, most equipment has been manufactured and delivered, and the core catcher has been installed – at least this is what the official documentation says. One has to read The Hindu to learn that due to various technological modifications, the inflation and additional project-related guarantees requested by the parties, the cost of the first two units has doubled, and another Indian trade magazine reports that the whole issue of insuring the project is becoming increasingly gibberish. And, as another journal adds, problems keep arising with regard to the insurance of the whole investment.

As for the 2019 cyber attack on the power plant, the official information was limited to the fact that some traces in the IT system evidenced the presence of malware. After that, the Indian Economic Times reported that, according to the incident report, the hackers (later identified to be of North Korean origin) "may have gone undetected for over six months", and that malware had spread in Kudankulam's IT network.
But the construction process was not affected. In the summer of 2020, it was reported that a cargo ship carrying equipment for Units 3 and 4 of the Kudankulam Nuclear Power Plants had left the port of St Petersburg, and, in spite of the Covid-19 restrictions, the time required for the collection, loading and delivery of 4,200 cubic metres of cargo (the 17th shipload) had been reduced by one-third, mainly as a result of bilateral diplomatic efforts. Likewise, "an interesting little news item" was published to let readers know that feed pumps manufactured for the turbine hall by Russia's TsKBM arrived on site. Currently, the planned dates for the start-up of Units 3 and 4 are still March and November 2023, respectively.

PFBR

The completion of the Prototype Fast Breeder Reactor (PFBR), to be built by Bharatiya Nabhikiya Vidyut Nigam Ltd (BHAVINI) in Kalpakkam, has been officially delayed for more than a decade now. Is it time for India to abandon the programme? The question is posed by an article published in February 2020 on The India Forum. The article then tries to list the reasons not only for the failure of the project, located in the vicinity of India's 4th largest city, Chennai (formerly: Madras), but also for the loss of strategic significance (i.e. importance with regard to India's nuclear arsenal) of the plant of a planned capacity of 500 MW, designed to use plutonium as one of the fuel types.
The article was prompted by the fact that the announcement made by PFBR in September 2020 on the expected commissioning in 2022 had also been found to be unfounded. The chronology and reasons for the delays and postponements was summarised by Florish Studio, too, and by the science column of The Wire. After all: the project was introduced by Indian politicians back in the 1970s, then for three decades planning was going on. In 2003 the project was shelved, in consideration of the immense expenses – and yet the construction has been underway since 2004. It was promised to be completed by 2010 but has never been finished in spite of the costs rising year by year. In 2014, when the project was subjected to a formal audit, it was concluded that 76% of the high-value orders from previous years had not been delivered on time (average delay being 158 days, and the highest 1092 days). It was also found that the whole project entailed systematic cost overruns and a lack of documentation. Since then, not much has changed. In 2015, during another audit, the government admitted that no financial constraints had been applied to PFBR; therefore, it comes as no surprise that in 2020 a paper entitled "India's fast reactor programme – A review and critical assessment" was published in the journal Progress in Nuclear Energy, which concluded that the reactor unit, with its current design, is nor suitable for operation. The paper was written by R.D. Kale, a key expert of the development of technologies involving sodium-cooling in India.
The deadlines for start-up and commissioning (which have been regularly updated since 2010) were previously related to the production (and, later, the manufacture) of plutonium. Yet in recent years, emphasis has gradually shifted to problems with sodium pumps. According to estimates, the original cost of ₹35 billion increased to nearly ₹70 billion, reported the International Panel on Fissile Materials in spring 2020. It is to be added that Fissile Materials explained why breeder reactors are expensive and problematic as early as in 2010.
In May 2020, the Indian minister for nuclear energy announced that the date for commissioning and start-up would be December 2021. When questioned in writing in December 2021 in Parliament, Foreign Minister Jitendra Singh said that "according to latest approval, the revised completion target for the project is October 2022."

RAJASTHAN 7 and 8

Most probably, the evolution of nuclear power generation in India is best illustrated with the Rajasthan Nuclear Power Plant. The history of the power plant shows the trajectory from a 100-MW imported technology to 700-MW units developed in-house. The Rajasthan Nuclear Power Plant in northern India has been constructed and extended for more than 50 years. Albeit the first Canadian Candu reactor unit (connected to the grid in 1973) was decommissioned in 2004, the 1180-MW total capacity of the five operating RAPS units is still

significant. This total capacity will be more than doubled when Units 7 and 8 are completed, given that the two new PHWR units will have a capacity of 700 MW each. The two new units have been "under construction" since 2011. Originally, they were scheduled to be connected to the grid in 2016. Nevertheless, the works are still ongoing. The latest official completion deadlines were December 2020 and then December 2021, which, however, were not met. World Nuclear News, which reported on the plant in 2019, said that according to World Nuclear Association information, Unit 7 and Unit 8 were not expected to be completed before March 2022 and 2023, respectively. The earlier deadline, March 2022 obviously was not met.

Iran

BUSHEHR 2 – 27 September 2019 – 1057 MW

On September 3, 2011, while the world was still preoccupied with the attack on the World Trade Center, Iran connected to the grid the first nuclear power plant in the Middle East. The Russian-built Bushehr 1 Plant, however, marked only the first phase of the plans. As per the agreement concluded with Russia's Rosatom, Bushehr 2 and Bushehr 3 would follow in 2024 and 2026, respectively. Main contractor ASE (a subsidiary of Rosatom), and the Iranian Nuclear Power Generation and Development Company signed the agreement in November 2014 on the turnkey construction of two upgraded VVER-1000 reactor units, accounting for a total of 2100 MW of additional power generating capacity. Iran and Russia also signed a fuel deal.

Construction work on Bushehr 2 started in autumn 2019. The inauguration ceremony organised when the first concrete was poured was of somewhat Russian style: Ali Akbar Salehi, President of the Atomic Energy Organization of Iran (AEIO), emphasising the enormous scale of the project, flooded the audience with facts and figures. As he said, by the time when pouring the concrete for Unit 2 has finished, 3 million cubic meters of earth will have been excavated, and 3000 tonnes of reinforced concrete and about 350,000 tonne of cement will have been used. Each unit that is constructed and switched on, he added, would save Iran 11 million barrels of oil or $660 million per year. A study published in February 2022, co-authored by two professors at the University of Tehran even added that this amount of 600 million, with a ten-year period of operation taken into consideration is actually 660 million, and that the radiation level emitted by the plant is tens of thousands of times lower than the natural background radiation.

In fact, neither the constructor nor the client reveals too much specific information about the construction of Unit 2. Even in the article of The Nuclear Threat Initiative (NTI) (a global non-profit expert organisation focusing on nuclear safety) on the announcements and events of Iran's nuclear industry the cited Iranian public administration sources are hardly available. Phase 2 of the construction of the nuclear power plant 17 kilometres southeast of the city of Bushehr on the coast of the Persian Gulf, is currently scheduled to be completed in 2024. Disruptions may be caused by earthquakes (common in the region) or by events similar to those reported by Bloomberg at the end of March 2021, when US banking restrictions made money transfer to Iran difficult, thus hindering the acquisition of the necessary equipment and payment of Russian contractors. Moreover, in May 2021, several global news services reported a major industrial fire located in the vicinity the nuclear power plant, for which no official explanation was offered. This happened after the power plant simply shut down for two weeks (officially as a consequence of a "technical fault" that was discovered during regular maintenance and, therefore, took longer to repair). Last December, there was an air defence exercise near the nuclear power plant; it has never been clarified what activated the systems. Certainly, none of these events contribute to a calm and predictable construction process.

Additionally, there is also news which indicates that the deadlines and the (unknown) costs of the construction of Bushehr 2 will not be met: last October, Mohammad Eslami, the head of Iran's Atomic Energy Agency announced that Russia had agreed to continue developing two new reactors at the Buhshehr NPP after a 22-month hiatus. This may be a reference to the announcement made by Russian Foreign Minister Sergei Lavrov in January 2021 that Russia

was ready to help Iran expand the capacity of the existing Bushehr NPP through the construction of new units - yet nothing happened. With Eslani's visit to Moscow, the process was brought back on track. Nevertheless, Alexei Likhachev, head of Russian state company Rosatom, in a comment on the new agreement, said that although they hoped to prevent further delays, Rosatom would have to be compensated for the delay. Most probably, this means that Bushehr 2 (currently under construction) will not be completed by 2024. The fact that Bushehr 3 is still in the project preparation stage (meaning that currently it does not fall into the "under construction" category) also suggests that the works on the unit will not be started in 2026. In February 2021, Iran's Atomic Energy Organization (AEOI) confidently announced that nuclear power potential of another 1000 MW may be added to the grid in the near future. However, it did not say exactly when. Instead, quite unexpectedly, it set the 2041 capacity of the Bushehr Nuclear Power Plant at 10 GW.

Japan
OHMA – 07 May 2010 – 1328 MW
SHIMANE 3 – 24 October 2006 – 1325 MW

In late March, Bloomberg published a Nikkei research summary according to which in Japan (for the first time since the Fukushima disaster), a majority (53%) of people surveyed responded that in order to have lower electricity bills they would prefer switching on those Japanese nuclear power plants that had been out of operation for 10 years. (As Reuters puts it, "As Fukushima memory fades, Japan's nuclear power proponents hope for reset.") There is yet another surprising survey result: those who voiced the majority opinion added that a key precondition for switching on the reactor units is that they must be safe. Even so, 38% of respondents opine that this promise is not enough, adding that the 23 offline units (out of the 33 operational units) must remain offline. As Bloomberg puts it, the results of a small-sample survey are far from being conclusive. While some of the Japanese political elite have been making attempts for years to get reactor units connected to the grid again, they have not proven to be successful because the Japanese nuclear regulator have regularly withheld approval, refusing to give green lights even to projects approved by the competent provincial or local government (as seen in the western prefecture of Fukui in December 2020).

There is a huge gap between this situation and what Shunsuke Kondo, Chairman of the Japan Atomic Energy Commission said in a presentation a few months before the Fukushima Nuclear Power Plant disaster. He envisioned a bright future for Japan's nuclear industry which must be achieved through the implementation of key concepts such as safety, cost-effectiveness, high quality and climate protection considerations. According to Kondo's calculations, Japan could have had 49% nuclear power in its energy mix by 2030. Now, it is certain that he will prove to be wrong: nuclear energy currently represents 5.1%, and is showing a downward trend.

Japan currently relies mainly on hydrocarbons (coal: 25%, natural gas: 23%, oil: 39 per cent), and while the government's original plan was to reach a 64-GW solar generation capacity by 2030, this level was already approached in 2018 (55GW), even though harnessing wind power is only in a very initial phase (3.6 GW in 2018). As evidenced by the data of the Institute for Sustainable Energy Policies (ISEP), the share of renewable energy in energy production reached 18.5% in 2019. With regard to nuclear energy, it is to be mentioned that its ratio was zero until 2015; since then it has increased to a level 6.5% (as a result of authorised restarts), to fall again to the current level of less than 5%.

While the government supports a marked transition of the Japanese economy and society to the renewables, and last April even pledged to abandon one of the last major coal-fired power plant projects, theoretically it is also aiming to reach a 20% share of nuclear energy in the energy mix by 2030. In principle, this objective should not be difficult to achieve: the offline units must be switched on, and, as a bonus, new nuclear power plants under construction must be completed, if possible. Switching on offline units is cumbersome and complicated, due to the social resistance referred to above, and also because of the

introduction of stricter safety regulations and obligations. The completion of power plants under construction entails an even greater challenge for Japanese politicians.

OHMA

The history of the Ohma Nuclear Power Plant in Aomori Prefecture, northern Japan, is a story of announced deadline changes that have never been met, which is typical of the industry. In fact, the construction of the Generation-III ABWR nuclear reactor unit of GE Hitachi Nuclear Energy in Ohma began as early as in the spring of 2008, with the objective of providing Japan with an earthquake-resistant nuclear power plant, constructed on the basis of a new set of standards, which will be operational for 60 years. The construction of the first Ohma unit was initially scheduled to be completed by March 2012, but work was about 40% complete in March 2011. Following the general shutdown after the Fukushima accident, construction was relaunched in October 2012. The then target date was November 2014. The constructor, Japan Electric Power Development (J-Power) pledged to make efforts to build a safe power plant, strengthen plant safety and take into consideration the lessons learned from the Fukushima disaster. This included, among others, that the main structural elements of the plant (reactor unit, turbine buildings etc.) are built at a height of 12 metres above ground level to ensure proper tsunami risk management, and that two 500-kV and one 66-kV line are planned to be installed to guarantee the power supply of emergency facilities.
In September 2015, J-Power announced that the project completion was rescheduled to 2021 due to delays in the production of safety equipment. A year later, citing delays in safety due diligence and the review protocol of the Nuclear Regulation Authority (NRA), it announced that Ohma would not be built until the second half of 2023. This deadline was also modified: in autumn 2018, another two-year delay was announced due to the fact that compliance with stricter safety protocols is more time consuming. And the story does not end here. In September 2020, J-Power announced that the project would be further delayed owing to the new NRA regulation which, among others, require compliance with stricter earthquake and tsunami protection regulations. Based on the new rules, however, only one thing is sure: that the additional construction work required cannot realistically be finished before the second half of 2027. The completion of the construction then is followed by a period of testing and licensing, so, to cite J-Power, “the start time of operation is still undecided.”

SHINAME 3

In April 2005, when the then Japanese Minister of Economy, Trade and Industry issued the permission to Chugoku Electric Power (the company which had already built two reactor units) to build a third one in Kashima, a city at the shore of the Sea of Japan, at about equal distance from Hiroshima and Kyoto, Nuclear Engineering International reported enthusiastically that after 13 years of waiting, a new ABWR would join the system, adding 1373 MW to the capacity. At the time no one knew that the fate of the Shiname 3 project would be even more problematic than that of the Ohma construction project. Originally, the unit was scheduled to start commercial power generation in December 2011, but the construction fell victim to the shutdown of the whole industry in response to the Fukushima disaster. The construction work stopped at a completion level of 94%, just before fuel loading. This was doubly ill-timed. The new unit, to be built by Hitachi-GE Nuclear Energy, would have replaced Unit 1 of the Shimane Nuclear Power Plant, but in March 2011, work was suspended on all three units, and 439-MW Shiname 1 was finally shut off on 30 April 2015 with no replacement. It must be added that 789-MW Shiname has also been out of operation since 2012.
None of the units suitable for activation met the safety review protocols that had been introduced after the industry-wide shutdown that followed the Fukushima disaster. Consequently, the construction of Unit 3 was suspended. Nothing happened until August 2018, when Chugoku Electric Power applied to NRA for a safety review, hoping to be able to complete the project. It may happen that Shimane 3 will be switched on before Ohma, but nobody knows when that might happen. In February 2020, SP Global reported, citing sources in Tokyo, that the power plant was complete and, what is more, met all NRA requirements. However, this information has not been reported elsewhere since then and Shiname 3 is still not operational. Most recently, after an on-site inspection Japan Forward reported that,

according to plant staff, the plant (which has been under maintenance for a decade) is finished but still not operational.

China
SANAOCUN 1 – 31 December 2020 – 1117 MW
SANAOCUN 2 – 30 December 2021 – 1117 MW
CHANGJIANG 3 – 31 March 2021 – 610 MW
CHANGJIANG 4 – 28 December 2021 – 1000 MW
LINGLONG 1 – 23 July 2021 – 100 MW
XIAPU 1 – 29 December 2017 – 642 MW
FANGCHENGGANG 3 – 24 December 2015 – 1000 MW
FANGCHENGGANG 4 – 23 December 2016 –1000 MW
HONGYANHE 6 – 24 July 2015 – 1061 MW
TAIPINGLING 1 – 26 December 2019 – 1116 MW
TAIPINGLING 2 – 15 October 2020 – 1116 MW
TIANWAN 7 – 19 May 2021 -1171 MW
TIANWAN 8 – 25 February 2022 – 1171 MW
XUDABU 3 – 28 July 2021 – 1200 MW
ZHANGZHOU 1 – 16 October 2019 – 1126 MW
ZHANGZHOU 2 – 04 September 2020 – 1126 MW

In the nuclear energy sector, the importance of China and the pace of its activity are best illustrated by large numbers and long lists, and by the fact that while in February 2020, NS Energy Business reported 48 reactors in operation and 9 under construction, two years later WNISR (which deals with data in a most precise manner) reported a ratio of 54 to 20. China has the youngest nuclear fleet in the world (average age: 8.8 years), with no reactors officially under repair, with no plans, projects (or power plants) ever rejected or stopped.

In terms of total nuclear power generation, China overtook France in 2020; even so, its performance does not reach 50% of that of the United States, which ranks first globally. Still, China has no problem whatsoever with the age of its reactor units. The age of Chinese fleet would reach the current global average of 30.8 years in more than 22 years (if from tomorrow onwards no new units were connected to the grid). Although the perception of nuclear power is changing in China too (in 2015, at least 110 more nuclear units were projected to be built by 2030, which currently seems to be unfeasible), but it has seven giant power plants, the nuclear industry enjoys a significant support, and it certainly plans to build more nuclear power plants. The combined capacity of the seven largest nuclear power plants is 31,472 MW, which is slightly lower than that of Japan was in 2019 (31 ,680 MW), and exceeds that of Russia (28,437 MW). In 2019, the total nominal capacity of Chinese nuclear power plants was 46,520 MW. Currently, it is 51,109 MW, which generated 330,300 GWh of electricity in 2020.

In the second half of the 2010s, nuclear power plant construction in China was of a smaller scale and took more time than previously. Then, in the 2020s, it returned to a period of rapid growth. Albeit the number of plants under construction are the same as it was at the time when this study was first published in June 2021, the list in fact includes four new units which replaced four completed projects. Fuqing 6 was connected to the grid on 1 January 2022 (but has not yet started commercial operation). Hogyanhe 5 and Tianwan 6 have been in commercial operation since 31 July 2021 and 2 June 2021, respectively.
Shidao Bay 1, a demonstration reactor, achieved first criticality in mid-September last year and on 10 December it was connected to the grid.

SANAOCUN 1 and 2
In Shanghai's southern neighbour, Zhejiang site assessment started in 2007. The National Energy Authority approved the project in 2015, and the State Council Executive Meeting approved the construction of Units 1 and 2 in December 2020. The National Nuclear Safety Authority issued the construction permit on 30 December, and at 9:30 the next morning the Secretary of the Party's Provincial Committee Secretary ordered the start of construction.

That is how it works in China. The work process, which commenced with the first concrete pour of Unit 1, has the objective of building the first unit of the Sanaocun Nuclear Power Plant (to be equipped with six domestically developed Hualong One reactors) by 2025. The state-owned China General Nuclear Power Group (CGN), which is currently building seven nuclear reactors to add to the existing 24, announced that this is the first investment in China which involves private capital "creating a new model of mixed reform of nuclear power enterprises". This means that alongside CGN, five other companies provide funding for the project. Of the five, only one is not state-owned: Geely Technology Group, perhaps best known in Europe as the manufacturer of Volvo and Lotus, with a 2% stake in the power plant.
In 2022, work also started early in China. News were published in early January that new domestically developed reactor units (Hualong One, also known as HPR1000, actually developed from the 900-MW units imported from France in the 1980s and 1990s) are being built, one of them being Sanaocun 2, where first concrete pour took place on 30 December. At the same time, news emerged that a total of six units are planned to be constructed on the same site; so far, the authorities issued the building licence for two.

CHANGJIANG 3 and 4

The new nuclear construction project ongoing in Hajnan Province (an island off China's southern coast, south-west of Hong Kong) is even more recent. Hajnan, the smallest province of the People's Republic of China has had two operating nuclear power plant units since 2015 and 2016. Both have a capacity of 601 MW and are of the CNP-600 PWR type, developed in-house. The first concrete pour for Unit 3 (currently of a capacity of 1,000 MW) took place on 31 March 2021. Work on Unit 4 was originally scheduled to start in February 2022, but actually took place earlier: the first concrete was poured on 28 December.
Construction company CHG expects the two Changjiang units to be completed by the end of 2026. The estimated cost for the system to be constructed around the Hualong One unit is ¥40 billion. The schedule has not changed in the previous years. The official press release on the start of construction of Changjiang 3 emphasised that this is the first nuclear power plant project that was launched during the 14th Five-Year Plan period.

LINGLONG 1

Last summer, an unconventional construction project also commenced at the Changjiang Nuclear Power Plant: a "baby reactor" is being built next to the two existing 601-MW units, at the site of the construction of Units 3 and 4. The Unit is named Hainan Changjiang or Linglong 1. The project is somewhat strange not only because its development basically entails the "downsizing" of the standard Chinese reactor unit type (Hualong One, CAPC1000), but also because it is not a common sectoral practice to plan demonstration projects next to nuclear infrastructures that are generating power (or are generating power and being extended).
Linglong 1 is an exception. This small modular reactor, with a planned capacity of 100 MW, is built to be the first commercial on-shore SMR in the world. As reported by World Nuclear News, the design and safety analysis of the APC100 power plant was approved in the spring of 2020 (after the preliminary design was completed in 2014, and two cycles before the 14th Five-Year Plan was decided on its necessity and a revised version of the first completed design was approved by the IAEA in 2016), and the construction was given final approval by the Chinese National Development and Reform Commission in early June 2021.
Upon the launch of the construction process, the Nuclear Power Institute of China (NPIC) and the contractor, China Nuclear Power Engineering Group specified a 58-month construction deadline. According to the information given by the Chinese builders, it is up to the client to decide what the reactor unit will produce: the client can choose from power generation, heating, steam production or desalination of seawater. In the event that the reactor unit is used for power generation, the Chinese claim, it will be capable of generating 1 billion kWh of electricity per year. According to the designers, nuclear power plants in the future can consist of two to six ACP100 reactors, capable of power generation for 24 months per refuelling.

XIAPU 1

After the successful test of CEFR (China's first sodium-cooled mini power plant, capable of generating 20 MW of electricity and 65 MW of heat) in 2010, China embarked on the

development of a larger 600-MW fast reactor. (Still, it is interesting and quite unusual that since the switch-on China has not provided any data on CEFR. Therefore, one cannot be certain if it is operating). The construction of XIAPU 1, the CFR600 sodium-cooled pool-type fast reactor, designed by the China Institute of Atomic Energy was launched in Fu Chien province, on the coast opposite Taiwan. Over time, its net power capacity and net heat capacity has grown to 642 MW and 1882 MW, respectively. Officially, the objective of the construction of the reactor unit is to reach 40% thermal efficiency. Yet, as World Nuclear News recalls, Chinese fast reactor research and development is based on Russian research (for example, the unit was built by OKBM Afrikantov in cooperation with Kurchatov Institute), and the core of the CEFR already contains 150 kilograms of plutonium. As for the latter, it must be emphasised that almost two thirds of it (98 kg) is the material (plutonium-239) that the military industry can use to make plutonium bombs.
13 months after the start of construction of Xiapu 1, Rosatom subsidiary TVEL entered the project: given that Rosatom officially supplies equipment to the project, TVEL will supply the Chinese reactor with Russian fuel. The fuel will be identical with that supplied by Russia for its own BN-600 fast neutron reactor. The refuelling of CFR600 will also be performed by Russians. Moreover, Russians were contracted to supply fuel for seven years after commissioning.
The launch date for Xiapu 1, a unit with a planned operation period of 40 years, is set to 2023 by CNLY, a subsidiary of state-owned China National Nuclear Corporation, a successor of the Ministry of Nuclear Industry and its task is defined as "overseeing all aspects of China's civilian and military nuclear programmes". The project must be completed by 2023, all the more so, because for the period until 2030 the plans foresee the development of CFR-1000 reactors with a capacity of 1000-1200 MW.
In early January 2021, Nuclear Engineering International announced that a few days before China had commenced construction of the second CFR-600. However, it has never been confirmed that the information was correct and pertained to the first concrete pour of Xiapu 2. The Chinese announcement specifies that the earthworks, which had commenced a year before, were completed, and, according to CNNC, all unfavourable conditions had been overcome, so construction could start as schedule, in 2020. However, to date, Xiapu 2 has not appeared on any international register of reactor units under construction. WNISR reports that "the construction start of a second CFR-600 is surprising as China so far does not have operational industrial facilities for the reprocessing of spent fuel (the separation of plutonium) and for the fabrication of breeder fuel."

FANGCHENGGANG 3 and 4

The first reactor unit was commissioned a few days after construction had begun on Unit 3 of the nuclear power plant on the Qisha peninsula in the South China Sea, near the Vietnamese border. In the summer of 2016, Unit 2 started generating electricity. In December 2016, the foundations of Unit 4 were poured. On the Fangchenggang site, a total of six units are planned. The operational units are equipped with CPR-1000 reactor units, while the future units will be equipped by Hualong One units (an upgraded version of the CPR-1000). When the dome of the reactor building of Unit 3 was installed in May 2018, Fangchenggang 5 and 6 were still planned to be equipped with Westinghouse AP1000s.
In 2010, when the first construction was announced, the China Daily reported that the budget for Phase 1 was ¥ 25 billion, and the investors intended to limit the total investment budget to ¥ 73 billion for the period until the end of Phase 3. Yet no further information has been released about the funds or the budget. In 2018, the joint investment of nuclear power plant operator Guangxi Fangchenggang Nuclear Power Group, provincial real estate development company Guangxi Investment Group and the China Guangdong Nuclear Power Co. was expected to connect Fangchenggang to the grid in 2020. However, this has never happened. The investors refrained from disclosing official information on the reason for the delay until January 2022. The only clue was given on the NPP's Wikipedia page , which stated (albeit without explanation or reference) that Unit 3 would not be completed until 2022. In a statement sent to the Hong Kong Stock Exchange at the end of January, CGN said that the delays which had kept recurring since 2020 was attributable to the Covid-19 epidemic. As they said, "The novel coronavirus pneumonia epidemic has had a certain impact on the units construction resources in the past two years." They confirmed only one piece of information,

namely that Fangchenggang 3 was in the commissioning phase and would be connected to the grid in the second half of 2022. However, they added, Fangchenggang 4 would not be launched until the first half of 2024, given that it is currently only at the equipment installation stage. In March 2022, it was reported that tighter Covid19 regulations were needed; the announcement, however did not specify if the new quarantine rules for the region would affect construction work on the plant.

TAIPINGLING 1 and 2

In the summer of 2019, Li Fulong, head of the Development and Planning Office of China's National Energy Administration (NEA), convened an international press conference where he informed the media that the construction of three new nuclear power plants would start soon. This announcement marked the end of the Chinese moratorium on construction that had been in effect from 2017. This means that from 2017 to 2019 Beijing did not approve any new nuclear power plant construction design. At the same time, as suggested by Michael Barnard, Chief Strategist at Vancouver-based The Future is Electric Strategy Inc. (TFIE), it is also possible that during this short period of time, China's energy strategy saw a shift in emphasis in terms of future energy investments. This means that while before (even in 2015) the government's plan was to have up to 110 operational nuclear reactors in China by 2030 and to invest up to $1 trillion from state resources to add 250 GW of nuclear capacity to the system by 2050, now, says Barnard, in this two-year pause the targets were abandoned and the primary focus shifted to solar and wind power plants.

Cleveland-based Institute for Energy Economics and Financial Analysis (IEEFA) discusses the same shift when pointing out that for a decade now, China has been increasing its renewable energy capacities at a pace double the global average and is slowly becoming ready to take up a global leading role in green energy development. Still, one of the new power plants announced in the summer of 2019 is a nuclear plant to be built in the city of Taipingling in Guangdong. Albeit the project had been granted a building permit in February, the first concrete pour in Taipingling 1 did not take place until the end of the year, that is, 10 months later. The design included six units and the delay of the launch of the construction, which was unusually long in China, was due to the fact that the reactor type was modified. The original designs for the Taipingling plant of China General Nuclear Power Corporation (CGN), owner of the plant, contained Westinghouse AP1000 light-water reactors which then were replaced with Chinese-designed Generation-III Hualong One reactors.

So far, no information about the construction has been published in the press. Even the related Wikipedia article is limited to basic information (c.f. Wikipedia normally provides ample information on similar projects). In the last six months, the date of commissioning has changed. Last summer, the table indicated that that the first unit was expected to be operational in 2024; by now, this date has been modified to 2025. In January 2022, Nuc Net published a brief news item that the containment dome was installed for Unit 1. This was, however, a Chinese news item already published in December 2021, which has never been confirmed.

The construction of Taiplingling 2 has been officially confirmed by the IAEA information system, according to which the new unit has been under construction since 15 October 2020. The unit is planned to be inaugurated in 2026.

TIANWAN 7 and 8

Lianyungang, located on the shores of the Yellow Sea, is a showcase of nuclear industrial relations between Russia and China, and in the past 15 years has grown into one of the world's largest power plants. When the casting of the first unit started in October 1999, perhaps neither nuclear equipment exporter Atomstroyexport (ASE, a Rosatom subsidiary) nor the Chinese National Nuclear Corporation (CNNC) expected to be able to construct six reactor units, without major disruptions. Yet this is what happened. Units 3 and 4 were completed in 2018, albeit more than a decade after the commissioning of the first two VVER-1000 units in 2007 (which is attributable to delays caused by the Fukushima disaster). Units 5 and 6 were connected to the grid in September 2020 and June 2021, respectively.

As per the agreements between China and Russia signed in 2018 and in March 2020, the two new units will be built by China's CNNC and Russia's ASE, but in Phase IV of Tianwan VVER-1200 reactor units will be installed at the plant. World Nuclear News reported on 19 May 2021

on the commencement of the construction of Tianwan 7 and on 5 February 2022 on the beginning of the first concrete pour for Unit 8. (Still, interestingly, no such information is available anywhere else. At the time, the portal referred to Tianwan 6 as still under construction.) At the end of February, World Nuclear Report reported that the foundation concrete for Tianwan 8 had been poured and the construction process had commenced. According to the official expectations, Unit 7 will be operational by 2026 and Unit 8 by 2027. The Tienwan 7 nuclear island (referred to by Chinese nuclear industry experts as a model project for the collaboration between China and Russia) is designed and supplied by Rosatom, along with the main equipment and, at some later point later, the fuel. WISR opines that seemingly there is only thing that may hinder the project: the fact that the European Nuclear Safety Regulators Group (ENSREG) inspections carried out in 2018 on the design of the VVER-1200s (planned to be installed at Tianwan) identified major problems with the design and with the safety systems, which is disputed by Rosatom . Under the agreement between China and Russia, four VVER-1200 pressurised-water reactors will be built in China by the end of 2020.

XUDABU 3

The agreement on the joint construction of a nuclear power plant between Russia and China stipulates that Rosatom and its Chinese partners will build and commission two Russian VVER-1200 reactor units in Haibin county, northeast China. An interesting piece of information about the plant under construction in Xudabu is that although the first concrete pour of Unit 3 took place in early August 2021, this is the first unit under construction. The reason for this is that Xudabu 1 and 2 (of the AP1000 type according to the original designs) did not commence because of the Fukushima nuclear disaster. And although they were given the green light by the regulator in 2014 and investors were available in 2016, this part of the project has never been launched. The Xudabao project, with an original budget of ¥ 110 billion, was planned to consist of six Chinese reactor units. This plan, however, has been modified since then. The price specified in the agreement with Russia is ¥ 20 billion per unit. Its components are Xunabu units. At the time of the first concrete pour for Unit 3, the construction of Unit 4 was promised to start operation in 2022.

ZHANGZHOU 1 and 2

Two and a half years ago, in October 2019, the construction of the first unit started on a site near Zhangzhou, a city in Fujian Province, China. China National Nuclear Corporation (CNNC), the majority (51%) owner of the nuclear power plant, started concrete pouring a week after the construction license was issued for a period of 10 years. By then, the project had already gone through a major delay and a large-scale redesign...

Five years earlier, in 2015, the original design contained Westinghouse AP1000 reactors, for which the Chinese nuclear safety administration issued a permit in December. However, after the approval of the construction site and getting the green light to choose the site, the Westinghouse AP1000 reactors were replaced by domestically produced HPR-1000 (Hualong One), which CNNC reported as a way to maximise design, development and optimisation and to “ensure further improvement of safety and economicalness”. Actually, the adjustment was more due to the fact that the supply chain of Westinghouse AP1000 faced difficulties, the costs of the construction of US reactor units sky-rocketed, and Westinghouse itself was saved from completed demise only by Toshiba’s kamikaze action in the value of $9 billion. From this point of view, making Zhangzhou 1 the fifth unit to be built around a Hualong One reactor unit may be regarded not only a logical step, but also a favourable change. And this holds true even if China’s National Energy Administration (NEA) did not approve the construction of the first two units in Zhangzhou until June 2019.

Construction of Unit 2 is scheduled to start in September 2020, and CNNC also reported that the entire project is “progressing smoothly”, and the major milestones are being realised in the planned quality and as scheduled. As of now, the target date for the first unit investment (originally planned to be completed in 2017) is still unknown, but – given the fact that the construction process was delayed by about 3 years due to reactor unit replacement and the fact that so far in China the majority of domestic reactor units have been connected to the grid within 5 years after the first concrete was poured – one may say that Zhangzhou 1 can be completed in 2023 or 2024, and the other one in the following year. In October 2021, the

Chinese construction company reported that after 9 hours of work the reactor pressure vessel of at Unit 1 had been hoisted into place and the main units had been installed. The original plan was to construct two more reactor pairs on the site after the completion of the Phase 1. However, the start of the design process depends on how rapidly CNNC, currently working on nuclear projects with its full capacity, can progress with the ongoing construction processes. For the time being, CNNC is optimistic: at the start of pouring the concrete base Zhangzhou 2, they announced that all six blocks would be built.

Russia
BALTIC 1 – 22 February 2012 – 1109 MW
KURSK II-1 – 29 April 2018 – 1175 MW
KURSK II-2 – 15 April 2019 – 1175 MW
BREST(OD-300) – 08 June 2021 – 300 MW

Russia's nuclear industry is linked to the state-owned Rosatom, which is also involved in the production and development of nuclear weapons and research. Currently, Russia's nuclear power plant fleet consists of 37 operational units, 10 decommissioned units, 3 units under construction and 12 abandoned projects. The average age of the operating units is 28.4 years. Such units account for 20.6% of the Russian energy mix. And albeit there is a theoretical study which assumes that Russia is capable of reaching up to 50% by 2050, this does not seem to be feasible either economically or technologically.

However, the impact of Russian nuclear industry on the world is considerable. A paper in the Atomdosszié series, posted on Energiaklub's blog Energiabox in December 2019, describes in detail how Rosatom operates and gains global industrial influence and, through that, how Russia uses nuclear energy as a geopolitical and strategic tool. Not much has changed since then. At that time, Rosatom supplied enriched uranium to 78 reactors around the world, and although, as a result of the war against Ukraine, Rosatom had to give up the construction of a power plant in Finland, it still has contracts on nuclear power plant construction with Armenia, China, Egypt, India, Iran and Uzbekistan, among others, and intergovernmental agreements in the same field with Algeria, Bolivia, Cambodia, Cuba, Ghana, Nigeria, Paraguay, Rwanda, Saudi Arabia, Sudan, Tajikistan, Tunisia, Uganda and Zambia. An article published two years ago by The Guardian summarised the project packages offered by Rosatom as follows: "A typical package offered to a nation interested in nuclear power includes generous loans and long-term supply contracts". The all-inclusive Russian packages, which include flexible financing, training opportunities given on a silver platter, knowledge transfers on development and safety or the take-back of spent fuel, have practically removed Western actors from the scene over the past decade.

Rosatom has also emerged as a new market player in the Chinese construction sector (examples include Tianwan 7and Tianwan 8, which have VVER-1200 units installed). This is an indication that China's nuclear industry operates at a pace that requires a construction capacity exceeding that of China and now needs external help.

Nevertheless, one has to bear in mind that while Rosatom is playing a proactive role in foreign countries, it has not achieved that much in Russia. Its room for manoeuvre is illustrated by the fact that when in 2016, during the lifting of the pressure vessel of Belarus 1 (Ostrovets) the cast item fell to the ground, Rosatom did not cast a new pressure vessel, but replaced the damaged pressure vessel with that of Belarus 2, while Belarus 2 was given the vessel of Baltic 2.

BALTIC 1
Also known as the "Kaliningrad NPP", the project has been "under construction" for more than 10 years. The original designs included two VVER-1200 reactor units to be connected to the grid in 2016 and in 2018. Baltic 1 was launched as a counter-project in response to Lithuania's plans to construct a nuclear power plant in Visaginas (which, despite a lengthy preparation phase, was dropped in 2016 due to a 2012 referendum that objected the project

and due to the fact that Hitachi, the chosen contractor proved to be unsuccessful and the construction process was suspended.) The Baltic Nuclear Power Plant, planned to be built near the town of Neman (in the north-east part of the Russian exclave of Kaliningrad, between Lithuania and Poland) would serve geopolitical purposes. While it would ensure power supply to the Kaliningrad region with one unit that would effectively replace local gas-based electricity generation, it would also export significant volumes to the greater region (above all, to Lithuania, Latvia and Sweden). This plan was thwarted when in 2013 the three Baltic member states of the EU decided to leave the electricity system dominated by Russia and to connect to the EU's electricity grid.

The construction of the Baltic Nuclear Power Plant was suspended, and, although equipment production continued as per the existing contracts (since then the equipment has been stored in warehouses), the construction itself was effectively halted. Pushing the construction of Baltic would have effectively meant bringing into the region a unit that is too large and of too high capacity (and, therefore, cannot be balanced out) for Kaliningrad, a city of a population of 500,000 people that has no opportunity to sell its surplus. Putting aside the occasional political tug-of-war, the problem seems so severe that while Russia's state-owned RosEnergoAtom has not given up on the Baltic, last summer TASS published a news item that has not been commented on ever since that in order to restart the construction, "Rosatom is open for dialogue with potential investors into the Baltic nuclear power plant (NPP) construction project." The announcement, intended to save the project, was mostly a response to the tentative interest shown by Polish private energy company ZE PAK. But Russia's war in Ukraine, which started in February 2022, certainly ended this process abruptly, especially given the fact that in the meantime Poland's nuclear industry has shifted its focus to the US.

There are several decisions which indicate that the Russians themselves do not believe that the Baltic 1 project will be ever finished. For example, in spring 2019, Russia decided to install new gas-powered power plants. It was at that time that Russian state-owned energy company InterRAO announced the launch of the Pregolsky gas-powered station (455 MW), which, combined with two smaller units installed earlier (Mayakovskaya and Talakhovskaya, each of a capacity of 156 MW), will be able to cover Kaliningrad's power supply needs. Last autumn, news broke that a battery factory would be constructed on the site of the nuclear power plant. The factory is planned to be able to meet much of the needs of Russia's automotive sector, which is currently preparing for switching to electric drive trains.

KURSK-II-1, II-2

The nuclear power plant, built 40 kilometres south-west of the city of Kursk, in the vicinity of Russia's western border, currently has four operating units. The units have been in operation since the late 1970s to mid-1980s. All four operate the same type of RBMK-1000 reactor unit, similar to the one at Chernobyl, albeit of a different model. Originally, two more similar 1000-MW units were planned to be installed, but the Kursk 5 investment was halted in 1989 and eventually cancelled in 2012. Russia gave up on the concept of the construction of Kursk 6 in 1993. Currently, the first two reactor units are approaching the end of their life cycle. They were planned to be replaced by Kursk II-1 and II-2 reactor units, which are of a different type and a larger capacity (1255 MW). On the site of Kursk II 1, concrete was first poured in April 2018. The construction process on Kursk II 2 was launched a year later. Kursk II will be the first Russian nuclear power plant where, throughout the construction process, cost management and construction scheduling are supported with digital automated systems, reported World Nuclear News in early 2020, adding that, besides the technical improvement of the VVER-1200 reactor units VVER-TOI), the plant will be equipped with improved safety systems, modern control systems and diagnostics. The deadline for the construction of Kursk II was in fact set as the date of decommissioning of the currently operational Kursk 1 and 2, which the new plant will replace on the grid. After 15-year extensions of operational lifetime, originally planned for 30 years, the old units (which have been in operation since 1977 and 1979) have been planned to be decommissioned in 2021 and 2024. Kursk 1 was closed in December 2021, but has not yet been replaced with another power generating unit in the energy mix.

According to the official figures provided by Rosatom, the estimated investment costs are $3.5 billion per unit and the units are expected to be completed by September 2023 and

August 2024, respectively. Based on the information published so far, this seems to be a plausible date. Albeit at the end of December 2020 Rosatom published a very optimistic account on the construction of Kursk II-1 (more specifically, on a completed reactor pressure vessel test), the power plant unit is still not completed. The fact that AEM Technologies, manufacturer and supplier of the 340-tonne tank, tested the tanks at pressure levels of 24.5 MPa (1.4 times higher than actual operating pressure) was not revealed until April, in an article which, like other news reports on the construction of the Kursk Power Plant, failed to specify any planned completion date. The latest news concerning Kursk II-1 was that the fourth steam generator (the last one for the unit) had been delivered, and the installation of the four steam generators was scheduled to start in May and June 2022. Kursk II-2 has not yet entered this phase. The latest news on the construction (published in September 2021) reports that the pressure vessel had been delivered to site.

BREST OD-300

In June 2021, Rosatom announced the start of the construction of the Generation IV BREST-OD-300 reactor. The project, named "Breakthrough" (Proryv), is a pilot project that concerns a demonstration infrastructure being built at the Siberian Chemical Combine. The project was not launched until 2013, after decades of theoretical preparation. According to the original schedule, the construction of the lead-cooled fast reactor would have started in 2017 and switch-on would have taken place in 2022; however, construction did not commence until 2021. The objective is to ensure that the 300-MW reactor, based on new technology, serves as a basis for the development of a new generation of 1200-MW power generating units. Alexey Likhachev, Director General of Rosatom, summarised the principle behind Brest at the launch ceremony as follows: "The nuclear power industry's resource base will practically become inexhaustible thanks to the infinite reprocessing of nuclear fuel. At the same time, future generations will be spared the problem of accumulating spent nuclear fuel."

The word "Brest" stands for the Russian name of a lead-cooled fast neutron reactor. "OD" denotes "experimental and demonstration". The idea is to physically rule out the possibility of severe accidents like those in Chernobyl or Fukushima. For example, this is the reason why lead is added to the system as a coolant. Lead (unlike water) cannot evaporate, ignite or explode, which is why Russians think the probability of a nuclear accident that may entail the evacuation of the local population is tens of thousands of times lower. However, this 300-MW reactor unit, equipped with this new technology, will not be connected to the grid as a generating unit. Instead, it is designed to be part of a complex which, when completed, will also contain of a fuel fabrication-refabrication module (MFR) and a spent fuel reprocessing module, and will demonstrate the closed fuel cycle operation of nuclear power plants. According to NS Energy Business, the system fuelled with uranium-plutonium-nitride (MNUP), will operate as follows: "the combination of the properties of the newly developed dense nitride uranium-plutonium nuclear fuel and lead coolant makes it possible to operate the reactor in a so-called 'equilibrium fuel' mode. As much plutonium is produced as is 'burned' in the fuel. The plutonium that has accumulated is abstracted from the spent nuclear fuel and combined with depleted uranium (the only fuel input) in fresh fuel, and so on in a circular production."

Rosatom announced that their Breakthrough Project had entered the phase of intensive implementation, which means that the new nuclear fuel fabrication and processing facility is completed, and works on the concrete base commenced in the turbine hall. Currently, Brest is expected to be operational by 2026. In August 2021, Nuclear Engineering reported that the first concrete pour had taken place. Rosatom announced the completion of concrete pouring work in late November. So far, there has been no news of delays.

Slovakia

MOCHOVCE 3 – 27 January 1987 – 440 MW
MOCHOVCE 4 – 27 January 1987 – 440 MW

Mohovce, located on the Hrone River, about 95 kilometres east of Bratislava, is Slovakia's local centre of nuclear energy, even if the units under construction are somewhat of

historical relics: the pressurised water reactor units (Number 3 and 4, each of a capacity of 471 MW, equipped with the VVER-440/V213 Soviet technology): officially, they have been under construction since 27 January 1987. Had they been completed on time, their decommissioning would be approaching now.

The construction work, halted after the change of regime in Central Europe, was re-launched in 2008 by the Italian company Enel, the majority shareholder in Slovenské Elektrárne (SE). Enel expected to finish Unit 3 in 2012 and Unit 4 in 2013 at a total expense of €1.8 billion before the set date of connection to the grid, but it was not be able to meet the deadlines, which, by then, had been modified several times. In fact, Enel left Slovakia in 2016 mainly due to the fact that the expenses of the Mochovce project were getting out of hand. In 2008, Enel had a projected budget of €2.8 billion, which increased to €3.8 billion in 2013 and to €4.63 billion in 2014. After the withdrawal of Enel, SE (now in Slovak ownership) was very optimistic: it expected that Unit 3 and Unit 4 (at a completion rate of 95% and 83%, respectively) would be switched on by 2020. Yet the expectations did not materialise due to the numerous faults identified during inspections, typically by the competent authorities. For example, in 2019, on a hearing before the Slovak parliament's economic committee, SE CEO Branislav Strycek stated that the commissioning of Unit 3, originally scheduled for July 2019, would be postponed. Obviously, this was not a result of the fact that Austrian newspaper Kronen Zeitung had just published an interview, recorded in Bratislava, with an anonymous former engineer from Mochovce about the very serious safety shortcomings he or she had experienced during the construction of the plant. SE dismissed the interview as a hoax, and UJD called it whipping up hysteria. Yet Strycek announced an eight-month delay (coupled with a €270-million project cost increase) attributed only to the fact that the investigation and troubleshooting a false alarm detected during the fire alarm tests took one and a half month.

Afterwards, still in September 2019, Slovakia's Nuclear Regulatory Authority identified faults, which lead to the decision to postpone the start of the reactor unit again. At the time, the cost was €5.7 billion. Finally, Slovakia's Nuclear Regulatory Authority (UJD) authorised the commissioning of Unit 3 of the Mochovce Nuclear Power Plant in mid-May 2021, and assured everyone that the authorisation was based on comprehensive tests, analysis and verification that were performed at levels higher than those specified by relevant established standards. But the authorisation ended up the same way as in February 2020: Austria's Global 2000 appealed the decision. At the time, Kronen reported that in early February the power plant had been on high alert due to the explosion of an emergency generator.

In mid-May, Reuters had the information that in March SE had reported Unit 3 and Unit 4 as of a completion rate of 99.95% and 88%, respectively. According to the latest information at the time, the Slovak state spends €6.8 billion to complete the Mochovce Nuclear Power Plant.

In January 2022 Slovak regulators (as they claimed, having examined all the objections raised by Global 2000) granted the start-up permit to Mohovce 3 again. Public approval is still needed for draft decision; public consultation ended on 21 March. Once Mohovce 3 and 4 are operational (which currently is expected to happen in 2023) the two units will make Slovakia self-sufficient for power.

Turkey
AKKUYU 1 – 03 April 2018 – 1114 MW
AKKUYU 2 – 08 April 2020 – 1114 MW
AKKUYU 3 – 10 March 2021 – 1114 MW

As of now, Turkey does not have an operating nuclear power plant, but it does have three nuclear reactors under construction at various phases of completion. Under the relevant agreement signed by Russia and Turkey in May 2010, these three reactor units should be completed and connected to the grid between 2023 and 2026. If this happens, Ankara will become a major nuclear power in the region by the second half of the 2020s. In fact, if in

addition to Akkuyu 1, 2 and 3 (of a designed total capacity of 3,600 MW), the construction of a fourth unit commences, then Turkey may all the more so rise to such an important position. The Turkish Nuclear Authority (Nükleer Düzenleme Kurumu, NDK) issued the construction licence for Unit 4 in October 2021, but the project has not entered the "under construction" category yet. According to NDK, the licence gives green light to the construction and installation work on Akkuyu 4, including the nuclear safety facilities, the nuclear reactor and the turbine islands. Rosatom will have seven years to complete the construction once the work commences.

The press gives little information about the construction of nuclear units ongoing on the Mediterranean coast, in the southern province of Mersin. And even if some pieces of information are published, most of them do not discuss problems or unfavourable facts, because of distortions by the Turkish government or the contractor, Rosatom. Based on such information one may think that the Akkuyu project is progressing smoothly.

However, the Turkish companies (Cengiz, Kalyon and Kolin) simply withdrew from the project when the construction was about to start, claiming that although after years of preparation they had signed a contract with Rosatom in 2017, under which they would have owned 49% of the project, they had failed to agree on the details. Since then, the location has become the largest nuclear construction site in the world. Moreover, this is the place where the completion of the first milestone cannot be delayed: Unit 1 must be completed by 29 October 2023, the centenary of the Republic of Turkey.

According to the latest news on Akkuyu 1, in December 2021 construction began on the seawater pumping station, and by early March 2022 the reactor pressure vessel and several other main components (the four main circulation pumps, the four hydraulic accumulators of the emergency core cooling system (ECCS) and the four steam generators) had been installed. The fact that the first concrete pour for Akkuyu 3 took place less than three months before the installation of the pressure vessel for Unit 1 shows that Rosatom most probably sees the success of the VVER-1200 reactors in Turkey as a priority. In the first quarter of 2022 alone, Rosatom published 13 project reports on the Akkuyu construction. At end of March, it even announced that the welding of the 160-metre long main circular pipeline (of a wall width of 7 centimetres) had begun.

A year before, in mid-March 2021, when concrete was first poured at Akkuyu 3, at a video conference between Russian President Vladimir Putin and his Turkish colleague Recep Erdoğan, Vladimir Putin gave an enthusiastic address, stressing that the plant is "truly a flagship project". The entire amount of $20 billion invested in the plant, designed to operate for 60 years, is paid by Rosatom, which will realise returns from the operation of the plant, via a power purchase agreement valid for 15-30 years. Rosatom promoted the launch of the construction of Unit 3 with a Twitter post, which also stated that the licence for Unit 4 was being issued. However, if the Unit is indeed built, it may have unexpected consequences. Henry D Sokolski opines that the funding model of the Akkuyu Nuclear Power Plant may not only further increase Turkey's dependence on Russia (which is already one of Turkey's main energy suppliers, c.f. Turkish Stream), but also poses new threats.

All news items point out that (1) once completed, Akkuyu will generate 35 billion kilowatt hours (kWh) of electricity per year, thus becoming capable of covering one-tenth of Turkey's total electricity supply, (2) for the first 15 years of its operational life of 60 years the Russians will be responsible for operation, but 600 students and graduates have already been trained in Russia to work as plant staff, and (3) the Akkuyu team was joined by approximately 150 graduates who had participated in personalised training. However, no mention is made of the fact that for Turkey the concentrated source of energy production of a capacity between 3,600 and 4,800 MW is a potential target for attacks. In March 2021, an Al Jazeera article highlighted the fact that the nuclear power plant is also a security issue in the Middle East (where Saudi Arabia and Jordan have been considering for years the possibility of building their own nuclear potential, while Egypt and the United Arab Emirates have actually started it, Israel has a nuclear bomb and Iran is on the same trajectory). Moreover, a nuclear power

plant can not only become a target for attack, but also opens up for its user/owner/operator the possibility of producing nuclear weapons. And it must be added that the Turkish government – which usually does not avoid conflicts, even armed conflicts – has serious enemies. In addition, Turkey has long-standing military cooperation agreements with Pakistan (which does not shy away from nuclear proliferation), and earlier this year Turkey signed military cooperation agreements with Kazakhstan (which holds more than 35% of the world's uranium reserves).

Ukraine
KHMELNYTSKYI 3 – 1 March 1986 – 1035 MW
KHMELNYTSKYI 4 – 1 February 1987 – 1035 MW

The construction of the Khmelnytskyi Nuclear Power Plant came to an abrupt end with the Chernobyl disaster. In the area designated for the construction in the late 1970s near the town of Netishyn, only two of the planned four reactor units (each of a capacity of 1000 MW) were fully completed. Khmelnitsky 1 was commissioned as early as in 1987, "on the fly". But due to lack of funds Unit 2 was not connected to the grid until 2004, after the collapse of the Soviet Union as Ukraine was reorganising itself. The situation of Units 3 and 4 is even less favourable. Their construction officially started in 1985 and 1986, respectively, but the project is still stuck in the state where it was in 1990.

More than 12 years ago, when Ukraine and Russia signed an agreement on the technical design of Units 3 and 4, Rosatom calculated that the plant would be completed in 5-6 years at a cost of €4-5 billion: Russia would install two 1000-MW VVER-1000 reactor units at its own expense, the amount then being paid back by Ukraine in goods. However, work has not been resumed ever since either on Khmelnitsky 3 or Khmelnitsky 4, which have been under construction since September 1985 and June 1986 respectively, and, therefore, are dubbed as "zombie" power plants. When, not unrelated to the 2014 war in Ukraine, Rosatom rejected criticism concerning its alleged failure to respect its contractual obligations, in 2015 Ukraine finally terminated the agreement. A year later, attempts were made to involve South Korean nuclear power company KHNP in the project. Ukraine's state-owned nuclear power plant operator Energoatom also considered the possibility of choosing China for the construction of nuclear power plants developed on the basis of Russian technology. This, however, has not materialised.

Another unsuccessful move was when Ukraine, "looking for an international partner", would have been willing to conclude an agreement with US company Westinghouse. Not only did Ukraine face the problem of lack of funds, the condition of the reactor units (whose construction was suspended in 1990, at a completion rate of 75% and 28%) had also been deteriorating. Had the two new Khmelnitsky reactor units been completed as originally planned, today's news would report either decommissioning or a lifetime extension. Instead, in 2019 Hungarian site Átlászó published a long article on the willingness to continue the construction, revealing the fact that according to impact assessments the building's degree of completion was maximum 30–40% (or, more likely, 5–10%). In addition, a study by the Environment Agency Austria concluded that the ageing of the unfinished structures renders a restart practically impossible, while it remains unclear how a reactor type that is different from the one in the original design could even be installed in a structure that, at some point, had been almost completed.

Still, in November 2020, it was officially announced that construction will continue on Units 3 and 4 of the Khmelnitsky plant. Yet no further details have been published on this new momentum, although Piotr Kotin, head of Energoatom, stated they hoped that the competent ministry would soon approve the environmental impact assessment report on the construction of the two units. Power Technology concluded its general description, published in March 2022, with the comment that in November 2021 Energoatom sent a draft contract to Westinghouse Electric for the supply of AP1000 reactors, yet gave no information whatsoever on the intended modifications of Khmelnitsky 3 and 4. The US became involved in November

2021: a tentative site visit was organised which, as reported by World Nuclear News at the time, was intended to perform a detailed examination of Unit 3 on the basis of which the possible ways to conclude the project could be identified. This is a far cry from the specific measures or from the planning of the construction work, even if the Vice President of Commercial Affairs of Westinghouse and the Vice President of the company responsible for the construction of the new nuclear power plant were also on site at the time. Yet Kotin's optimism, based on the mission (which was regarded as a diplomatic success) has proven to be unfounded. After the Russian army entered Ukraine, Ukrainian experts and the country itself have to face completely different problems.

It was Kotin who officially notified IAEA that the Russians attempted trying to take control of the Zaporizhzhya NPP (ZNPP). In mid-March, he was the one who announced that Ukraine would also break cancel purchasing nuclear fuel from Russia and would seek a US supplier for its operational systems. The latter is a pragmatic decision: when the war in Ukraine is over, the construction of a new nuclear power plant will not be a priority for years to come.

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