THE WORLD NUCLEAR INDUSTRY STATUS REPORT 2017

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The World Nuclear Industry
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The cover page was designed by Agnès Stienne. The picture below the solar panel is based on a photography of the Juragua site in Cuba, where building of two Russian-designed 413 MW reactors started in 1983 and was abandoned in 1992. Photography by © Darmon Richter – August 2014.

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NOTE

This report contains a very large amount of factual and numerical data. While we do our utmost to verify and double-check, nobody is perfect. The authors are always grateful for corrections and suggested improvements.

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FOREWORD

by S. David Freeman[1]

Nuclear power was born in a sea of euphoria out of a collective American guilt over dropping the atomic bomb. And for at least two decades it was the "clean" alternative to coal that was going to meet all of our energy needs forever.

Perhaps the most decisive document in the history of nuclear power...

The Three Mile Island meltdown, in 1979, ended the euphoria but the dream continued and it still goes on without much regard to contrary facts.

The opponents of nuclear power have shown a similar disregard for changing facts. They largely ignored the fact that many well-meaning people viewed local air pollution and climate change more of a danger than nuclear. In those years shutting down a nuclear plant did mean increased emissions of local pollutants and green house gases.

The debate about nuclear power was similar to talking about a religion. It was seldom grounded in all the relevant facts- each side had a religious belief in their point of view boosted by whatever ad hoc facts supported their view.

Because of that history, this 2017 *World Nuclear Industry Status Report* is perhaps the most decisive document in the history of nuclear power. The report makes clear, in telling detail, that the debate is over. Nuclear power has been eclipsed by the sun and the wind. These renewable, free-fuel sources are no longer a dream or a projection-they are a reality that are replacing nuclear as the preferred choice for new power plants worldwide.

It no longer matters whether your greatest concern is nuclear power or climate change the answer is the same. The modern-day "Edisons" have learned to harness economically the everlasting sources of energy delivered to earth by Mother Nature free of charge.

The value of this report is that this conclusion no longer relies on hope or opinion but is what is actually happening. In country after country the facts are the same. Nuclear power is far from dead but it is in decline and renewable energy is growing by leaps and bounds.

The entire Report is must reading so that the facts of nuclear decline in the U.S., Germany, Japan, and France –indeed just about every country- really sinks in. It is more than symbolic that the Japanese Government has formally accepted the death of its breeder reactor, which was the original holy-grail of nuclear power.

Most revealing is the fact that nowhere in the world, where there is a competitive market for electricity, has even one single nuclear power plant been initiated. Only where the government or the consumer takes the risks of cost overruns and delays is nuclear power even being considered.

1 - S. David Freeman was appointed Chairman of the Tennessee Valley Authority (TVA) by President Jimmy Carter in 1977. Subsequently, he served for two decades as general manager of several large public power agencies including the Los Angeles Department of Water and Power, the New York Power Authority, and the Sacramento Municipal Utility District.

The report makes clear, in telling detail, that the debate is over

The most decisive part of this report is the final section- Nuclear Power vs Renewable Energy Development. It reveals that since 1997, worldwide, renewable energy has produced four times as many new kilowatt-hours of electricity than nuclear power.

Maybe the Revolution has not been televised, but it is well underway. Renewable energy is a lower cost and cleaner, safer alternative to fossil fuels than nuclear power.

The world no longer needs to build nuclear power plants to avoid climate change and certainly not to save money. If you have any doubt about that fact please read the *World Nuclear Industry Status Report 2017*.

S. David Freeman

KEY INSIGHTS IN BRIEF

Global Overview—The Chinese Exception, Yet

- Global nuclear power generation increased by 1.4% in 2016, due to a 23% increase in China, although the share of nuclear energy in electricity generation stagnated at 10.5% (–0.2%).
- Ten reactors started up in 2016, of which one-half were in China. Two reactors were connected to the grid in the first half of 2017—one in China, one in Pakistan (by a Chinese company)—the first units to start up in the world whose construction started after the Fukushima disaster began.
- Three construction starts in the world in 2016—two in China, one in Pakistan (by a Chinese company)—down from 15 in 2010, of which 10 were in China. One construction start in India in the first half of 2017, none in China or in the rest of the world.
- The number of units under construction is declining for the fourth year in a row, from 68 reactors at the end of 2013 to 53 by mid-2017, of which 20 are in China.

Closures and Construction Delays

- Russia and the U.S. shut down reactors in 2016, while Sweden and South Korea both closed their oldest units in the first half of 2017.
- Election of a new President in South Korea, who closed one plant and suspended the construction of two more, puts hopes of the national nuclear industry to expand and export into jeopardy.
- Thirteen countries are building new reactors, one less than in WNISR2016, as the construction of Angra-3 in Brazil was abandoned following a massive corruption scandal involving senior project management.
- There are 37 reactor constructions behind schedule, of which 19 reported further delays over the past year. China is no exception, at least 11 of 20 units under construction are behind schedule.
- Eight projects have been under construction for a decade or more, of which three for over 30 years.
- WNISR2016 noted 17 reactors scheduled for startup in 2017. As of mid-2017, only two of these units had started up and 11 were delayed until at least 2018.

Bankruptcy/Bailout of Historic Nuclear Giants – Deep Financial Crisis for Nuclear Utilities

- After the discovery of massive losses over its nuclear construction projects, Toshiba filed for bankruptcy of its U.S. subsidiary Westinghouse, the largest nuclear power builder in history.
- AREVA has accumulated US$12.3 billion in losses over the past six years. French government has provided a US$5.3 billion bailout and continues break-up strategy.
- The large quality-control scandal at AREVA's Creusot Forge further erodes confidence in the industry.
- Share-value erosion and downgrading by credit-rating agencies of major nuclear utilities.

Fukushima Status Report

- Six years after the Fukushima disaster began, the Japanese Government started lifting evacuation orders in order to limit skyrocketing compensation costs. The total official cost estimate for the catastrophe has doubled from US$100 billion to US$200 billion. A new independent assessment has put the cost at US$444–630 billion (depending on the level of water decontamination). Only five reactors have been restarted.

Renewables Distance Nuclear

- Globally, wind power output grew by 16%, solar by 30%, nuclear by 1.4% in 2016. Wind power increased generation by 132 TWh, solar by 77 TWh, respectively 3.8 times and 2.2 times more than nuclear's 35 TWh. Renewables represented 62% of global power generating capacity additions.
- New renewables beat existing nuclear. Renewable energy auctions achieved record low prices at and below US$30/MWh in Chile, Mexico, Morocco, United Arab Emirates, and the United States. Average generating costs of amortized nuclear power plants in the U.S. were US$35.5 in 2015.

EXECUTIVE SUMMARY AND CONCLUSIONS

The *World Nuclear Industry Status Report 2017* (*WNISR2017*) provides a comprehensive overview of nuclear power plant data, including information on operation, production and construction. The WNISR assesses the status of new-build programs in current nuclear countries as well as in potential newcomer countries. The WNISR2017 edition includes a new assessment from an equity analyst view of the financial crisis of the nuclear sector and some of its biggest industrial players. The Fukushima Status Report provides not only an update on onsite and offsite issues six years after the beginning of the catastrophe, but also the latest official and new independent cost evaluations of the disaster. Focus chapters provide in-depth analysis of France, Japan, South Korea, the United Kingdom and the United States. The Nuclear Power vs. Renewable Energy chapter provides global comparative data on investment, capacity, and generation from nuclear, wind and solar energy. Finally, Annex 1 presents a country-by-country overview of all other countries operating nuclear power plants.

Reactor Status and Nuclear Programs

Startups and Shutdowns. In 2016, ten reactors started up, five in China, one each was commissioned in India (Kudankulam-2), Pakistan (Chasnupp-3), Russia (Novovoronezh-2-1), South Korea (Shin-Kori-3) and the U.S. (Watts Bar-2, after 43 years of construction). Two reactors were closed in 2016, Novovoronezh-3 in Russia and Fort Calhoun-1 in the U.S.

In the first half of 2017, two reactors started up in the world, one each in China (Yangjiang) and Pakistan (Chasnupp-4, built by a Chinese company), while two were shut down, the oldest units respectively in South Korea (Kori-1, after 40 years of operation) and in Sweden (Oskarshamn-1, after close to 46 years of operation).

Operation and Construction Data

Reactor Operation. There are 31 countries operating nuclear power plants.[1] These countries operate a total of 403 reactors—excluding Long-Term Outages (LTOs)—just one unit more compared to the situation mid-2016, 35 fewer than the 2002 peak of 438. The total installed capacity increased over the past year by less than one percent to reach 351 GW,[2] which is comparable to levels in 2000. Installed capacity peaked in 2006 at 368 GW. Annual nuclear electricity generation reached 2,476 TWh in 2016—a 1.4 percent increase over the previous year, but about 7 percent below the historic peak of 2006. As in 2015, the 2016 global increase of 35 TWh is due to the production hike in China, where nuclear generation increased by 23 percent or 36.6 TWh.

1 - Unless otherwise noted, the figures indicated are as of 1 July 2017.

2 - All figures are given for reference net electricity generating capacity. GW stands for gigawatt or thousand megawatt.

WNISR2017 classifies 33 Japanese reactors as being in LTO,[3] three less than in WNISR2016, as two were restarted (Ikata-3 et Takahama-4) and Monju was closed permanently.

Besides the Japanese reactors, two French units (Bugey-5, Paluel-2), as well as one unit each in Argentina (Embalse), India (Kakrapar-2), Switzerland (Beznau-1) and Taiwan (Chinshan-1) meet the LTO criteria.

All ten reactors at Fukushima Daiichi and Daini are considered permanently closed and are therefore also excluded in the count of operating nuclear power plants.

Share in Electricity/Energy Mix. The nuclear share of the world's power generation remained stable[4] over the past five years, with 10.5 percent in 2016 after declining steadily from a historic peak of 17.5 percent in 1996. Nuclear power's share of global commercial primary energy consumption also remained stable at 4.5 percent—prior to 2014 the lowest level since 1984.[5]

The "big five" nuclear generating countries—by rank, the U.S., France, China, Russia, and South Korea—generated 70 percent of the world's nuclear electricity in 2016. China moved up one rank. The U.S. and France accounted for 48 percent of global nuclear generation.

Reactor Age. In the absence of major new-build programs apart from China, the unit-weighted average age of the world operating nuclear reactor fleet continues to rise, and by mid-2017 stood at 29.3 years. Over half of the total, or 234 units, have operated for 31 years and more, including 64 that have run for 41 years and more.

Lifetime Extension. The extension of operating periods beyond the original design is regulated differently from country to country. While in the U.S., 84 of the 99 operating reactors have already received license extensions for up to a total lifetime of 60 years, in France, only 10-year extensions are granted and the safety authorities have made it clear that there is no guarantee that all units will pass the 40-year in-depth safety assessment. Furthermore, the proposals for lifetime extensions are in conflict with the French legal target to reduce the nuclear share from the current three-quarters to half by 2025.

Lifetime Projections. If all currently operating reactors were shut down at the end of a 40-year lifetime—with the exception of the 72 that have passed the 40-year mark—by 2020 the number of operating units would be 11 below the total at the end of 2016, even if all reactors currently under active construction were completed. The installed capacity, however, will increase by 4 GW, because many of the older units have lower power outputs when compared to most of the reactors currently under construction. In the following decade, between 2020 and 2030, 194 units (179 GW) would have to be replaced—almost four times the number of startups achieved over the past decade. If all licensed lifetime extensions were actually implemented and achieved, the number of operating reactors would still increase by only five, and adding 16.5 GW in 2020. By 2030, 163 reactors would have to be shut down and the loss of 144.5 GW would have to be compensated for.

3 - WNISR considers that a unit is in Long-Term Outage (LTO) if it produced zero power in the previous calendar year and in the first half of the current calendar year. This classification is applied retroactively starting on the day the unit is disconnected from the grid. WNISR counts the startup of a reactor from its day of grid connection, and its shutdown from the day of grid disconnection.

4 - Less than 0.2 percentage points difference with 2015 and the five years on average, a level that is certainly within statistical uncertainties.

5 - According to BP, "Statistical Review of World Energy", June 2017.

Construction. Thirteen countries are currently building nuclear power plants, one less than in previous years. Construction at the only new-build project in Brazil, Angra-3, was halted after corruption charges were brought against senior management.

As of 1 July 2017, 53 reactors were under construction[6]—five less than one year earlier and 15 fewer than in 2013. Twenty of the 53 reactors are being constructed in China.[7] Total capacity under construction is 53.2 GW (–8%).

- The current average time since work started at the 53 units under construction is 6.8 years, an increase of 0.6 years from the status one year ago. The main reasons are the low number of construction starts and new delays. At mid-2017, 11 of 17 scheduled startups for the year had already been pushed into 2018 or beyond.[8]
- All of the reactors under construction in 8 out of the 13 countries have experienced delays, mostly by a year or more. Over two thirds (37) of all construction projects are behind schedule. Most of the 16 remaining units under construction, of which 9 are in China, were begun within the past three years or have not yet reached projected start-up dates, making it difficult to assess whether or not they are on schedule.
- Of the 37 reactors behind schedule, 19 have reported increased delays over the past year since WNISR2016.
- Construction of three reactors has started more than 30 years ago: Mochovce-3 and -4 in Slovakia and Rostov-4 in Russia.
- Two units, the Prototype Fast Breeder Reactor (PFBR) in India and Olkiluoto-3 in Finland, have been listed as "under construction" for a decade or more, while Shimane-3 in Japan and Flamanville-3 in France will reach 10 years of construction before the end of 2017.
- The average construction time of the latest 51 units in ten countries that started up in the past decade, since 2007, was 10.1 years with a very large range from 4 to over 43 years.

Construction Starts & New Build Issues

Construction Starts. In 2016, construction began on 3 reactors, 2 of which were in China and one in Pakistan (by a Chinese company). This compares to 15 construction starts—of which 10 were in China alone—in 2010. In the first half of 2017, only India started building a reactor. Historically, construction starts in the world peaked in 1976 at 44.

Construction Cancellations. Between 1977 and 1 July 2017, a total of at least 91 (one in eight) of all construction sites were abandoned or suspended in 17 countries in various stages of advancement.

Newcomer Program Delays/Cancellation. Only two newcomer countries are actually building reactors—Belarus and UAE. Progress was halted at Belarus' Ostrovets project, when the reactor pressure vessel was dropped during installation and had to be replaced. The UAE an-

6 - In late July 2017, construction of two units at the V.C. Summer site in the U.S. was suspended and one additional reactor started up in China. This leads to 50 units under construction as of 1 September 2017.

7 - One unit started up in China in July 2017 was on schedule. As of 1 September, that leaves 11 of 19 units under construction in China behind schedule.

8 - A third unit started up in China in July 2017. As of 1 September, that leaves three units scheduled for startup in 2017.

nounced that it had to delay startup of the first of four units to 2018, due to a lack of locally trained and licensed domestic personnel.

Further delays have occurred over the year in the development of nuclear programs for most of the more or less advanced potential newcomer countries, including Bangladesh, Egypt, Jordan, Poland, Saudi Arabia, and Turkey. Vietnam abandoned its new-build project due to slowing electricity demand increases, concerns over safety and rising construction costs.

Nuclear Finances: A Tough Market Environment

Bankruptcy of Historic Builder Toshiba-Westinghouse. Following technical problems, delays and massive cost overruns at its U.S. construction projects V.C. Summer and Vogtle, the Japanese group Toshiba in March 2017 filed for bankruptcy protection of its US. subsidiary Westinghouse. As a consequence, construction at the two V.C. Summer reactors in the U.S. was halted.

AREVA Debacle (another new episode). The French state-controlled integrated nuclear company AREVA went technically bankrupt after a cumulative six-year loss of US$12.3 billion. The French government has provided a bailout for US$5.3 billion and continued a break-up strategy that has state utility EDF take over the nuclear building and services subsidiary AREVA-NP. The rescue scheme has been approved by the European Commission. AREVA has been delisted from the Paris stock market since August 2017. The embattled company is struggling also with a vast quality-control scandal that led to the provisional shutdown of a dozen reactors in France. Thousands of fabrication dossiers have to be examined for irregularities or falsifications. The safety implications remain to be assessed.

Nuclear Utilities in Difficulty. Many of the traditional nuclear and fossil fuel based utilities continue to struggle with low wholesale power prices, a shrinking client base, declining power consumption, high debt loads, increasing production costs at aging facilities, and stiff competition, especially from renewables.

- In **Europe**, energy utilities Centrica (U.K.), EDF, Engie (France), E.ON, and RWE (Germany) have all been downgraded by credit-rating agencies over the past year. As of early July 2017, compared to their peak values during the past decade, the utilities' shares had lost most of their value: RWE –82%, E.ON –87%, EDF –89%, Engie –75%.
- In **Asia**, the share value of Japanese utility TEPCO, de facto nationalized after the Fukushima disaster, as of early July 2017, was still 89% below its February 2007 peak value. Toshiba, hit by the bankruptcy of its U.S. subsidiary Westinghouse, saw its share value shrink again to a quarter of its 2007 peak level. Chinese utility CGN, listed on the Hong Kong stock exchange since December 2014, over the past year and a half never recovered from the 60 percent loss of its share value compared to the peak in June 2015. The Korean utility KEPCO, the only major nuclear utility to reach its peak share value in 2016, has lost 37% of its value over the past year following tariff cuts, increased operating expenses and the temporary shutdown of four reactors. The election of a new president exacerbates the situation.

The German Singularity. Lower electricity and commodity prices, added to increased competition and the implementation of the country's Energiewende have led private utilities RWE

and E.ON to make the strategic choice to split themselves in two. They separated their generation and trading activities from network operations and renewables in an attempt to reduce their exposure to commodity price movements, while providing new growth opportunities and value creation. Following this, the German government set up an independent commission (KFK) to review the process. As a result, the German government created a sovereign nuclear waste fund to cover future storage costs, transferring the risk from operators to the government.

A Low-Rate Environment. The positive effect from a lower cost of debt following the financial crisis had additional effects on nuclear operators. As in many cases nuclear generators are also operators on electricity networks, allowed returns have been revised downwards by regulators to avoid excessive gains. Moreover, lower interest rates imply that nuclear operators have to set aside more money today for future expected costs, increasing the total amount of provisions required.

Sector Developments.

- Emission Trading System (ETS) prices are near historical low levels, while new measures have been taken by the European Union to boost prices in the mid-term by reducing allowance supply. New trading systems are being implanted in the world similar to the European model to comply with COP21 agreements.
- Power prices touched historical low levels in the first half of 2016, with a rebound on the second half, which continued in 2017. The increase has been driven by a rebound on coal prices added to capacity shortages in France due to a lower nuclear generation from reactor inspections concerning the AREVA manufacturing irregularities. The rebound should positively impact earnings from 2018 onwards, but profits in 2017 are expected to tighten further as most of the generation has already been contracted at a lower price level.

Fukushima Status Report

Six and a half years have passed since the Fukushima Daiichi nuclear power plant accidents (Fukushima accident) were triggered by the East Japan Great Earthquake on 11 March 2011 (also referred to as 3/11 throughout the report). A number of onsite and offsite challenges have arisen since and remain significant today.

Onsite Challenges. The latest revision (June 2016) of the government's mid-and-long-term roadmap fixed new target dates, some of which, one year later, are already outdated.

- **Spent Fuel Removal.** Spent fuel was to be removed from unit 3 in Financial Year (FY) 2017, but is now envisaged for the middle of 2018. Spent fuel removal from unit 1 was to be carried out by FY 2020 and is now scheduled for in 2021 at the earliest. No new timescale is available for unit 2.
- **Molten Fuel Removal.** Radiation levels remain very high inside the reactor buildings and make human intervention impossible. Fuel debris removal at unit 1 has been delayed to start in 2021. A robot was introduced into unit 2, but it got stuck in debris. No conclusive video footage is available and it remains unknown where the molten fuel is actually located. A radiation dose level of 210 Sv/h has been measured close to the pressure vessel.

- **Contaminated Water Management.** Every day, still over 200 m^3 of water are injected into the three reactor cores to cool the molten fuel. The highly contaminated water runs out of the cracked containments into the basement where it mixes with water that has penetrated the basements from an underground river. A frozen soil wall that was designed to reduce the influx of water was commissioned at end of March 2016. Its effectiveness is limited and has reduced the influx of water only from 760 m^3 to 580 m^3 per day. The cumulated amount has increased by 100,000 m^3 to 750,000 m^3 over the past year. The commissioning of a dedicated bypass system and the pumping of groundwater has reduced the influx of water into the basements to about 130 m^3/day. An equivalent amount of water is decontaminated to some degree, but still contains very high levels of tritium (over 500,000 Bq/l) and is stored in large tanks.
- **Workers.** About 8,000 workers per month are involved in decommissioning work. Several fatal accidents have occurred at the site. In December 2016, the Ministry of Health recognized, for the first time, recognized the thyroid cancer developed by a TEPCO employee in his forties as occupational disease.

Offsite Challenges. The future of tens of thousands of evacuees, the assessment of health consequences of the disaster, the management of decontamination wastes and the costs involved range amongst the main offsite challenges.

Evacuees and Compensation. According to government figures, the number of evacuees from Fukushima Prefecture as of March 2017 was about 79,000 or less than half of almost 165,000 in May 2012. On 31 March/1 April 2017, the government lifted restriction orders for 32,000 people. According to a survey of residents' intentions conducted by the Reconstruction Agency, at the maximum only 18 percent of the households desired to return in each of three of the five municipalities located in the evacuation zones. The government has decided to terminate the monthly compensation of about US$900 per person by March 2018 for all evacuees, except for those from so-called difficult-to-return areas for which there is no plan to lift the evacuation order. Compensation for some 12,400 Fukushima-Prefecture households that evacuated voluntarily was terminated in March 2017. The social effects of this termination are severe.

Health Issues. The controversy around health effects, especially thyroid cancer, continues. At present, the number of cancer cases found in children is about 30 times that of the national average. The official survey consistently stated that "it cannot be concluded whether or not the incidences of thyroid cancer found in the examination are due to exposure from the Fukushima accident." This implies that a causal effect cannot be excluded.

Decontamination. By the end of March 2017, 22,000 residential areas, 8,500 hectares (ha) of farmland, 5,800 ha of forest and 1,400 ha of roads had been "decontaminated". While the Environment Ministry claims dose rate reductions at 1 m above ground between 61% on roads and 71% on residential land, the effectiveness of these measures remains questionable, especially in the case of wooded areas that have only been decontaminated up to a radius of roughly 20 m around homes.

Cost of the Accidents. Official cost estimates have doubled over the years and increased by one third over the past year to reach about US$200 billion, of which 36% each for decommissioning and compensation, 18% for decontamination and the remaining 10% for interim sto-

rage of waste. A new independent assessment has put the cost at US$444–630 billion (depending on the level of water decontamination).

Small Modular Reactors (SMR)

WNISR2017 provides an update of the 2015 assessment of the status of Small Modular Reactor (SMR) programs around the world. While some design went to the construction phase with one reactor in China scheduled for startup in 2018, global interest in the technologies has faded. Some of the most promising designs (SMART in South Korea and mPower in the U.S.) have not found any buyers. While SMRs were meant to solve the size issues (capacity and investment) of large nuclear plants, they are affected by the general decline in interest in nuclear new-build.

Nuclear Power vs. Renewable Energy Deployment

Investment and Installed Capacity. After an all-time high of over US$310 billion in 2015, global investment in new renewable energy based electricity generating capacity dropped to about US$240 billion. However, the 23-percent fall in investment volume mainly reflects the rapid reduction in costs per GW as total renewable capacities installed in 2016 (excluding large hydro) added up to 138.5 GW, more than 127.5 GW the year before. Renewables accounted for 62% of additions to global power generating capacity.

China remains the largest investor with US$78 billion, doubled its solar capacity to a cumulated 78 GW and added 20 GW of wind power capacity to reach just under 150 GW in total, more than all of Europe combined. This compares with China's addition of 4.6 GW of nuclear capacity in 2016 to reach a total of 32 GW.

Net global increase of nuclear capacity in 2016 was 9 GW—vs. a record 75 GW for solar and 55 GW for wind—and was limited to 3 GW over the year since July 2016.

Since 2000, countries have added 451 GW of wind energy and 301 GW of solar energy to power grids around the world, which dwarfs the increase of only 36 GW, including all reactors in LTO status, in nuclear power capacity over the same period. Taking into account the fact that 36 GW of nuclear power were in LTO as of the end of 2016, and thus not operating, the current nuclear capacity is just the same as in 2000.

Electricity Generation. Brazil, China, Germany, India, Japan, Mexico, the Netherlands, Spain and the U.K.—a list that includes three of the world's four largest economies—all generate more electricity from non-hydro renewables than from nuclear power.

In 2016, annual growth rates for global generation from solar was 30 percent, for wind power almost 16 percent, and for nuclear power 1.4 percent, exclusively due to China.

Compared to 1997, when the Kyoto Protocol on climate change was signed, in 2016 an additional 948 TWh of wind power was produced globally and 332 TWh of solar photovoltaics electricity, compared to nuclear's additional 212 TWh.

In China, as in every year since 2012, electricity production from wind alone (241 TWh), exceeded that from nuclear (198 TWh) in 2016. The same phenomenon is seen in India, where wind

power (45 TWh) outpaced nuclear (35 TWh) again. In fact, while annual Indian nuclear power generation increased by 5 TWh since 2014, solar power alone added 7.5 TWh over those two years.

The figures for the European Union illustrate the rapid decline of the role of nuclear: during 1997–2014, wind produced an additional 293 TWh and solar 111 TWh, while nuclear power generation *declined* by 82 TWh.

Record Low-Price Levels. New renewables come in cheaper than operating and maintenance costs of existing nuclear power plants. Renewable energy auctions achieved record low prices at and below US$30/MWh in Chile, Mexico, Morocco, United Arab Emirates, and the United States. In comparison, average generating costs of amortized nuclear power plants in the U.S., about one quarter of the world's nuclear fleet, stood at US$35.5 in 2015.

INTRODUCTION

Where to start? Since we released the *World Nuclear Industry Status Report 2016* (*WNISR2016*) in Tokyo, in July 2016, potentially seismic shifts have occurred inside and outside the nuclear industry.

First, on the political level. Some sort of "regime change" occurred in some key (nuclear power) countries. Incoming Presidents in France (Emmanuel Macron), South Korea (Moon Jae-in) and the United States of America (Donald Trump), representing three of the top-five nuclear electricity generators in the world, and all bringing along a distinctly different energy agenda than their predecessors. In addition, Japan's Prime Minister Shinzō Abe recently implemented a surprising cabinet reshuffle.

Then, on the industrial level, with bankruptcies of the largest historic nuclear builder in the world, Toshiba-Westinghouse and its French equivalent AREVA. The long-awaited go-ahead for the controversial Hinkley Point C in the U.K. and the shock of the abandoned V.C. Summer construction project in South Carolina, U.S. While depressed wholesale market-prices continue to challenge the competitiveness even of amortized nuclear reactors around the world.

Third, there is the ongoing surge in renewable energy deployment around the world, beating out nuclear power everywhere. This is best illustrated by developments in China, currently the global leader in nuclear power plant construction by a wide margin, where only one new 1 GW nuclear reactor was added to the grid in the first half of 2017. During the same period, 24.4 GW of solar capacity came on-line. An additional 10.5 GW of solar photovoltaics began generating power in the month of July 2017 alone.[9] Compare this to 2012, barely five years ago, when Germany set the world record with 7.5 GW of photovoltaic capacity added in a whole year. Current projections are: "By the end of 2017, solar PV capacity will rival nuclear. By 2022, it could more than double nuclear capacity."[10]

What will the new governments change for the nuclear and energy sectors?

The Macron administration vows to implement the energy transition legislation inherited from its predecessor and design a pathway towards the 2025-goal to reduce the nuclear share in power production from about three quarters to one half. With electricity consumption stagnating or dropping, there is no doubt what that means: Shutting down at least one third of France's nuclear fleet of 58 reactors.

South Korea's new President Moon was in office for less than a month before he presided over a highly symbolic shutdown ceremony for Korea's oldest nuclear reactor stating: "We will scrap the nuclear-centered polices and move toward a nuclear-free era. We will eliminate all plans

9 - Mark Osborne, "China installs 10.52GW of solar in July: Exceeds 2020 target by 7%", *PVTech*, 22 August 2017, see https://www.pv-tech.org/news/china-installs-10.52gw-of-solar-in-july-exceeds-2020-target-by-7, accessed 24 August 2017.

10 - Stephen Lacey, "Global Solar Capacity Set to Surpass Nuclear for the First Time", *GreenTech Media*, 21 August 2017, see https://www.greentechmedia.com/articles/read/global-solar-capacity-set-to-surpass-global-nuclear-capacity, accessed 24 August 2017.

to build new nuclear plants."[11] Moon has studied the issue intensively.[12] The move represents a radical shift from the previous government, but is de facto an "alignment" (as local key stakeholders put it) with the successful Seoul Mayor Park Won-soon. In 2012, Park launched his emblematic "One Less Nuclear Power Plant Plan", vowing to reduce/substitute the consumption of his city to equal the output of a nuclear reactor by 2014. He succeeded, and doubled the substitution target level for 2020.

President Trump has made some announcements in the past giving his strong support for nuclear power. However, his administration turned down calls for subsidies to help the troubled V.C. Summer construction project in South Carolina. As a consequence, the utilities pulled the plug on the failed industrial project that has been subject to delays and budget overrides ever since it got underway in 2013. Now, the only remaining construction project in the U.S. is the Vogtle plant in Georgia, that is comparable to the V.C. Summer project in terms of planning, implementing and financial problems. At the end of August 2017, Georgia Power has recommended the completion of the two AP1000 reactors, in spite of vast cost overruns. After four years of construction, at a time when the plant was originally scheduled to start operating, the project is only 32 percent completed. The fate of the plant now rests with the state's Public Service Commission, which will conduct a six-month review before deciding.[13]

Japan's Prime Minister Abe, struggling with a range of domestic policy issues and falling public approval, announced a wide-ranging reorganization of his government. Most significant for nuclear power, this reorganization includes the appointment of Taro Kono—the most outspoken nuclear critic in the governing Liberal Democratic Party (LDP)—as Foreign Minister. Only five reactors have restarted in Japan that had seen its entire nuclear fleet stranded with no nuclear power generation in 2014. Kono's appointment is also a blow to the Japanese industry's ambitions to export nuclear equipment.

The 2017 edition of the *World Nuclear Industry Status Report* (*WNISR*) provides in-depth analysis of the nuclear sectors and the implications of recent industrial and political developments in the Focus-Country chapters on France, Germany, Japan, South Korea, the U.K. and the U.S. as part of the main report. Developments in the 25 other nuclear countries are covered in Annex 1. The WNISR2017 also introduces a new section devoted to the financial assessment of the nuclear sector and a selection of key companies.

11 - Hojun Hwang, "Korea's first nuclear power reactor turned off for good", *Arirang*, 20 June 2017, see http://www.arirang.co.kr/News/News_View.asp?nseq=205377, accessed 22 June 2017.

12 - This was witnessed by convening lead author Mycle Schneider during a one-and-a-half-hour one-to-one meeting in 2015 in Seoul, when Moon was a Member of Parliament. See http://blog.naver.com/moonjaein2/220180179357, accessed 7 September 2017.

13 - Brad Plumer, "The U.S. Backs Off Nuclear Power. Georgia Wants to Keep Building Reactors.", *The New York Times*, 31 August 2017, see https://www.nytimes.com/2017/08/31/business/georgia-vogtle-nuclear-reactors.html, accessed 7 September 2017.

GENERAL OVERVIEW WORLDWIDE

THE ROLE OF NUCLEAR POWER

As of the middle of 2017, 31 countries were operating nuclear power reactors, which generated 2,476 net terawatt-hours (TWh or billion kilowatt-hours) of electricity in 2016[14], a 1.4 percent increase, but still less than in 2000, and 6.9 percent below the historic peak nuclear generation in 2006 (see Figure 1). Without China—which increased nuclear output by 36.6 TWh (+23 percent), more than the worldwide increase of 35 TWh—global nuclear power generation would have slightly decreased in 2016. A similar result as in 2015.

However, nuclear electricity generation worldwide, after dropping by 264 TWh (10 percent) following the 3/11 in Fukushima, Japan, has increased moderately but continuously and added 130 TWh since 2012. In other words, in the five years after the disaster, nuclear generation recovered only about half of the lost production.

Nuclear energy's share of global commercial gross electricity generation remained roughly stable over the past four years[15], but declined from a peak of 17.6 percent in 1996 to 10.5 percent in 2016.[16] With electricity generation worldwide increasing slightly faster (+8.9 percent since 2012) than the increase in nuclear generation (+5.5 percent since 2012), nuclear has been losing roughly 0.3 percentage points in the nuclear share since 2012. However, whether this is statistically significant is debatable.

In 2016, nuclear generation increased in 15 countries, declined in 12, and remained stable in four.[17] Seven countries (China, Hungary, India, Iran, Pakistan, Russia, South Africa) achieved their greatest nuclear production in 2016, of these, China, India, Pakistan and Russia connected new reactors to the grid. China started up five units, half of the world's total. Besides China, five other countries increased their output by more than 20 percent in 2016 (see country-specific sections for details):

- Belgium increased generation by two thirds after the restart of three reactors that had been down for extended periods due to technical and legal issues;
- Iran boosted output by 85 percent after the load factor of its single reactor almost doubled;
- Japan quadrupled nuclear generation, after the restart of two reactors halted post-3/11 bringing the total to five units;
- Pakistan increased production by 26 percent, in part by adding a new reactor.
- South Africa augmented generation of its two units by close to 39 percent after technical issues had seriously impacted output in 2015.

14 - If not otherwise noted, all nuclear capacity and electricity generation figures based on International Atomic Energy Agency (IAEA), Power Reactor Information System (PRIS) online database, see https://www.iaea.org/pris/. Production figures are net of the plant's own consumption unless otherwise noted.

15 - In 2015, as in previous years, BP applied minor corrections to the 2014 figure, from 10.78 to 10.64 percent. These differences are no doubt within statistical uncertainties.

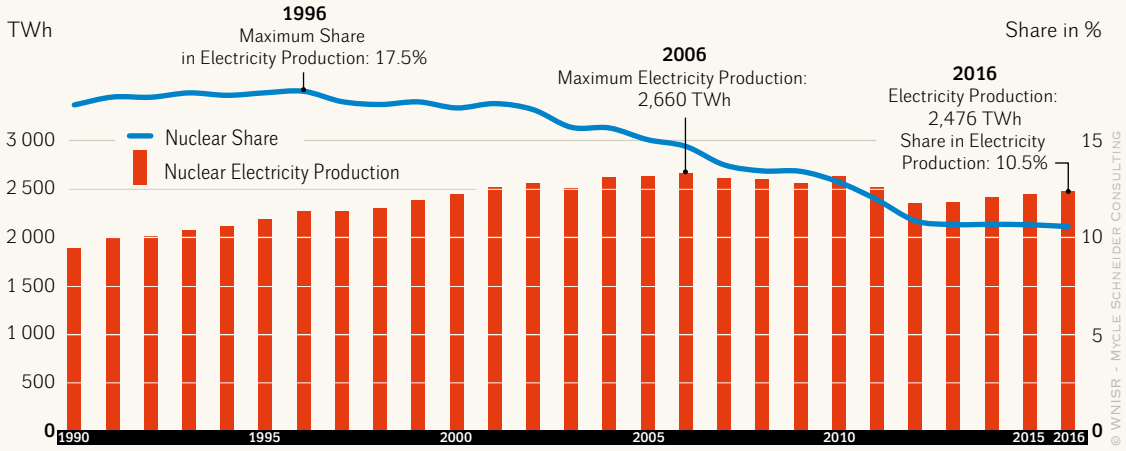
16 - BP, "Statistical Review of World Energy", June 2017, see www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf, accessed 1 July 2016.

17 - Less than 1 percentage point variation from the previous year.

In relative terms, only small programs registered generation drops beyond 10 percent: Armenia (–15 percent), Czech Republic (–10 percent) and Taiwan (–13 percent). However, some countries with larger nuclear programs dropped generation by almost 8 percent, as there were France, Germany and Ukraine. France's significant decline (–32.6 TWh) due to a series of quality-control issues and two reactors down for the entire year almost equivalent to the entire Chinese increase (+36.6 TWh).

Figure 1 | Nuclear Electricity Generation in the World

Nuclear Electricity Production in the World 1990-2016
in TWh (net) and Share in Electricity Generation (gross)



Sources: IAEA-PRIS, BP, 2017[18]

Similar to previous years, in 2016, the "big five" nuclear generating countries—by rank, the United States, France, China, Russia and South Korea—generated 70 percent of all nuclear electricity in the world (see Figure 2, left side). China surpassed Russia and moved one place up. In 2002, China held position 15, in 2007 it was tenth, before reaching third place in 2016.

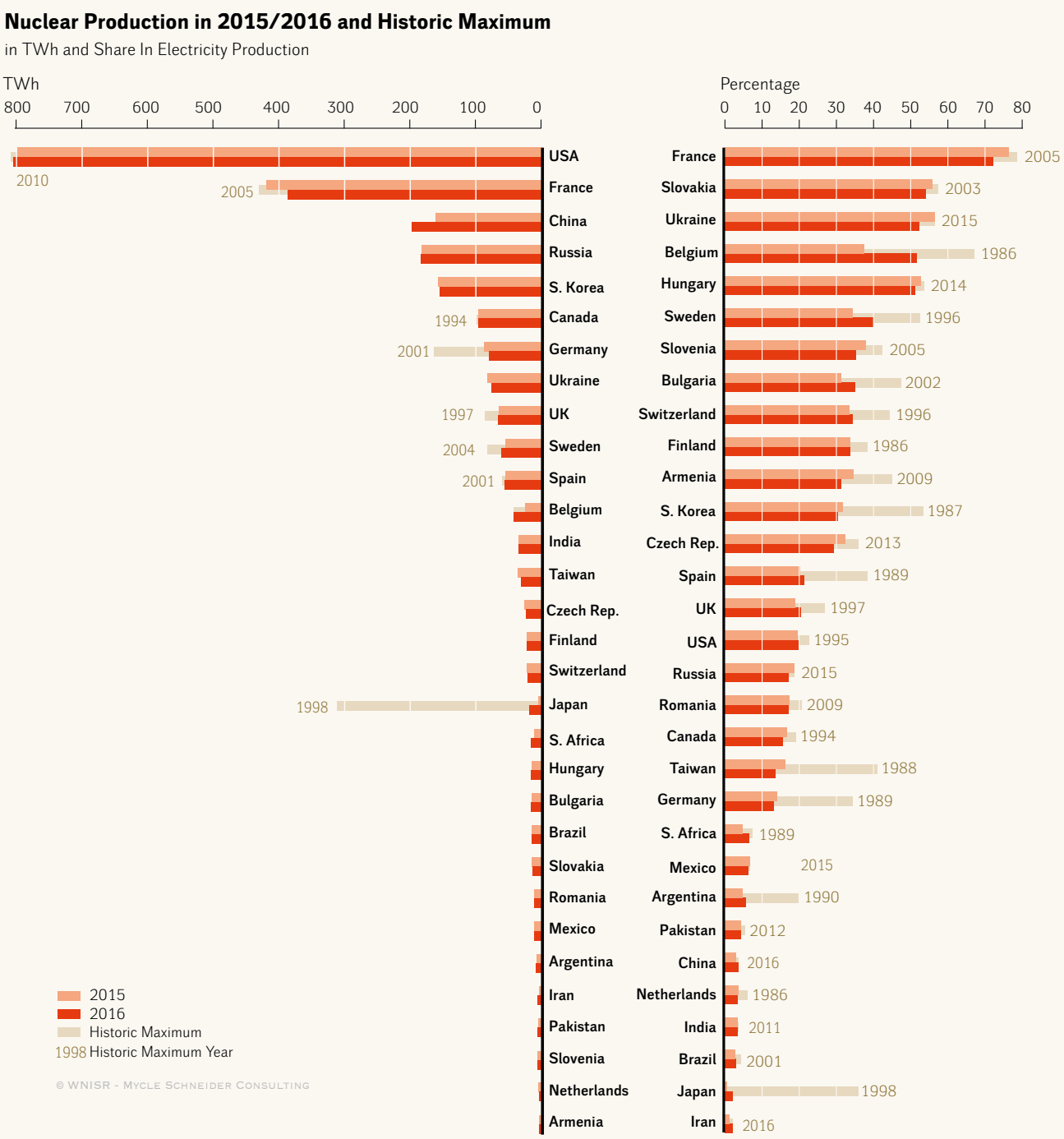
Just two countries, the U.S. and France, accounted for 48 percent of global nuclear production in 2016.

Seven countries' nuclear power generation peaked in the 1990s, among them Belgium, Canada, Japan, and the U.K. A further eleven countries' nuclear generation peaked between 2001 and 2010 including France, Germany, Spain, and Sweden. Fourteen countries generated their maximum amount of nuclear power in the past six years, half of which peaked in 2016 alone: China, India, Pakistan, Russia, Hungary, Iran, and South Africa; while the first four added new reactors, the remaining three boosted output by uprating (Hungary, South Africa) or by successfully overcoming technical issues during startup (Iran).

In most cases, even where nuclear power generation augmented, the development is not keeping pace with overall increases in electricity production, leading to a nuclear share below the respective historic maximum (see Figure 2, right side). In 2016, there were 15 countries that maintained their nuclear share at a constant level (change of less than 1 percentage-point), 10 decreased the relative share and six increased their nuclear portion.

18 - BP, "Statistical Review of World Energy", 2017.

Figure 2 | Nuclear Electricity Generation and Share in Global Power Generation



Source: IAEA-PRIS, 2017

There were two exceptions in 2016 that peaked their respective nuclear share in power generation:

- Starting up five new reactors throughout the year, China increased the 2015 maximum of 3.0 percent, to reach a 3.6 percent nuclear share. The 0.6 percentage-point increase was achieved with a 23 percent higher nuclear power output.

→ Iran's only commercial reactor started up in 2011 after 33 years of construction but it took another five years to reach a reasonable grid-connection time and load factor in 2016. As a consequence, the nuclear share increased from 1.3 percent to 2.1 percent.

OPERATION, POWER GENERATION, AGE DISTRIBUTION

Since the first nuclear power reactor was connected to the Soviet power grid at Obninsk on 27 June 1954, there have been two major waves of startups. The first peaked in 1974, with 26 grid connections in that year. The second reached a historic maximum in 1984 and 1985, just before the Chernobyl accident, reaching 33 grid connections in each year. By the end of the 1980s, the uninterrupted net increase of operating units had ceased, and in 1990 for the first time the number of reactor shutdowns outweighed the number of startups. The 1991–2000 decade showed far more startups than shutdowns (52/30), while in the decade 2001–2010, startups did not match shutdowns (32/35). Furthermore, after 2000, it took a whole decade to connect as many units as in a single year in the middle of the 1980s. Between 2011 and mid-2017, the startup of 41 reactors—of which 24 in China alone—narrowly outpaced the closure of 38 units over the same period. (See Figure 3).

In 2016—just as in 2015—ten reactors started up, more than in any previous year since 1990. However, this is again the result of the "China Effect", as the country contributed five out of the ten reactor startups (see Figure 4), while one each was commissioned in India (Kudankulam-2), Pakistan (Chasnupp-3), Russia (Novovoronezh-2-1), South Korea (Shin-Kori-3) and the U.S. (Watts Bar-2, after 43 years of construction).

Two reactors were closed in 2016, Novovoronezh-3 in Russia and Fort Calhoun-1 in the U.S.[19]

In the first half of 2017, two reactors started up in the world, one each in China (Yangjiang) and Pakistan (Chasnupp-4, built by a Chinese company), while two were shut down, the oldest units respectively in South Korea (Kori-1, after 40 years of operation) and in Sweden (Oskarshamn-1, after almost 46 years of operation).

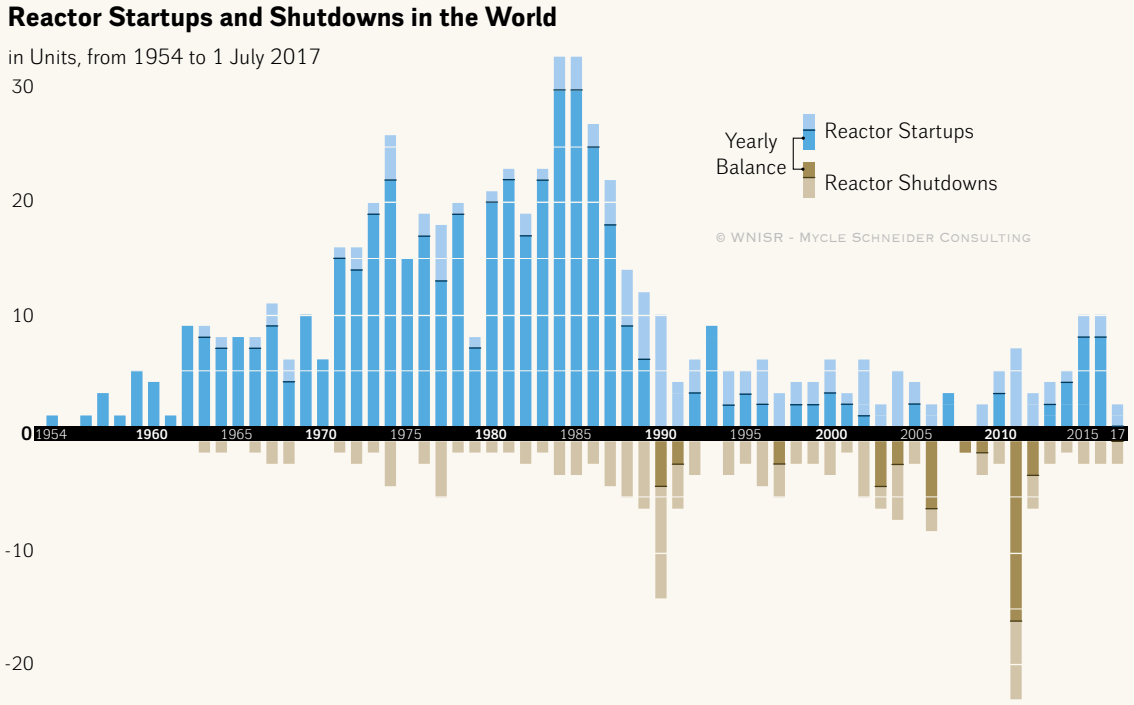
All 41 reactors, except for three that were commissioned since 2011 are in Asia (China, India, Pakistan, South Korea) or Eastern Europe (Russia). China started up 24 units followed by South Korea and Russia (four each), India and Pakistan (three each). Argentina, Iran and USA started one reactor each.

The IAEA continues to count 42 units in Japan in its total number of 446 reactors "in operation" in the world[20]; yet no nuclear electricity has been generated in Japan between September 2013 and August 2015, and as of 1 July 2017, only five reactors (Sendai-1 and -2, Takahama-3 and -4, Ikata-3) are operating (see Japan Focus for details).

19 - The International Atomic Energy Agency (IAEA), in its online database Power Reactor Information System (PRIS), in addition to the closures in Russia and the U.S., states that there was one shutdown in Japan (Ikata-1) and one in Sweden (Oskarshamn-2) in 2016. As WNISR (World Nuclear Industry Status Report) considers shutdowns from the moment of grid disconnection—and not from the moment of the industrial, political or economic decision—and as the units have not generated power for several years, in WNISR statistics, they are closed in the year of the latest power generation. Ikata-1 had not produced any electricity since 2011, Oskarshamn-2 was taken off the grid in 2013.

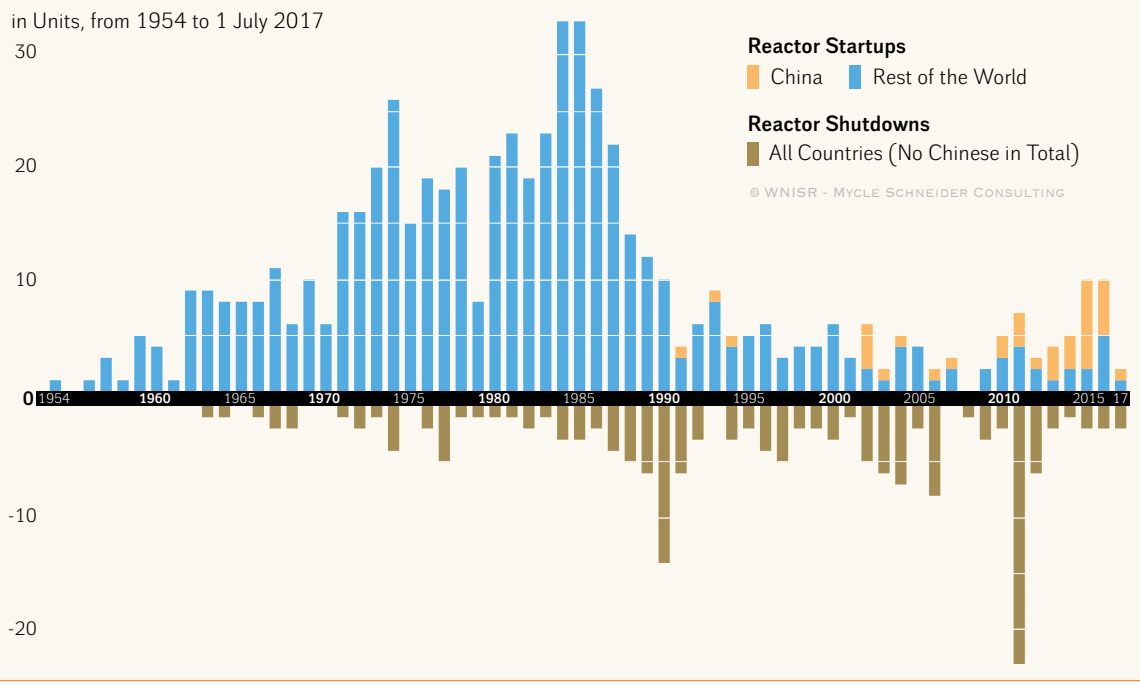
20 - IAEA, "Power Reactor Information System", see http://www.iaea.org/pris/, accessed 13 August 2017.

Figure 3 | Nuclear Power Reactor Grid Connections and Shutdowns



Sources: WNISR, with IAEA-PRIS, 2017

Figure 4 | Nuclear Power Reactor Grid Connections and Shutdowns - The China Effect



Sources: WNISR, with IAEA-PRIS, 2017

The unique situation in Japan needs to be reflected in world nuclear statistics. The attitude taken by the IAEA, the Japanese government, utilities, industry and many research bodies as well as other governments and organizations, to continue considering the entire stranded reactor fleet in the country, 10 percent of the world total, as "in operation" or "operational" remains a misleading distortion of facts. Steve Kidd, long-time industry strategist, agreed in a World Nuclear Industry Status Report 2016 (WNISR2016) review in *Nuclear Engineering International*:

> Including reactors as "operable" along with those definitely in service, when they have not generated power for many years (and don't even have a licence to do so) is clearly ridiculous.[21]

Maybe as a result of such criticism, the World Nuclear Association (WNA), in its second "World Nuclear Performance Report", has distinguished between "generating" and "not generating" nuclear generating capacity. The World Nuclear Performance Report was launched by WNA in 2016, "perhaps as a reaction to the success of successive WNISRs".[22]

The IAEA actually does have a reactor-status category called "Long-term Shutdown" or LTS.[23] Under the IAEA's definition, a reactor is considered in LTS if it has been shut down for an "extended period (usually more than one year)", and in early period of shutdown either restart is not being "aggressively pursued" or "no firm restart date or recovery schedule has been established".

The IAEA criteria are vague and hence subject to arbitrary interpretation. What exactly are *extended* periods? What is *aggressively* pursuing? What is a *firm* restart date or recovery schedule? Faced with this dilemma, the WNISR team in 2014 decided to create a new category with a simple definition, based on empirical fact, without room for speculation: "Long-term Outage" or LTO. Its definition:

> A nuclear reactor is considered in Long-term Outage or LTO if it has not generated any electricity in the previous calendar year and in the first half of the current calendar year. It is withdrawn from operational status retroactively from the day it has been disconnected from the grid.

When subsequently the decision is taken to permanently close a reactor, the shutdown status starts with the day of the last electricity generation, and the WNISR statistics are modified retroactively accordingly.

Tatsujiro Suzuki, former Vice-Chairman of the Japan Atomic Energy Commission (JAEC) has called the establishment of the LTO category an "important innovation" with a "very clear and empirical definition".[24]

21 - *NEI*, "Nuclear power in the world – pessimism or optimism?", 13 October 2016, see http://www.neimagazine.com/opinion/opinionnuclear-power-in-the-world-pessimism-or-optimism-5031270/, accessed 13 August 2017.

22 - Ibidem. In fact, in its September 2015 "Update for Members", WNA reported that its Fuel Report Working Group "discussed the merits of producing an annual nuclear capacity scenario update. Such an update would be a useful communications tool and a counter to the industry-critical World Nuclear Industry Status Report".

23 - See IAEA Glossary, at www.iaea.org/pris/Glossary.aspx, accessed 1 July 2016.

24 - Tatsujiro Suzuki, "Foreword", *WNISR2014*, 18 August 2014, see http://www.worldnuclearreport.org/WNISR2014.html - _Toc268768687, accessed 1 July 2017.

Applying this definition to the world nuclear reactor fleet, as of 1 July 2017, leads to considering 33 Japanese units in LTO. WNISR considers all ten Fukushima reactors shut down permanently—while the operator Tokyo Electric Power Company (TEPCO) has written off the six Daiichi units, it keeps the four Daini reactors in the list of operational facilities. Annex 2 provides a detailed overview of the status of the Japanese reactor fleet. In addition, the IAEA still classifies as LTS the fast breeder reactor Monju,[25] although it has been officially closed in November 2016. It was thus moved from the WNISR's LTO category to shutdown.

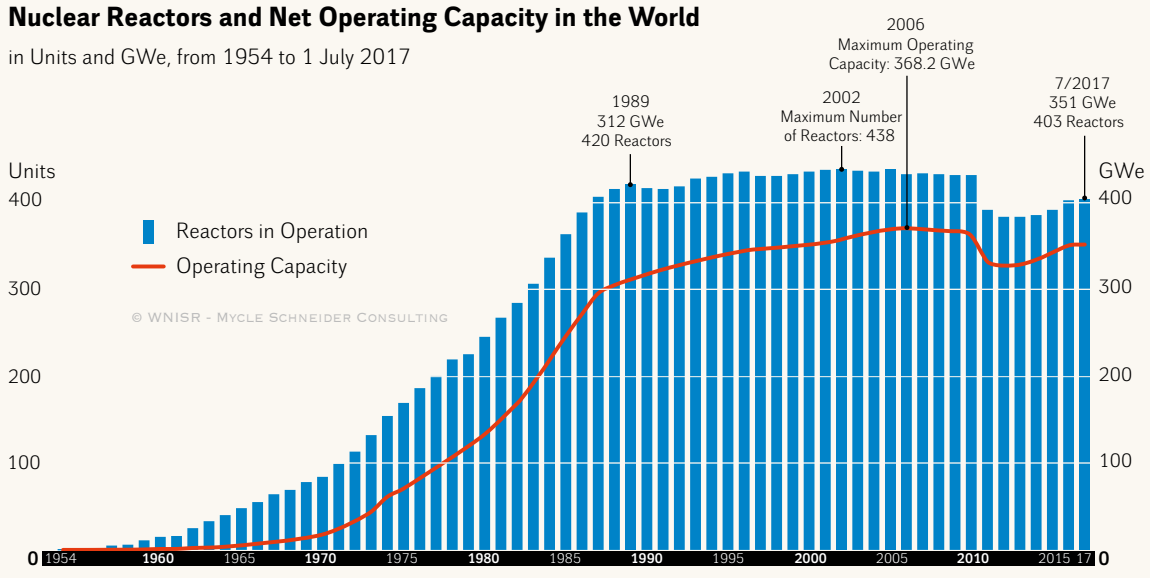
Besides the 33 Japanese reactors, two French reactors (Bugey-5 and Paluel-2) and one each in Argentina (Embalse), India (Kakrapar-2), Switzerland (Beznau-1), and Taiwan (Chinshan-1) met the LTO criterion. The total number of nuclear reactors in LTO as of 1 July 2017 is therefore 39[26]; yet all are considered by the IAEA as "in operation".

As of 1 July 2017, a total of 403 nuclear reactors are operating in 31 countries, up just one unit from the situation in July 2016.

The current world fleet has a total nominal electric net capacity of 351 gigawatts (GW or thousand megawatts), up by 3 GW (+0.9 percent) from one year earlier (see Figure 5).

For many years, the net installed capacity has continued to increase more than the net increase of numbers of operating reactors. This is a result of the combined effects of larger units replacing smaller ones and, mainly, technical alterations at existing plants, a process known as upra-

Figure 5 | World Nuclear Reactor Fleet, 1954–2017



Sources: WNISR, with IAEA-PRIS, 2017

25 - The IAEA also considers the Spanish reactor Garoña in LTS, while WNISR considers it shut down permanently.

26 - This number does not include the China Experimental Fast Reactor (CEFR), a 20 MWe research reactor that was connected to the grid in 2011 for only 20 hours, according to IAEA-PRIS. However, other sources indicate it has been operating intermittendly. In the absence of any precise information as to the power generation of CEFR, we have considered the reactor as operating, even though it might fulfill the LTO criteria.

ting.[27] In the United States alone, the Nuclear Regulatory Commission (NRC) has approved 156 uprates since 1977. The cumulative approved uprates in the United States total 7.365 GW.[28]

A similar trend of uprates and major overhauls in view of lifetime extensions of existing reactors has been seen in Europe. The main incentive for lifetime extensions is their considerable economic advantage over new-build, however, this advantage is diminishing. In Sweden, for example, uprating work was halted midway at Oskarshamn-2, when it turned out that the option was not economically viable, and the unit was closed for good.

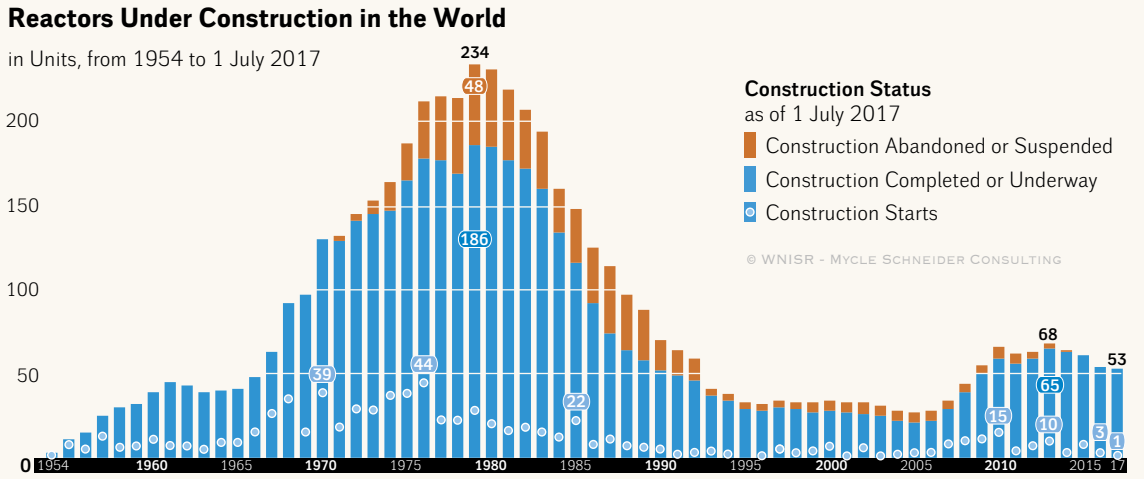
The use of nuclear energy remains limited to a small number of countries, with only 31 countries, or 16 percent of the 193 members of the United Nations, operating nuclear power plants. Close to half of the world's nuclear power countries are located in the European Union (EU), and, in 2016, they accounted for 32 percent (down 1.2 percentage points) of the world's gross nuclear production, with half that EU generation in France.

OVERVIEW OF CURRENT NEW BUILD

As of 1 July 2017, 53 reactors are considered here as under construction[29], five fewer than WNISR reported a year ago, and 14 less than in mid-2014. Almost 80 percent of all new-build units (42) are in Asia and Eastern Europe, of which 20 in China alone (see Figure 6 and Table 1).

Three building projects were launched in 2016, two of which in China, and one in Pakistan (by a Chinese builder). One new construction got underway in India in the first half of 2017.

Figure 6 | Nuclear Reactors Under Construction



Sources: WNISR, with IAEA-PRIS, 2017

27 - Increasing the capacity of nuclear reactors by equipment upgrades e.g. more powerful steam generators or turbines.

28 - U.S. Nuclear Regulatory Commission (NRC), "Approved Applications for Power Uprates", Updated 19 May 2017, see http://www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications.html, accessed 10 June 2017.

29 - Construction of the V.C. Summer project with two AP1000 reactors has been abandoned at the end of July 2017.

WNISR2017 applies two changes over the previous edition. One unit each in Japan (Ohma) and in Brazil (Angra-3) have been taken off the list of reactors "under construction" (see discussion in respective country sections).

The number of active building sites has been shrinking from 68 in 2013 to 53 in mid-2017. This is relatively small compared to a peak of 234 units—totaling more than 200 GW—in 1979. However, many of those projects (48) were never finished (see Figure 6). The year 2005, with 26 units under construction, marked a record low since the early nuclear age in the 1950s. Compared to the situation described a year ago, the total capacity of units now under construction in the world dropped again, by 4.3 GW to 52.3 GW, with an average unit size of 987 MW (see Annex 7 for details).

Table 1 | Nuclear Reactors "Under Construction" (as of 1 July 2017) [30]

Country	Units	Capacity (MW net)	Construction Starts	Scheduled Grid Connection	Behind Schedule
China	20	20 500	2009 - 2016	2017 - 2021	11
Russia	6	4 359	1983 - 2010	2017 - 2019	6
India	6	3 907	2004 - 2017	2018 - 2023	5
UAE	4	5 380	2012 - 2015	2018 - 2020	1
USA	4[a]	4 468	2013	2019 - 2020	4
South Korea	3	4 020	2009 - 2013	2018 - 2019	3
Belarus	2	2 218	2013 - 2014	2019 - 2020	1
Pakistan	2	2 028	2015 - 2016	2021 - 2022	?
Slovakia	2	880	1985	2018 - 2019	2
Finland	1	1 600	2005	2018	1
France	1	1 600	2007	2019	1
Japan	1	1 325	2007	?	1
Argentina	1	25	2014	2019	1
WORLD	**53**[b]	**52 310**	**1983 - 2017**	**2017 - 2023**	**37**

Sources: WNISR, with IAEA-PRIS and WNA, 2017

a - Construction of the V.C. Summer project with two AP1000 reactors with 1117 MW net design capacity has been abandoned at the end of July 2017.

b - A total of 50, as of mid-August 2017, after the abandonment of the V.C. Summer project in the U.S, and grid-connection of Fuqing-4 (China) on 29 July 2017.

30 - For further details, see Annex 7.

CONSTRUCTION TIMES

CONSTRUCTION TIMES OF REACTORS CURRENTLY UNDER CONSTRUCTION

A closer look at projects currently listed as "under construction" illustrates the level of uncertainty and problems associated with many of these projects, especially given that most constructors assume a five-year construction period:

- As of 1 July 2017, the 53 reactors being built have been under construction for an average of 6.8 years, many of which are still far from completion.
- All reactors under construction in 8 out of 13 countries have experienced mostly year-long delays. Over two-thirds (37) of all building projects are delayed. Most of the 16 remaining units under construction in the world, of which nine are in China, were begun within the past three years or have not yet reached projected start-up dates, making it difficult to assess, whether or not they are on schedule. Particular uncertainty remains over two Pakistani construction sites.
- Of the 37 reactors behind schedule, 19 have reported increased delays over the past year since WNISR2016.
- Three projects have been listed as "under construction" for more than 30 years, Mochovce-3 and -4 in Slovakia, and Rostov-4 in Russia.
- Two reactors have been listed as "under construction" for a decade or more, the Prototype Fast Breeder Reactor (PFBR) in India, and the Olkiluoto-3 reactor project in Finland. While Shimane-3 in Japan and French Flamanville-3 unit will reach 10 years of construction in October and December 2017 respectively.
- WNISR2016 noted a total of 17 reactors scheduled for startup in 2017. As of mid-2017, only two reactors were connected to the grid and 11 have already been officially delayed until at least 2018.

It should be stressed that the actual lead time for nuclear plant projects includes not only the construction itself but also lengthy licensing procedures in most countries, complex financing negotiations, site preparation and other infrastructure development.

CONSTRUCTION TIMES OF PAST AND CURRENTLY OPERATING REACTORS

There has been a clear global trend towards increasing construction times. National building programs were faster in the early years of nuclear power. As Figure 7 illustrates, construction times of reactors completed in the 1970s and 1980s were quite homogenous, while in the past two decades they have varied widely (see Table 2).

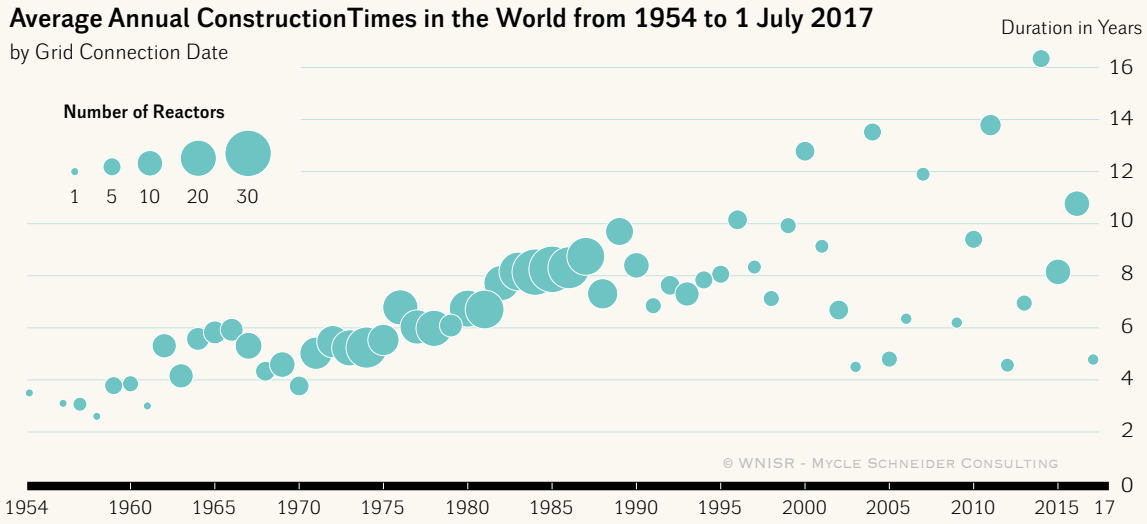
Average construction time of the 10 units that started up in 2016—five Chinese, one each in India, Pakistan (built by a Chinese company), Russia, South Korea and the U.S. —was 10.6 years (7.1 years, when not counting the veteran Watts-Bar-2), while it took an average of 4.8 years to connect two units—one Chinese and one Pakistani (by a Chinese company)—to the grid in the first half of 2017.

Table 2 | Reactor Construction Times 2007–2017

Construction Times of 51 Units started-up 2007–7/2017				
Country	Units	Construction Time (in Years)		
		Mean Time	Minimum	Maximum
China	27	6.0	4.1	11.2
India	6	9.0	5.0	14.2
South Korea	5	5.3	4.1	7.2
Russia	5	24.6	8.1	32.0
Pakistan	3	5.4	5.2	5.5
Argentina	1	33.0		
Iran	1	36.3		
Japan	1	5.1		
Romania	1	24.1		
USA	1	43.5		
WORLD	**51**	**10.1**	**4.1**	**43.5**

Sources: WNISR, with IAEA-PRIS, 2017

Figure 7 | Average Annual Construction Times in the World



Sources: WNISR, with IAEA-PRIS, 2017

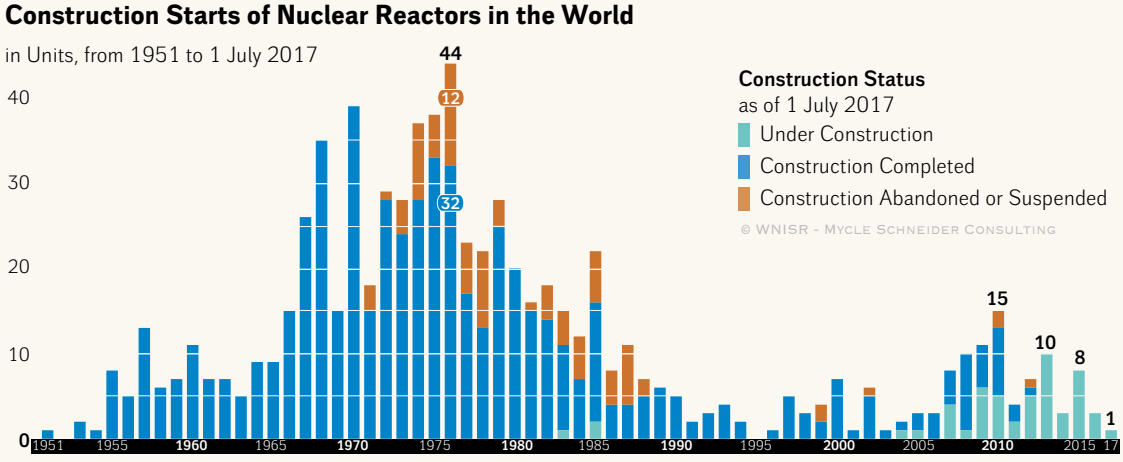
CONSTRUCTION STARTS AND CANCELLATIONS

The number of annual construction starts[31] in the world peaked in 1976 at 44, of which 12 projects were later abandoned. In 2010, there were 15 construction starts—including 10 in China alone—the highest level since 1985 (see Figure 8). That number dropped to 10 in 2013, eight in 2015, three in 2016 and one in 2017 as of mid-year.

Seriously affected by the Fukushima events, China did not start any new building site in 2011 and 2014. While utilities began constructing six more units in 2015, the number shrank to two in 2016, and none in 2017 as of mid-year (see Figure 9).

Over the decade 2007–2016, construction began on 79 reactors (of which three have been cancelled, not including V.C. Summer), that is more than twice as many as in the decade 1997–2006, when work started on 35 units (of which three have been abandoned). However, more than half (42) of these units are in China alone, and even the increased order rate remains much too low to make up for upcoming reactor closures.

Figure 8 | Construction Starts in the World



Sources: WNISR, with IAEA-PRIS, 2017

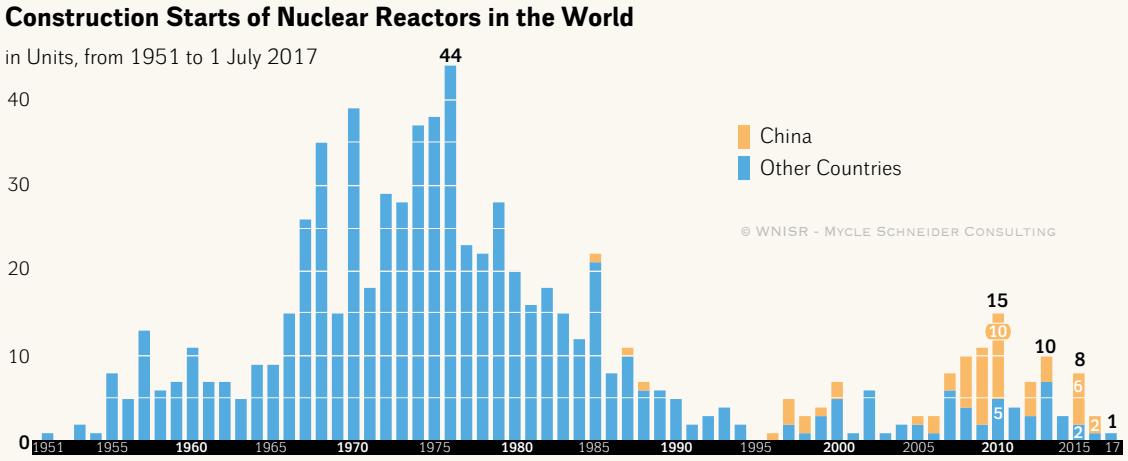
In addition, past experience shows that simply having an order for a reactor, or even having a nuclear plant at an advanced stage of construction, is no guarantee of ultimate grid connection and power production. The abandonment of the two V.C. Summer units at the end of July 2017 after four years of construction and a multi-billion-dollar investment is only the latest example in a long list of failed nuclear power plant projects.

French Atomic Energy Commission (CEA) statistics through 2002 indicate 253 "cancelled orders" in 31 countries, many of them at an advanced construction stage (see also Figure 10). The United States alone accounted for 138 of these order cancellations.[32]

31 - Generally, a reactor is considered under construction, when the base slab of the reactor building is being concreted. Site preparation work, excavation and other infrastructure developments are not included.

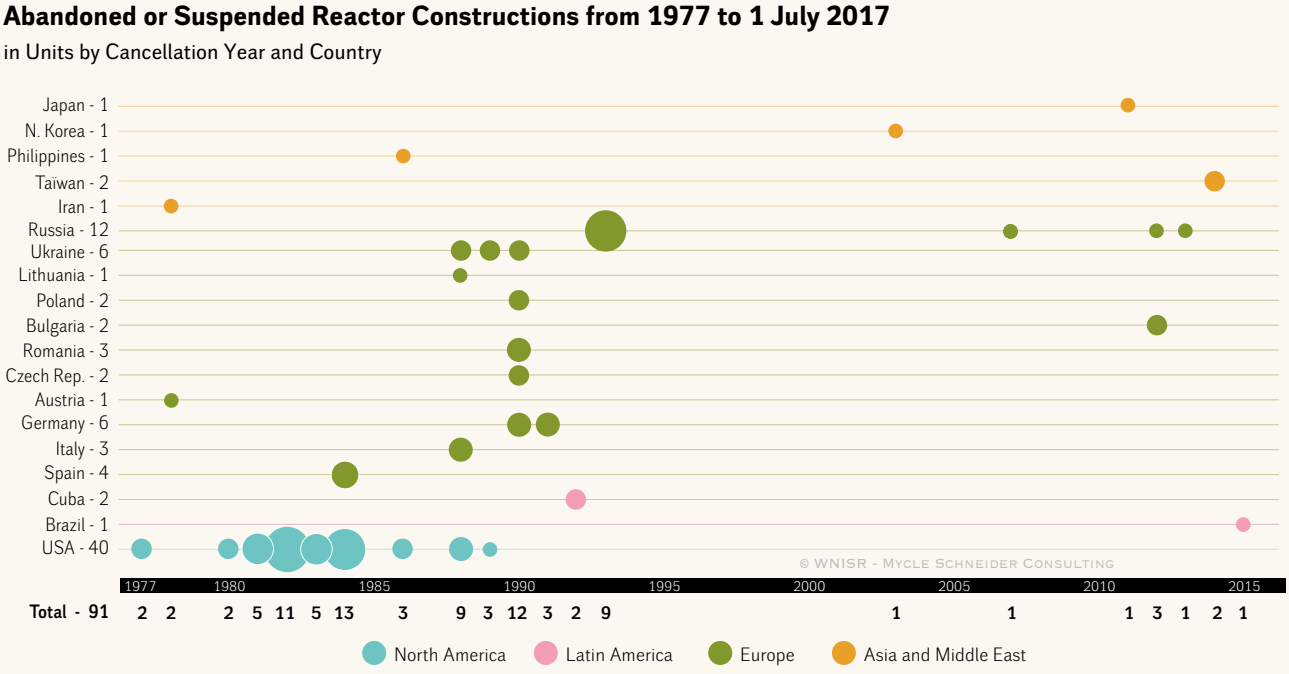
32 - French Atomic Energy Commission (CEA), "Elecnuc—Nuclear Power Plants in the World", 2002. The section "cancelled orders" has disappeared after the 2002 edition.

Figure 9 | Construction Starts in the World - China



Sources: WNISR, with IAEA-PRIS, 2017

Figure 10 | Cancelled or Suspended Reactor Constructions



Note: This graph only includes constructions that had already started.

Sources: WNISR, with IAEA-PRIS, 2017

Of the 755 reactor constructions launched since 1951, at least 91 units (12 percent) in 19 countries had been abandoned as of 1 July 2017, of which 87, according to the IAEA, between 1977 and 2012—no earlier or later IAEA data available—at various stages after they had reached construction status. In addition, in late July 2017, the construction of two reactors was halted at the V.C. Summer site in the U.S.

Three-quarters (70) of the cancellations happened during a 12-year period between 1982 and 1993, 11 were decided prior to this period, and only 10 over the 23-year period between 1993 and 2015.

Close to three quarters (64 units) of all cancelled projects were in four countries alone—the U.S. (40, not including V.C. Summer), Russia (12), Germany and Ukraine (six each). Some units were actually 100 percent completed—including Kalkar in Germany and Zwentendorf in Austria—before the decision was taken not to operate them.

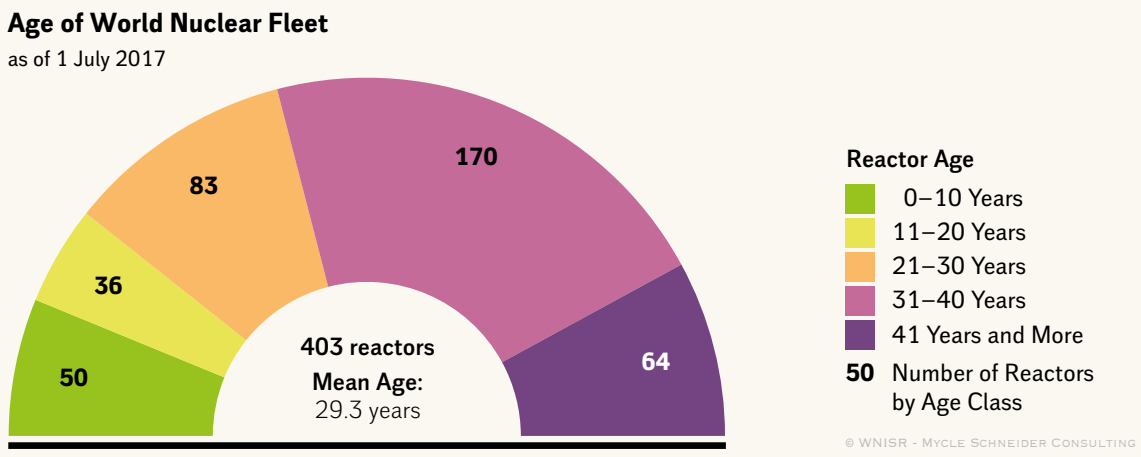
There is no thorough analysis of the cumulated economic loss of these failed investments.

Juragua site in Cuba, where building of two Russian-designed 413 MWe reactors started in 1983 and was abandoned in 1992. Photography by © Darmon Richter, August 2014, see http://www.thebohemianblog.com/2014/08/cuba-abandoned-unfinished-soviet-nuclear-power-station.html.

OPERATING AGE

In the absence of any significant new-build *and* grid connection over many years, the average age (from grid connection) of operating nuclear power plants has been increasing steadily and at mid-2017 stands at 29.3 years, up from 29.0 a year ago (see Figure 11).[33]

Figure 11 | Age Distribution of Operating Reactors in the World



Sources: WNISR, with IAEA-PRIS, 2017

Some nuclear utilities envisage average reactor lifetimes of beyond 40 years up to 60 and even 80 years. In the United States, reactors are initially licensed to operate for 40 years, but nuclear operators can request a license renewal for an additional 20 years from the Nuclear Regulatory Commission (NRC).

As of June 2017, 84 of the 99 operating U.S. units have received an extension, with another nine applications under NRC review. Since the World Nuclear Industry Status Report 2016 (WNISR2016), three license renewals (LaSalle-1 and -2, Fermi-2) have been granted and an additional one applied for (River Bend).[34]

In the U.S., only the latest of the 34 units that have been shut down had reached 40 years on the grid—Vermont Yankee, closed in December 2014, at the age of 42, and Fort Calhoun, shut down in October 2016, after 43 years of operation. Both had obtained licenses to operate up to 60 years but were closed mainly for economic reasons. In other words, at least a quarter of the reactors connected to the grid in the U.S. never reached their initial design lifetime of 40 years. On the other hand, of the 99 currently operating plants, 40 units have operated for 41 years and more; thus, almost half of the units with license renewals have already entered the life

33 - WNISR calculates reactor age from grid connection to final disconnection from the grid. In WNISR statistics, "startup" is synonymous with grid connection and "shutdown" with withdrawal from the grid. In previous editions of the WNISR, the reactor age was automatically rounded to the year. In order to have a better image of the fleet and ease calculations, the age of a reactor is considered to be 1 between the first and second grid connection anniversaries. For some calculations, we also use operating years: the reactor is in its first operating year until the first grid connection anniversary, when it enters the second operating year.

34 - NRC, "Status of License Renewal Applications and Industry Activities", Updated 27 June 2017, see http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 15 August 2017.

extension period, and that share is growing rapidly with the mid-2017 average age of the U.S. operational fleet exceeding 37 years (see United States Focus).

Many other countries have no specific time limits on operating licenses. In France, where the country's first operating Pressurized Water Reactor (PWR) started up in 1977, reactors must undergo in-depth inspection and testing every decade against reinforced safety requirements. The French reactors have operated for 32.4 years on average, and the oldest have completed the process with the French Nuclear Safety Authority (ASN) evaluating each reactor before allowing a unit to operate for more than 30 years. However, the assessments are years behind schedule. They could then operate until they reach 40 years, which is the limit of their initial design age. The French utility Électricité de France (EDF) plans to prioritize lifetime extension beyond 40 years over large-scale new-build. EDF's approach to lifetime extension is currently under review by ASN's Technical Support Organization, the Institute for Radiation Protection and Nuclear Safety (IRSN) and will be examined by its expert committees (Groupes Permanents) in early 2018. In addition, lifetime extension beyond 40 years requires site-specific public enquiries.

If ASN gave the go-ahead for all of the oldest units to operate for 40 years, 22 of the 58 French operating reactors would reach that age already by 2020.

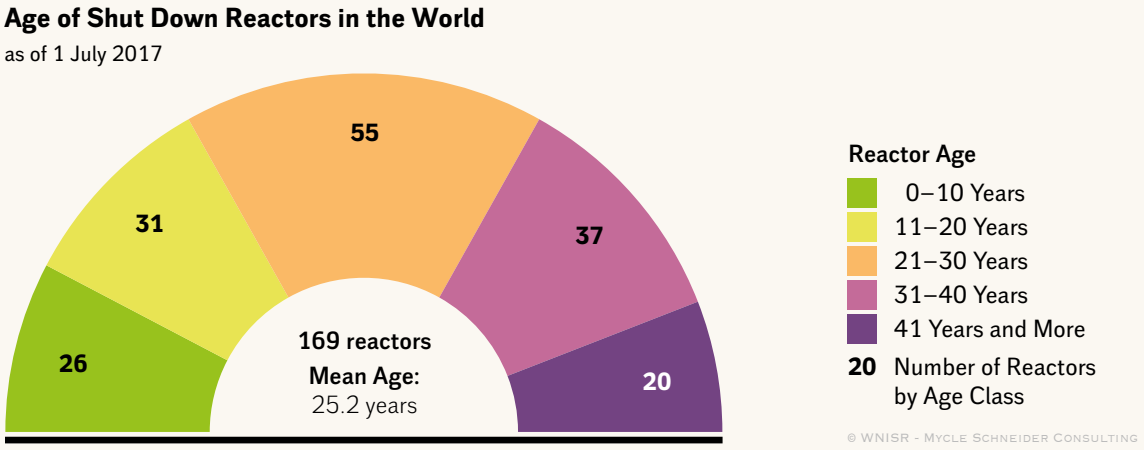
Current French energy legislation requires planning to limit the nuclear share in power production to 50 percent by 2025 (see France Focus). The implementation of this legislation, in a context of stagnating electricity consumption, would mean the closure of about one third of the French reactor fleet. In other words, many of the lifetime extensions would become obsolete. A particularly difficult aspect of the lifetime management in France is that the units licensed to use plutonium-uranium mixed oxide fuel (MOX) are precisely amongst the oldest reactors. The criteria for selection of reactors to be closed remain unclear.

In assessing the likelihood of reactors being able to operate for up to 60 years, it is useful to compare the age distribution of reactors that are currently operating with those that have already shut down (see Figure 11 and Figure 12). As of mid-2017, 64 of the world's reactors have operated for 41 years and more, and a total of 72 that have already passed their 40-year lifetime are considered in lifetime extension.[35] As the age pyramid illustrates, that number could rapidly increase over the next few years. A total of 234 units (58 percent) have already exceeded age 30.

The age structure of the 169 units already shut down completes the picture. In total, 57 of these units operated for 31 years and more, and of those, 22 reactors operated for 41 years and more (see Figure 12). Many units of the first generation designs only operated for a few years. Considering that the average age of the 169 units that have already shut down is about 25 years, plans to extend the operational lifetime of large numbers of units to 40 years and far beyond seemed rather optimistic. The operating time prior to shutdown has clearly increased continuously. But while the *average* annual age at shutdown got close to 40 years, it only passed that age twice so far: in 2014, when the only such unit shut down that year (Vermont Yankee in the U.S.) after 42 years of operation; and in 2016, with two reactors shutting down at age 43 (Fort Calhoun, U.S.) and 45 (Novovoronezh, Russia) respectively.

35 - WNISR considers the age starting with grid connection, and while figures used to be rounded by half-years, as of WNISR2016 they are rounded by the tenth of the year.

Figure 12 | Age Distribution of Shut Down Nuclear Power Reactors



Sources: WNISR, with IAEA-PRIS, 2017

As a result of the Fukushima nuclear disaster, more pressing questions have been raised about the wisdom of operating older reactors. The Fukushima Daiichi units (1 to 4) were connected to the grid between 1971 and 1974. The license for unit 1 had been extended for another 10 years in February 2011, a month before the catastrophe began. Four days after the accidents in Japan, the German government ordered the shutdown of seven reactors that had started up before 1981. These reactors, together with another unit that was closed at the time, never restarted. The sole selection criterion was operational age. Other countries did not adopt the same approach, but it is clear that the 3/11 events had an impact on previously assumed extended lifetimes in other countries as well, including in Belgium, Switzerland, and Taiwan. And more recently, in the first half of 2017, South Korea's incoming President Moon shut down the country's oldest reactor (Kori-1), explicitly at the age of forty, ruling out lifetime extensions in the future. Sweden also closed its oldest unit, Oskarshamn-1 at age 46.

LIFETIME PROJECTIONS

Many countries continue to implement or prepare for lifetime extensions. As in previous years, WNISR has therefore created two lifetime projections. A first scenario (40-Year Lifetime Projection, see Figure 13), assumes a general lifetime of 40 years for worldwide operating reactors (not including reactors in LTO, as they are not considered operating). The 40-year number corresponds to the design lifetimes of most operating reactors. Some countries have legislation (Belgium) or policy in place that limit operating lifetime to 40 years. The most recent, major policy shift was the decision by the incoming Moon administration in South Korea not to allow the extension of lifetimes of operating units.

For the 72 reactors that have passed the 40-year lifetime, we assume they will operate to the end of their licensed extended operating time.

A second scenario (Plant Life Extension or PLEX Projection, see Figure 14) takes into account all already-authorized lifetime extensions.

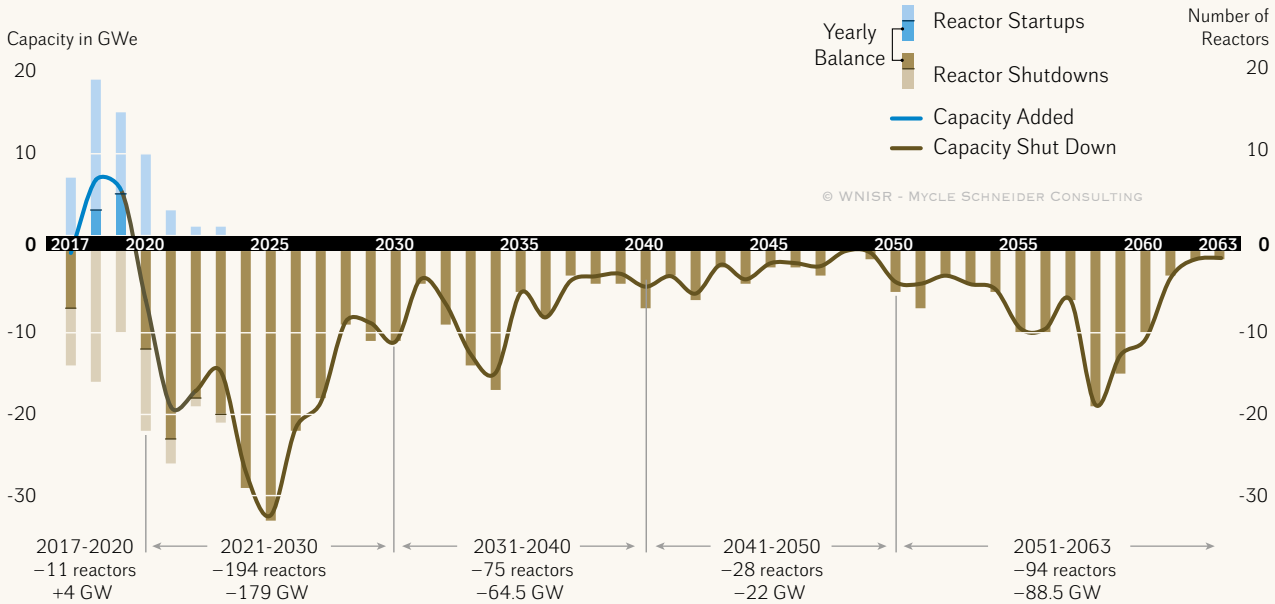
The lifetime projections allow for an evaluation of the number of plants and respective power generating capacity that would have to come on line over the next decades to offset closures and simply maintain the same number of operating plants and capacity. With all units under construction scheduled to have gone online, installed nuclear capacity would increase by 4 GW by 2020, which is marginal. However, in total, 11 additional reactors (compared to the end of 2016 status) would have to be started up prior to the end of 2020 in order to maintain the status quo of the number of operating units.

Figure 13 | The 40-Year Lifetime Projection

Projection 2017-2063 of Nuclear Reactors/Capacity in the World

General assumption of 40-year mean lifetime

Operating and Under Construction as of 1 July 2017, in GWe and Units



Sources: Various sources, compiled by WNISR, 2017

In the following decade to 2030, 194 additional new reactors (179 GW) would have to be connected to the grid to maintain the status quo, 3.8 times the rate achieved over the past decade (51 units between 2007 and mid-2017).

The achievement to return to the current situation by 2020 will exclusively depend on the number of Japanese reactors currently in LTO possibly coming back online, as it is technically impossible to start and complete construction of a new plant within three-and-a-half-year period.

As a result, the number of reactors in operation will stagnate at best but will more likely decline over the coming years unless lifetime extensions far beyond 40 years become widespread. With "poor economic prospects for new-build in the developed world and the financial problems of major suppliers such as Areva and Westinghouse", such generalized lifetime extensions are clearly the objective of the nuclear power industry—thus "defending the currently operating plants", as an industry strategist puts it.[36]

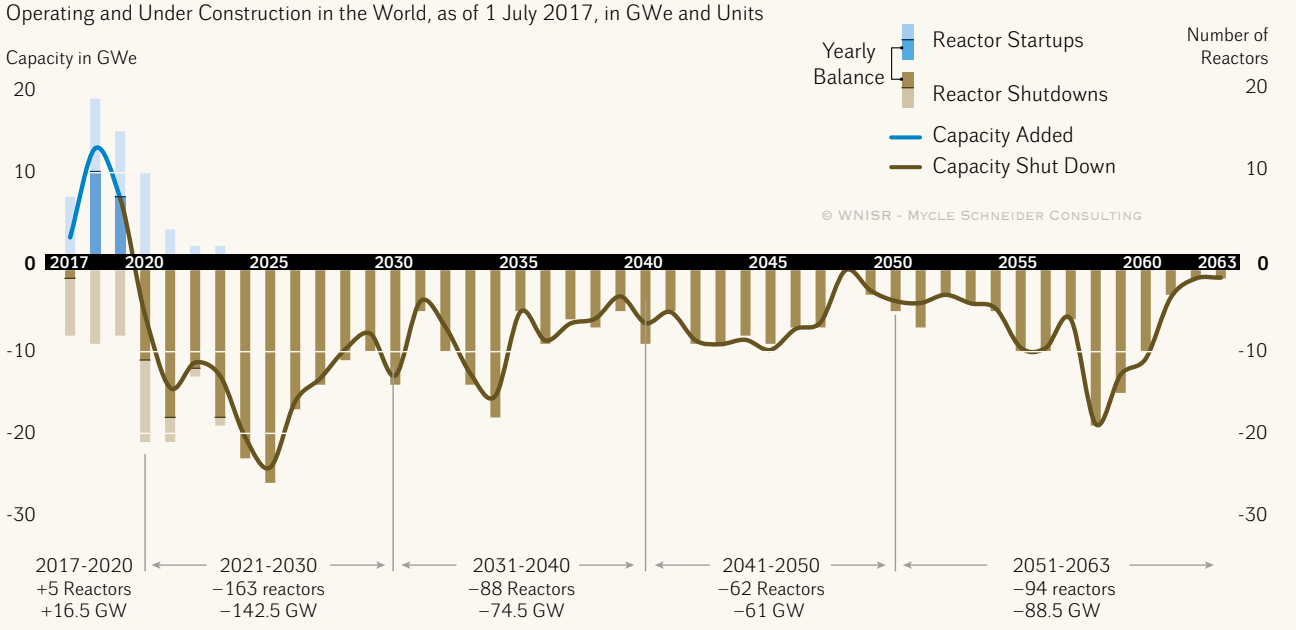
Indeed, the economic pressure has increased significantly over the past five years or so (see Nuclear Finances Chapter). Soaring maintenance and upgrading costs, as well as decreasing system costs of nuclear power's main competitors, create an economic environment with dropping wholesale electricity prices that leads to the situation of an increasing number of nuclear plants "at risk" of early closures.

Figure 14 | The PLEX Projection

Projection 2017-2063 of Nuclear Reactor Numbers/Capacity

General assumption of 40-year mean lifetime + Authorized lifetime extensions

Operating and Under Construction in the World, as of 1 July 2017, in GWe and Units



Sources: Various sources, compiled by WNISR, 2017

Developments in Asia, and particularly in China, do not fundamentally change the global picture. Reported figures for China's 2020 target for installed nuclear capacity have fluctuated

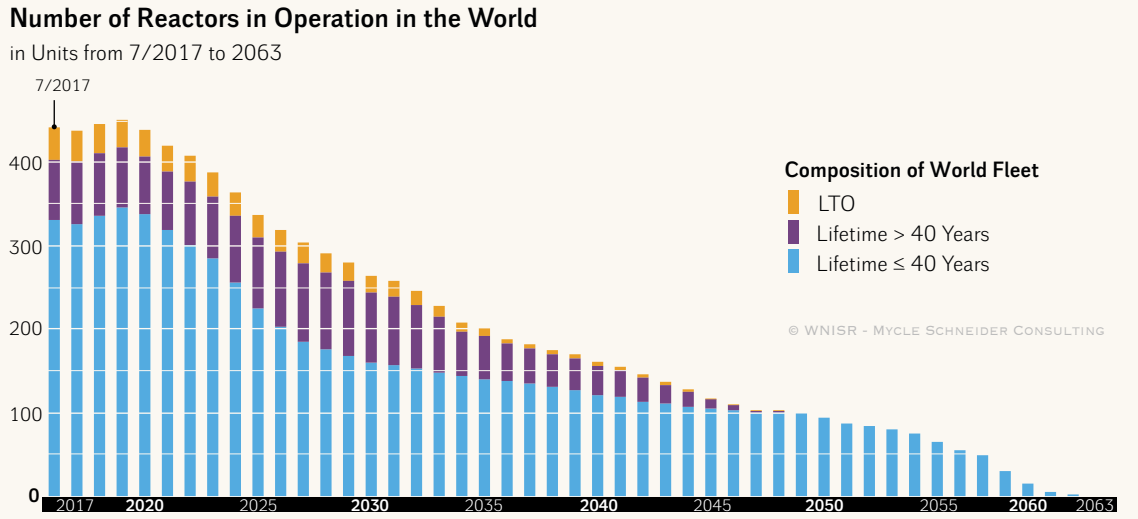
36 - Steve Kidd, "The era of nuclear power – can we prevent it coming to an end", 4 July 2017, *NEI*, see http://www.neimagazine.com/opinion/opiniontheera-of-nuclear-power-can-we-prevent-it-coming-to-an-end-5861158/, accessed 16 August 2017.

between 40 GW and 120 GW in the past. The freeze of construction initiation for almost two years and new siting authorizations for four years has significantly reduced Chinese ambitions. China will clearly miss the latest official target of 58 GW for 2020. And with only two construction starts in 2016 and none in 2017 as of mid-year, the outlook is not improving.

We have also modeled a scenario, in which all currently licensed lifetime extensions and license renewals (mainly in the United States) are maintained and all construction sites are completed. For all other units, we have maintained a 40-year lifetime projection, unless a firm earlier or later shutdown date has been announced. By 2020, the net number of operating reactors would have increased by only five and the installed capacity would grow by 16.5 GW. This modest outlook reflects the recent early closure announcements of units that, for economic reasons, will not operate up to the end of their licensed operational lifetime. A continuation of this trend can be expected over the coming years, especially with the confirmation by the incoming Macron Government in France of the legal 50 percent nuclear share target for 2025 in France.

In the following decade to 2030, still 163 new reactors (142.5 GW)—practically identical to the WNISR2016 projection—would have to start up to replace shutdowns. In other words, the overall pattern of decline would hardly be altered: it would merely be delayed by some years (see Figure 13, Figure 14 and the cumulated effect in Figure 15).

Figure 15 | Forty-Year Lifetime Projection versus PLEX Projection



Sources: Various sources, compiled by WNISR, 2017

FOCUS COUNTRIES

FRANCE FOCUS

Introduction

The French nuclear power house is shaking. For decades France has been considered as the show case for the international nuclear industry, with the largest nuclear share in its electricity mix, virtually unlimited government support and vast ambitions on the export market. Then France became the European exception. With the hope for a global "nuclear renaissance" vanishing and literally all of its continental neighbors—Belgium, Germany, Italy, Spain, Switzerland—abandoning the technology as a strategic option, France was the only European country to drive new-build projects, at home (Flamanville-3) and abroad (Olkiluoto-3 in Finland, Taishan in China, Hinkley Point C in the U.K.). All of these new-build projects are European Pressurized Water Reactors (EPRs), and all turned into industrial and economic nightmares. Olkiluoto-3 was supposed to start up in 2009, Flamanville-3 in 2012, Taishan-1 in 2013 and Hinkley Point C in 2017. The latest schedule has Olkiluoto-3 and Taishan-1 on for 2018, Flamanville-3 for 2019 and Hinkley Point C for 2025 at the very, very earliest.

> *"What happened at AREVA is strictly scandalous", Economy and Finances Minister Bruno Le Maire*

Delays cost money, as do over-optimistic commercial assumptions and the incapacity to correct a failing industrial strategy. The three costly items combined are at the core of the French situation. Builder and fuel company AREVA, the self-proclaimed "global leader in nuclear energy"[37] went technically bankrupt after cumulating over a six-year period the stunning loss of €10.5 billion (US$12.3 billion). EDF, with 58 reactors at home and 15 in the U.K., the largest nuclear operator in the world, carries the burden of a huge debt load of €37.4 billion (US$43.8 billion) with an impressive investment wall ahead: post-3/11 upgrades, decommissioning, waste management, ageing mitigation and life extension measures, workforce renewal, mandatory expenditures into renewables and energy efficiency.

In an unprecedented declaration during a hearing of the Finance Committee of the National Assembly incoming Economy and Finances Minister Bruno Le Maire stated: "What happened at AREVA is strictly scandalous", the company's liquidity needs "exceeding the total of the economies that the Minister of the public accounts must find to get us below the 3 percent" of budget deficit compared to Gross Domestic Product or GDP (EU-imposed limit). He added "such a poor management of public funds is absolutely unacceptable". The French State is expected to inject €4.5 billion (US$5.3 billion) into AREVA before the end of 2017. Concerning EDF, Le Maire said, he had "the occasion to pound the table concerning what is happening with Hinkley Point",[38] reference to the most recent cost overruns, and has asked for a detailed action plan to avoid further difficulties.

37 - AREVA, Homepage, see http://www.areva.com, accessed 25 May 2015.

38 - Bruno Le Maire citations from *Reuters*, "France–Bruno Le Maire stigmatise la gestion d'Areva", 12 July 2017, (in French), see http://fr.reuters.com/article/companyNews/idFRL8N1K338H, accessed 29 July 2017.

At the same time, the President Emmanuel Macron has confirmed that his new administration will implement the "Law Relative to the Energy Transition for Green Growth" inherited from the previous Hollande Administration and adopted by the National Assembly on 17 August 2015. The law—which effectively ends the nuclear program expansion that went on ever since the first power reactor started up in 1959—stipulates in particular the capping of the currently installed nuclear capacity of 63.2 GW and the reduction of the nuclear share in France's electricity generation mix from three-quarters to half.[39] However, while an unprecedented five of the seven major presidential candidates favored some kind of nuclear reduction, unlike the German or Belgian nuclear phase-out plans, at this point, there are no precise dates for reactor shutdowns... yet.

We need to straighten things out, in order to really reduce the nuclear share to 50 percent", Ecology Minister Nicolas Hulot

The new Minister for the Ecological and Inclusive Transition, who has full control over the energy portfolio, is the first French political leader to express the obvious: no way to reach the 50 percent share without shutting down roughly one third of the French reactors. "I have well inherited a law, but also a lack of strategy. We need to straighten things out, in order to really reduce the nuclear share to 50 percent", Minister Nicolas Hulot stated in an interview. On 18 July 2017, he told the Parliament's Finances Committee that the goal would be difficult to achieve and that his services had calculated that it would mean closing 25 reactors. An online French Government statement specifies that the 50 percent goal supposes "to favor energy savings and the development of renewable energies".[40] It is the Pluriannual Energy Program, a planning tool introduced through the Energy Transition Law, that will define the framework for the coming years to 2023. According to the French Government: "The work has been launched. It will be completed by the end of 2018".[41]

French Nuclear Power and Electricity Mix

In 2016, 56 operating reactors[42] in France produced 384 TWh or 72.3 percent of the country's electricity, the lowest share since 1988, that is 4 percentage points less than in the previous year and more than 6 percentage points below peak year 2005 with 78.5 percent of the total.

Two additional reactors, Bugey-5 (880 MW) and Paluel-2 (1330 MW) did not produce any electricity during 2016 and the first half of 2017, and as of 1 July 2017 both were considered in WNISR category LTO. Bugey-5 was shut down on 27 August 2015 for maintenance and refueling. Subsequently, an overpressure test of the containment revealed an excessive leak rate. Work went on until 15 May 2017, followed by a new leak test that confirmed the validity of the repair. Almost two years after shutdown, it eventually was reconnected to the grid on

39 - Journal Officiel de la République Française, "Loi n°2015-002 du 17 août 2015 relative à la transition énergétique pour la croissance verte", 18 August 2015.

40 - French Government, "Des mesures pour réduire la part du nucléaire à 50% à l'horizon 2025", undated, (in French), see http://www.gouvernement.fr/des-mesures-pour-reduire-la-part-du-nucleaire-a-50-a-l-horizon-2025, accessed 29 July 2017.

41 - Ibidem.

42 - All pressurized water reactors, 33 x 900 MW, 19 x 1300 MW, and 4 x 1400 MW.

23 July 2017.[43] The Paluel-2 reactor was taken off the grid for maintenance in May 2015. During a replacement operation, a 22-meter-high steam generator was dropped on the floor inside the reactor building,[44] an accident deemed impossible in the safety case. Restart has been postponed several times, and is currently scheduled for February 2018.[45]

While Bugey-5 and Paluel-2 did not generate any power in 2016, the main reason for the significant 7.9-percent drop in nuclear production is the snow-balling effect of ongoing investigations into irregularities in quality-control documentation and manufacturing defects (especially excessive carbon content of steel) of pieces produced by AREVA's Creusot Forge and a Japanese AREVA sub-contractor, leading to multiple reactor shutdowns, starting in November 2016. One reactor, Fessenheim-2, has been shut down since June 2016, and in July 2016, French Nuclear Safety Authority (ASN) withdrew the licensing certificate for a steam generator, as it had been revealed that it had not been manufactured according to technical specifications, a fact that had been hidden by AREVA-Creusot Forge. In a similar case, a replacement steam generator for Gravelines-5 that was about to be installed was rejected, after the reexamination of the safety files "showed a major irregularity whose origins were unacceptable", EDF Vice President for Nuclear and Thermal Dominique Miniere, told a parliamentary committee in October 2016.[46] The reactor was shut down between April 2016 and July 2017.

For the first time, Germany overtook France and became the biggest net power exporter in Europe

Natural gas generation increased by over 60 percent in 2016 compared to the previous year, and made up for some of the lacking nuclear capacity. Natural gas still represented only 6.6 percent of the total, coal and oil together just 2 percent. Hydro—mainly large dams—covered 12 percent, while non-hydro renewables (wind, solar, biomass) contributed just 6.7 percent.[47]

For many years, France was Europe's largest electricity exporter, and after a drop in the late 2000s, 61.7 TWh were exported net in 2015, a trade surplus approaching previous levels. But in 2016, net exports dropped by 36.6 percent to 39.1 TWh, the lowest level since 2010. On the contrary, Germany's 2016 net power exports hit a new record at 53.7 TWh, an increase of 1.9 TWh. For the first time, Germany overtook France and became the biggest net power exporter in Europe.[48]

43 - EDF, "Bugey 5 de nouveau connectée au réseau national d'électricité", 24 July 2017, (in French), see https://www.edf.fr/groupe-edf/nos-energies/carte-de-nos-implantations-industrielles-en-france/centrale-nucleaire-du-bugey/actualites/bugey-5-de-nouveau-connectee-au-reseau-national-d-electricite, accessed 30 July 2017.

44 - EDF, "Accident de manutention à la centrale de Paluel", 31 March 2016, see https://www.edf.fr/groupe-edf/producteur-industriel/carte-des-implantations/centrale-nucleaire-de-paluel/actualites/accident-de-manutention-a-la-centrale-de-paluel, accessed 9 June 2017.

45 - EDF, "Paluel 2—version actuelle de l'indisponibilité v17 (05470_EDF_T_00010060)", 11 August 2017, see https://one.edf.fr/edf/05470-edf-t-00010060, accessed 13 August 2017.

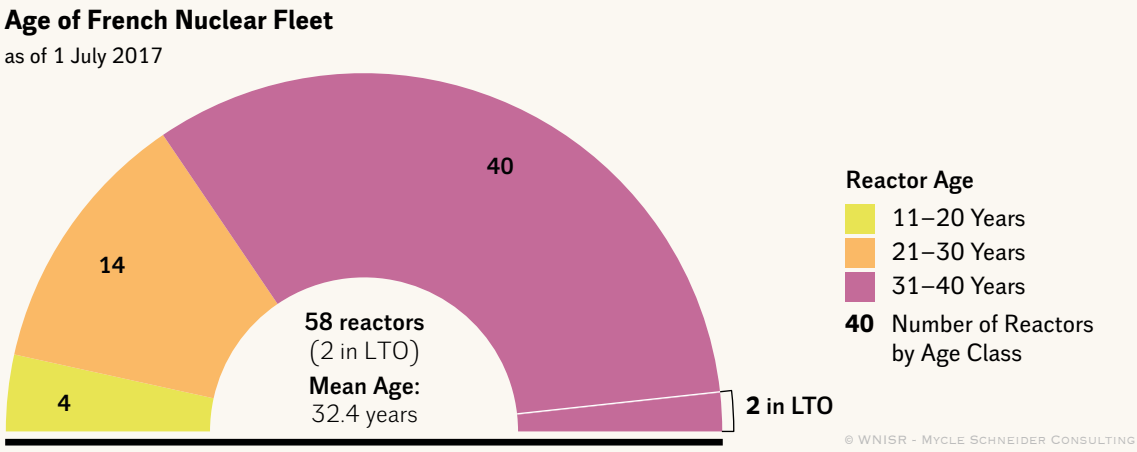
46 - Bate Felix, Geert De Clercq, "Major irregularity detected at EDF's Gravelines 5 reactor - EDF executive", *Reuters*, 25 October 2016, see http://af.reuters.com/article/commoditiesNews/idAFL8N1CV7I8, accessed 7 August 2017.

47 - RTE, "Bilan Électrique 2016", February 2017.

48 - AGEB, "Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern", Arbeitsgruppe Energiebilanzen, February 2017, (in German), see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20170207_brd_stromerzeugung1990-2016.pdf, accessed 23 June 2017.

The creation of the Central West Europe (CWE) region (France, Germany, Austria, Belgium, the Netherlands and Luxembourg), replacing the Net Transfer Capacities model previously used, cumulates exchanges with the national entities involved. France's annual export balance with CWE is negative—the first time since 2010—by 5.3 TWh, it is positive with the other neighboring countries (Great Britain, Italy, Spain, Switzerland). Contrary to the general perception, France remains a net importer of power from Germany, and has been for a number of years, because German wholesale electricity generally undercuts French wholesale prices.[49] In December 2016, France imported up to 8.2 GW of power from its neighbors, to help compensate for shutdown nuclear plants.[50]

Figure 16 | Age Distribution of French Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2017

The average age of France's 58 power reactors is 32.4 years by mid-2017 (see Figure 16). In the absence of new reactor commissioning and any shutdown, the fleet is simply aging by one year every year. Simultaneously, questions are being raised about the investment needed to enable them to continue operating, as aging reactors increasingly need parts to be replaced. Moreover, life extension beyond 40 years of some reactors—a deadline many of the oldest reactors are approaching—would require significant additional upgrades, as ASN requires to bring extended reactors to a safety level "as close as possible" to evolutionary reactors like the EPR. Also, relicensing will be subject to public inquiries reactor by reactor.

Operating costs have increased substantially over the past years. Investments for life extensions will need to be balanced against the already excessive nuclear share in the power mix, the stagnating or decreasing electricity consumption—it has been roughly stable for the past six years—the shrinking client base, successful competitors, and the energy efficiency and renewable energy production targets set at both the EU and the French levels. It remains plausible that EDF will attempt to extend lifetimes of some units, while others might be closed even prior to reaching the 40-year age limit. Any decision remains suspended to the revision of the Pluriannual Energy Plan (end of 2018) and the nuclear safety authority's generic judgement over lifetime extensions (probably 2019), followed by a case-by-case procedure.

49 - RTE, "2015–Annual Electricity Report", March 2016.

50 - RTE, "Bilan Électrique 2016", February 2017.

The Troubled Flamanville-3 EPR and the Creusot Forge Affair

The 2005 construction decision of Flamanville-3 (FL3) was mainly motivated by the industry's attempt to confront the serious problem of maintaining nuclear competence. In December 2007, EDF started construction on FL3. The project has been plagued with detailed design issues and quality-control problems, including basic concrete and welding similar to those at the Olkiluoto (OL3) project in Finland, which started two-and-a-half years earlier.

The Flamanville-3 project is now at least 6.5 years late

The Flamanville-3 project is now at least 6.5 years late and now expected to start generating power in May 2019, reaching full capacity in November 2019.51 The official cost estimate for Flamanville-3 stood at €8.5 billion (US$11.6 billion) as of December 2012.52 In its annual report 2015, EDF updated the figure to €10.5 billion (US$12.3 billion)[53], equivalent to the current estimate for the Olkiluoto-3 EPR project in Finland, and 3.2 times the estimate at construction start. EDF's President Bernard Lévy stated on 28 July 2017: "We are in line with the schedule and the budget that we announced in 2015."[54] In fact, the road map presented by EDF in September 201555 scheduled "fuel loading and startup" for the forth quarter 2018 but omitted to provide a grid-connection date, which was given only in 2017 as the second quarter of 2019. De facto, the current planning represents about another six months delay in the construction schedule since 2015.

In April 2015, ASN revealed that the bottom piece and the lid of the FL3 pressure vessel had "very serious" defects.56 Chemical and mechanical tests "revealed the presence of a zone in which there was a high carbon concentration, leading to lower than expected mechanical toughness values".[57] Both pieces were fabricated and assembled by AREVA in France, while the center piece was forged by Japan Steel Works (JSW) in Japan. ASN stated then that the same fabrication procedure by AREVA's Creusot Forge was applied to "certain calottes" (also called bottom heads and closure heads) of the two pressure vessels made for the two EPRs under construction at Taishan in China, while the EPR under construction in Finland was entirely manufactured in Japan. It remains unclear, which of the two bottoms and two lids have been manufactured by Creusot Forge, but likely at least the ones for Taishan-1, while, accor-

51 - Bate Felix, Benjamin Mallet, "L'EPR de Flamanville attendu à pleine puissance en novembre 2019", *Reuters*, 11 July 2017, (in French), see http://fr.reuters.com/article/businessNews/idFRKBN19W21B-OFRBS, accessed 31 July 2017.

52 - Ludovic Dupin, "EDF a évité le pire sur l'EPR de Flamanville", *Usine Nouvelle*, 7 December 2012, (in French), see http://www.usinenouvelle.com/article/edf-a-evite-le-pire-sur-l-epr-de-flamanville.N187560, accessed 18 June 2017.

53 - EDF, "2015 Management Report—Group Results", 13 May 2016.

54 - EDF, "Half-Year Results 2017", Conference call Jean-Bernard Lévy with Analysts and Investors, 28 July 2017.

55 - Jean-Bernard Lévy, Xavier Ursat, "Conférence de Presse", EDF, 3 September 2015, (in French), see https://www.edf.fr/sites/default/files/Finance/EDF_Presentation_EPR_Flamanville_03_09_2015.pdf, accessed 17 March 2017.

56 - Ludovic Dupin, "Le cri d'alarme de l'ASN sur le nucléaire français", *Usine Nouvelle*, 20 January 2016, (in French) see http://www.usinenouvelle.com/article/le-cri-d-alarme-de-l-asn-sur-le-nucleaire-francais.N374729, accessed 11 June 2017.

57 - ASN, "Flamanville EPR reactor vessel manufacturing anomalies", Press Release, 7 April 2015, see http://www.french-nuclear-safety.fr/Information/News-releases/Flamanville-EPR-reactor-vessel-manufacturing-anomalies, accessed 14 August 2017.

ding to AREVA[58] and media reports[59], the pressure vessel for Taishan-2 has been manufactured by Chinese company Dongfang Electric Corporation (DEC). However, no specific mention is made of the vessel bottoms and lids.

AREVA's challenge was to prove that, although clearly below technical specifications, the EPR pressure vessels could withstand any major transient and submitted a proposal for a major test program to ASN in the summer of 2015. By September 2015, ASN had realized that the pressure vessel had not been manufactured according to technical specifications and, thus, its use would require an exemption from the rule. In December 2015, ASN approved the program, considering that the "test program proposed on two scale-one replica domes should be able to assess the scale and depth of the segregated zone as well as its influence on the mechanical properties". For the initial material destructive tests and the following test program, AREVA sacrificed vessel head and bottom that had already been manufactured for a never-built reactor project in the U.S. (Calvert Cliffs) and the vessel head for a maybe-built EPR at Hinkley Point in the U.K. In fact, AREVA could have, should have carried out destructive tests long before the vessel installation on-site in 2013, but only fulfilled that regulatory requirement in 2014—with the results that triggered the entire Creusot Forge affair.

In December 2016, AREVA submitted its "justification of sufficient toughness" for the FL3 reactor pressure vessel heads (cover and bottom) to ASN.[60] ASN drafted an opinion to be adopted by the technical advisory expert group on nuclear pressurized equipment (Groupe permanent d'experts pour les équipements sous pression nucléaires). The document was approved on 27 June 2017 by majority vote.[61] It states that the Group considers that the material in question shows "mechanical properties of a sufficient level to prevent the feared risks". However, the Group also states that "the reduction of the [safety] margin against the risk of sudden rupture affects the robustness of the first level of defense in depth". In addition, the experts request that, within two years, EDF provides the feasibility demonstration for specific in-service inspections of the reactor pressure vessel head. In an unprecedented minority opinion, two independent experts[62] explained their vote against the statement by the "significantly reduced" safety margin and the "unprecedented threat, due to its nature and context, for the first level of defence in depth", the projected in-service inspections failing to represent "effective compensatory measures".[63]

58 - AREVA, "Taishan 1&2 - China—AREVA Supply Chain", undated, see http://www.areva.com/EN/operations-2404/china-taishan-12.html - tab=tab5, accessed 14 August 2017.

59 - *FactWire*, "Made in China: critical component of Taishan nuclear plant manufactured in Guangzhou", 26 May 2016, see https://www.factwire.org/single-post/2016/05/27/Made-in-China-critical-component-of-Taishan-nuclear-plant-manufactured-in-Guangzhou, accessed 2 July 2016.

60 - AREVA, "Justification of sufficient toughness for FA3 RPV heads (cover and bottom)", 27 April 2017, redacted summary of the original report, dated 16 December 2016, uploaded on 11 May 2017, see http://www.areva-np.com/businessnews/liblocal/docs/3_Actualites/Dossiers/Note_synthese_tenacite_calottes_cuve_EPR_FA3.pdf, accessed 31 July 2017.

61 - Advisory Committee of Experts for Nuclear Pressure Equipment (GP ESPN), "Opinion on the Consequences of the carbon concentration anomaly on the fitness for service of the Flamanville EPR reactor pressure vessel domes", Meeting held in Montrouge (France), 26-27 June 2017, see www.french-nuclear-safety.fr/Media/Files/00-Publications/Opinion-on-the-consequences-of-the-carbon-concentration-anomaly-on-the-fitness-for-service-of-the-Flamanville-EPR-reactor-pressure-vessel-domes, accessed 14 August 2017.

62 - Yves Marignac, Director of WISE-Paris, and Jean-Claude Autret, President of the Association pour le Contrôle de la Radioactivité dans l'Ouest (ACRO).

63 - Advisory Committee of Experts for Nuclear Pressure Equipment (GP ESPN), "Avis relatif aux conséquences de l'anomalie de concentration en carbone des calottes de la cuve du réacteur EPR de Flamanville sur leur aptitude au service", Meeting held in Montrouge (France), 26-27 June 2017.

The day following the expert group's meetings, ASN released its official judgement on the issue considering the "mechanical characteristics" of vessel cover and bottom "adequate". ASN considers however that EDF "must implement additional periodic inspections to ensure that no flaws appear subsequently". As the technical feasibility at this point cannot be considered established for the cover, "ASN therefore considers that the use of the closure head must be limited in time" and as a new closure head could be available by 2024, the current piece "shall not be operated beyond that date".[64]

The "irregularities" included "inconsistencies, modifications or omissions in the production files"

Meanwhile, the finding of carbon segregations in the pressure vessel of Flamanville-3 had raised concerns about the possibility that other components could have been fabricated below technical specifications due to poor quality processes at Creusot Forge on one hand, and about the possibility that components fabricated up to technical specifications under pre-2005 regulation could present similar undetected carbon segregation on the other hand.[65]

Media reports revealed in March 2017 that ASN had warned AREVA and EDF as early as 2005-06 about quality issues at Creusot Forge. Then ASN President André-Claude Lacoste stated: "Your supplier has big problems, either replace it or buy it!"[66] AREVA chose to buy Creusot Forge in 2006. However, this did not solve the issue.

It is therefore unclear, why it took the detection of the manufacturing problems with the EPR pressure vessel for ASN to request an audit of the Creusot Forge plant, a decade after the first major issues had been identified. On 25 April 2016, AREVA informed ASN that "irregularities in the manufacturing checks", the quality-control procedures, were detected at about 400 pieces fabricated since 1969, about 50 of which would be installed in the French currently operating reactor fleet. The "irregularities" included "inconsistencies, modifications or omissions in the production files, concerning manufacturing parameters or test results".[67]

The most serious offense led ASN to withdraw the certificate of a replacement steam generator introduced in Fessenheim-2 in 2012 –because the forging process of its central part was not compliant to qualified methods, and this was covered in the documentation submitted to ASN and EDF–, leaving the reactor shutdown since July 2016, with restart subject to ASN authorization[68].

64 - ASN, "ASN presents its position regarding the Flamanville EPR reactor vessel anomaly", Press Release, 28 June 2017, see http://www.french-nuclear-safety.fr/Information/News-releases/ASN-presents-its-position-regarding-the-Flamanville-EPR-reactor-vessel-anomaly, accessed 31 July 2017.

65 - The regulation on pressurised components of nuclear facilities changed in 2005. In particular, it now requires that mechanical properties should be verified in every areas of the components, instead of only the most sensitive areas before.

66 - *France Inter*, "Cuve de l'EPR de Flamanville : l'incroyable légèreté d'Areva et EDF", 31 March 2017, see https://www.franceinter.fr/sciences/cuve-de-l-epr-de-flamanville-l-incroyable-legerete-d-areva-et-edf, accessed 15 August 2017.

67 - ASN, "AREVA has informed ASN of irregularities concerning components manufactured in its Creusot Forge plant", 4 May 2016, see http://www.french-nuclear-safety.fr/Information/News-releases/Irregularities-concerning-components-manufactured-in-its-Creusot-Forge-plant, accessed 14 August 2017.

68 - ASN, "Décision n° CODEP-CLG-2016-02945 du 18 juillet 2016 du Président de l'Autorité de sûreté nucléaire suspendant le certificat d'épreuve du générateur de vapeur n° 335 fabriqué par AREVA NP", 18 July 2016, (in French), see https://www.asn.fr/content/download/105596/795168/version/1/file/Décision n° CODEP-CLG-2016-02945 du 18 juillet 2016.pdf, accessed 10 August 2017.

According to ASN's Annual Report 2016:

> As at the end of 2016, Areva NP had identified 91 irregularities concerning EDF reactors in operation, 20 affecting equipment intended for the Flamanville EPR reactor, one concerning a steam generator intended for but not yet installed in Gravelines NPP reactor 5 and four affecting transport packagings for radioactive substances. (...) Regardless of their actual safety consequences, these irregularities reveal unacceptable practices. Some of these irregularities could constitute falsifications. ASN is in contact with the services of the Ministry of Justice on this subject.[69]

In September 2016, AREVA took the decision to review all of the several thousand manufacturing files for nuclear components from Creusot Forge, which is supposed to take about one year. ASN warned that it was not ruling out further problematic discoveries.

In addition, ASN's own inspections at the Creusot Forge plant in January 2016 also revealed that high carbon concentrations also had been found in the calottes for the FL3 pressurizer, following a request for additional tests by AREVA NP dating as early as December 2008. Neither the request for these tests nor their results had been communicated to ASN.[70]

ASN had also requested EDF to review the safety files of equipment that could present undetected carbon segregations, although fabricated according to specifications of the time. A problem of particularly high carbon content—up to 50 percent higher than the limit in technical specifications—was found in the channel head steel of 20 steam generators fabricated at the Creusot Forge and 26 by AREVA sub-contractor Japan Casting and Forging Corporation (JCFC), that had not been reported by the manufacturer. This led to the provisional shutdown for inspections of a dozen reactors in France in the winter 2016-17. ASN had considered the potential risk of failure high enough to order EDF to carry out inspections within three months.

Rising Costs and a Lurking Investment Wall

As of the end of 2016, EDF had an official net debt €37.4 billion (US$40.3 billion), identical to the end-of-2015 figure. Following a €4 billion (US$4.6 billion) capital increase and €4.35 billion (US$5 billion) in asset disposals, by mid-2017, net debt had declined to €31.3 billion (US$36.8 billion)[71]. For further financial analysis see Nuclear Finances Chapter.

Investment needs remain substantial with €4.9 billion (US$5.6 billion) in the first half of 2017. One particular item is the controversial Hinkley Point C project (see also U.K. Section, and WNISR2016 for "The Hinkley Point C Saga – A French Perspective"). According to EDF's Reference Document 2016, the strategic investment agreement relating to the construction and the operation of the Hinkley Point C nuclear power plant by EDF and China General Nuclear Power Corporation (CGN) has been approved on 28 July 2016 by EDF's Board of Directors. The contractual documentation was signed on 29 September 2016 by EDF, CGN and the British Government. The agreements cover three aspects:

69 - ASN, "ASN Annual Report 2016—ASN Report on the state of nuclear safety and radiation protection in France in 2016", 12 July 2017, see https://www.asn.fr/annual_report/2016gb/, accessed 14 August 2017.

70 - ASN, Letter to the Director General of AREVA NP, 9 May 2016.

71 - EDF, "Half-Year Results 2017", 28 July 2017, see https://www.edf.fr/en/the-edf-group/dedicated-sections/investors-shareholders/financial-information/regulated-information/financial-results, accessed 15 August 2017.

- construction and operation of two EPRs at Hinkley Point under the leadership of EDF (66.5%), with CGN's share at 33.5%. EDF will consider bringing other investors into the project in due course but will not reduce its initial stake to below 50%;
- development of two EPRs at the Sizewell site, under the leadership of EDF (80%), in preparation for a possible final investment decision. CGN will take a 20% share;
- adaptation and certification in the United Kingdom of the HPR 1000 technology (a third-generation Chinese 1,000MW reactor), and its development on the Bradwell site, under the leadership of CGN (66.5%), in preparation for a possible final investment decision. The EDF group will take a 33.5% share.[72]

While EDF had already spent €3 billion (US$5.5 billion) prior to the signature of the contracts, for 2017, EDF announced that "firm commitments" in connection with the "acquisition of tangible assets for the building of Hinkley Point C have been formalized under contractual agreements for an amount of €2.7 billion [US$2.9 billion]".[73] EDF's Reference Document 2016 contains under the section "Specific risks related to the Group's nuclear activities" a risk factor entitled "Construction of EPRs may encounter problems meeting the implementation schedule or the budgetary envelope or not be completed".[74] A few months into 2017, EDF's CEO admits:

- Project completion costs are now estimated at £19.6 billion$_{2015}$ [US$29 billion$_{2015}$]. This is an increase of £1.5 billion$_{2015}$ [US$ 2.2 billion$_{2015}$], compared to previous valuations. The project review, on top of this, identified a potential 15-month deferral of the delivery date of Unit 1 and a potential nine-month deferral for Unit 2.[75]

The fact that a "not be completed" risk assumption is quite realistic has been illustrated by 90 abandoned nuclear construction sites up to 1 January 2017, documented in the WNISR's Global Nuclear Power Database[76]. The latest case to be added is the abandoning of the two AP1000 reactors under construction at the Summer site in South Carolina, U.S. (see Focus United States).

EDF has committed to additional investment efforts, including for the development of new reactor designs. But it is "renewables and services activities, which are key growth drivers", according to EDF's CEO.[77] However, EDF's total net installed renewables capacity of 6.7 GW (excluding large hydro) remains modest.

72 - EDF, "Reference Document—2016 Annual Financial Report", filed 6 March 2017, published April 2017, see https://www.edf.fr/en/the-edf-group/dedicated-sections/investors-shareholders/financial-information/regulated-information/reference-documents, accessed 14 August 2017.

73 - Ibidem.

74 - Ibidem.

75 - EDF, "Clarifications on Hinkley Point C project", 3 July 2017, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/clarifications-on-hinkley-point-c-project, accessed 14 August 2017.

76 - *WNISR/Visionscarto/Bulletin of the Atomic Scientists*, "The Global Nuclear Power Database", see http://thebulletin.org/global-nuclear-power-database.

77 - EDF, "Half-Year Results 2017", Conference call Jean-Bernard Lévy with Analysts and Investors, 28 July 2017.

GERMANY FOCUS

Germany's remaining eight nuclear reactors generated 80.1 TWh net in 2016—50.5 percent less than in their record year 2001—and provided 13 percent of Germany's electricity generation, less than half of the historic maximum of 30.8 percent in 1997. One more reactor (Grundremmingen-B) will be shut down at the end of 2017, according to the nuclear phase-out legislation (see Table 3 for details).

Germany decided immediately after 3/11 to shut down the eight oldest of its 17 operating reactors and to phase out the remaining nine until 2022. This choice was led by a conservative, pro-business, and, until the Fukushima disaster, very pro-nuclear Government, led by physicist Chancellor Angela Merkel, with no political party dissenting, which makes it virtually irreversible under any political constellation. On 6 June 2011, the Bundestag passed a seven-part energy transition legislation almost by consensus and it came into force on 6 August 2011 (see earlier WNISR editions for details).

With a total generation of 188.4 TWh, in 2016, renewables were again the largest contributor to the power mix and supplied 29.1 percent of gross generation—more than lignite (23.1 percent), hard coal (17.2 percent) and natural gas (12.4 percent). With new investments of over €14 billion (US$15.7), renewable generation capacities grew by 6.7 GW in 2016 to a total of 104 GW, mainly driven by the 5 GW of new wind power plants (onshore and offshore) and a 1.5 GW addition of solar power capacities.[78]

Germany's net power exports hit a new record at 53.7 TWh

In 2016, Germany's net power exports hit a new record at 53.7 TWh, an increase of 1.9 TWh over 2015. As the French electricity trade surplus plunged from 61.7 TWh in 2015 to 39.1 TWh in 2016 (–37 percent), due to the reduction in nuclear generation, for the first time, Germany became the biggest net exporter in Europe.[79] The main driver for high exports were the wholesale market prices, which hit a historic low yearly average of €28.81/MWh (US$32.24/MWh) on the spot market, leading to further difficulties for the main German utilities (see below).[80]

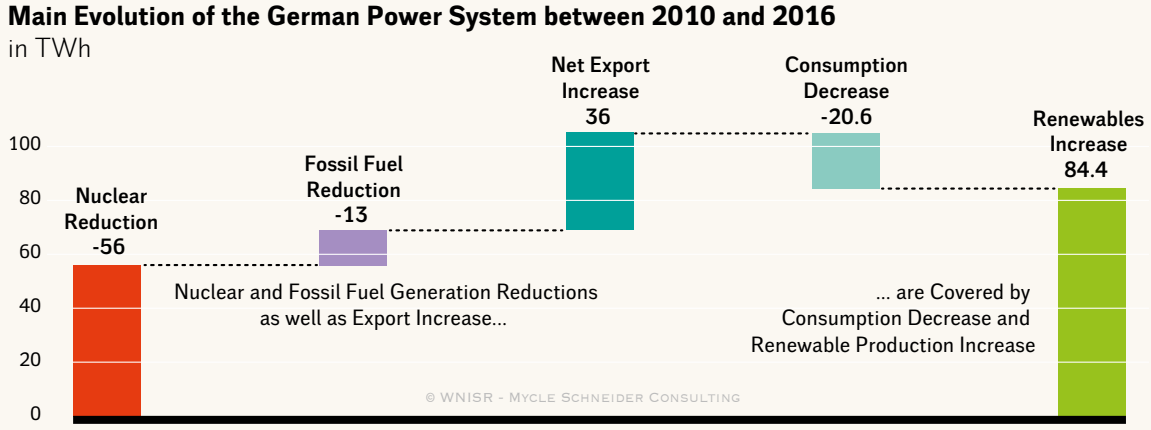
Figure 17 summarizes the main developments of the German power system between 2010—the last year prior to the post-3/11 shutdown of the eight oldest nuclear power plants—and 2016. It clearly shows that the increase of renewable electricity generation (+84.4 TWh) and the noticeable reduction in domestic consumption (20.6 TWh) were more than sufficient to compensate the planned reduction of nuclear generation (56 TWh), enabling also a slight reduction in power generation from fossil fuels (-13 TWh) and a threefold increase in net exports.

78 - Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), "Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland—Stand: Februar 2017", Umweltbundesamt, Federal Ministry for Economic Affairs and Energy (BMWi), February 2017, (in German), see http://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html, accessed 23 June 2017.

79 - Arbeitsgruppe Energiebilanzen (AGEB), "Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern", February 2017, (in German), see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20170207_brd_stromerzeugung1990-2016.pdf, accessed 23 June 2017.

80 - Agora Energiewende, "Die Energiewende im Stromsektor : Stand der Dinge 2016—Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2017", January 2017, (in German), see https://www.agora-energiewende.de/fileadmin/Projekte/2017/Jahresauswertung_2016/Agora_Jahresauswertung-2016_WEB.pdf, accessed 23 June 2017.

Figure 17 | Main Developments of the German Power System Between 2010 and 2016



Sources: WNISR based on AGEB, 2017[81]

After the inspection protocol falsification scandal that shook the German nuclear industry in 2015 (see WNISR 2016), 2016 was marked by the adoption of new legislation to regulate the funding of nuclear waste management in December and several legal decisions in favor of the nuclear utilities.[82] Following the recommendations of the independent Commission to Review the Financing for the Phase-out of Nuclear Energy (KFK)[83], the law creates a new public fund dedicated to the funding of long-term storage of radioactive waste. The major utilities are due to pay €23.5 billion (US$26.3 billion) into the fund, including a risk premium of €6.5 billion (US$7.3 billion) to free them from any responsibility in case of cost overruns in the future. The compromise has received political support across the main parties. Environmental NGOs however criticize the fact that this law creates a precedent to free nuclear operators from their long-term responsibilities, considering in particular major uncertainties over future costs. Much alike other countries operating nuclear power plants, Germany has yet to find suitable solutions and localizations for the disposal of radioactive wastes.[84]

Furthermore, as part of the deal, the major nuclear operators agreed to withdraw up to 20 legal cases they initiated to request compensation for losses mainly incurred due to the precipitated shutdown of reactors after the Fukushima accident.[85] Nevertheless, this does not affect the ongoing case over compensation demands of up to €19 billion (US$21.3 billion) related to the phase-out of currently operating reactors. In late 2016, the Federal Constitutional Court ruled

81 - Arbeitsgruppe Energiebilanzen, "Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern", February 2017, (in German), see http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20170207_brd_stromerzeugung1990-2016.pdf, accessed 23 June 2017.

82 - Bundesrat, "Drucksache 768/16: Gesetzesbeschluss des Deutschen Bundestages—Gesetz zur Neuordnung der Verantwortung in der kerntechnischen Entsorgung", German Government, 16 December 2016, (in German), see https://www.bundesrat.de/SharedDocs/drucksachen/2016/0701-0800/768-16.pdf?__blob=publicationFile&v=1, accessed 23 June 2017.

83 - Kommission zur Überprüfung der Finanzierung des Kernenergieausstiegs (KFK), "Verantwortung und Sicherheit-Ein neuer Entsorgungskonsens—Abschlussbericht der Kommission zur Überprüfung der Finanzierung des Kernenergieausstiegs", BMWi, 25 May 2016, (in German), see https://www.bmwi.de/Redaktion/DE/Downloads/B/bericht-der-expertenkommission-kernenergie.html, accessed 23 June 2017.

84 - BUND, "Die Kosten der Atomkraft – die AKW-Betreiber müssen zahlen", Friends of the Earth Germany, 2016, see https://www.bund.net/atomkraft/atommuell/folgekosten/?wc=21731, accessed 23 June 2017.

85 - Stefan Schultz, "Atomausstieg: Energiekonzerne verzichten auf Schadensersatz", *Spiegel Online*, 9 December 2016, (in German), see http://www.spiegel.de/wirtschaft/unternehmen/atomausstieg-energiekonzerne-verzichten-auf-schadensersatz-a-1125261.html, accessed 23 June 2017.

that the nuclear operators must be compensated and it now belongs to the Government to find a suitable agreement until 2018.[86]

Furthermore, the German Constitutional Court ruled in favor of the utilities in June 2017, declaring the German nuclear fuel tax unconstitutional. The tax had been introduced in 2010. This is a major success for the utilities, who will be reimbursed as much as €6.3 billion (US$7.1 billion) plus interest, a welcome ease to the strain on their balance sheets.[87]

Nuclear operators in Germany, the traditional virtually integrated utilities, are struggling with low prices and reduced income from tradition thermal power plants (for details on share-price developments and credit-rating see the Nuclear Finances Chapter). After losing 36 percent in 2015, E.ON's market value incurred a loss of 25 percent in 2016. In total, the company indicates a net loss of €16 billion (US$17.9 billion), mainly due to the in-depth restructuring, which led to the transfer of the company's conventional assets (gas, hydro and thermal power plants) into a new company called Uniper.[88]

Similar to E.ON, RWE (Rheinisch-Westfälisches Elektrizitätswerk) is conducting an in-depth restructuring to face the difficult market environment and created a spin-off franchise (Innogy SE) in 2016. Innogy took over activities in renewable electricity generation, grid management and trading. Due to these changes and the harsh market environment, the company's net result indicates a loss of €5.7 billion (US$6.4 billion) for 2016 and restrained from paying any dividends for the second year in a row.[89] After a record loss in 2015 (–54 percent), the market capitalization of RWE remained stable in 2016 at around €7 billion (US$7.8 billion). Vattenfall Germany results are difficult to assess as they are incorporated into the Swedish government-owned Group results. Vattenfall is not listed. Overall, Vattenfall Group lost €2.7 billion (US$3 billion) in spite of increasing sales. EnBW (Energie Baden-Württemberg) filed a net loss of €1.7 billion (US$1.9 billion), mainly due to a 56 percent decrease in revenues from conventional generation and trading and an almost threefold increase in net investments.

86 - *Spiegel Online*, "Bundesverfassungsgericht zum Atomausstieg—Regierung muss Energiekonzerne entschädigen", 6 December 2016, (in German), see http://www.spiegel.de/wirtschaft/soziales/bundesverfassungsgericht-zum-atomausstieg-energie-konzerne-haben-anspruch-auf-entschaedigung-a-1124612.html, accessed 23 June 2017.

87 - Christoph Steitz, "German utilities set for multi-billion euro windfall after nuclear tax ruling", *Reuters*, 7 June 2017, see http://www.reuters.com/article/us-germany-nuclear-court-idUSKBN18Y0PX, accessed 23 June 2017.

88 - E.ON, "2016 Annual Report", 15 March 2017, see http://www.eon.com/en/about-us/publications/annual-report.html, accessed 23 June 2017.

89 - RWE, "Annual Report 2016", 14 March 2017, see http://www.rwe.com/web/cms/mediablob/en/3688522/data/110822/7/rwe/investor-relations/reports/RWE-annual-report-2016.pdf, accessed 23 June 2017.

Table 3 | Legal Closure Dates for German Nuclear Reactors 2011-2022

Reactor Name (Type, Net Capacity)	**Owner/Operator**	**First Grid Connection**	**End of License** (latest closure date)
Biblis-A (PWR, 1167 MW)	RWE	1974	6 August 2011
Biblis-B (PWR, 1240 MW)	RWE	1976	
Brunsbüttel (BWR, 771 MW)	KKW Brunsbüttel[a]	1976	
Isar-1 (BWR, 878 MW)	E.ON	1977	
Krümmel (BWR, 1346 MW)	KKW Krümmel[b]	1983	
Neckarwestheim-1 (PWR, 785 MW)	EnBW	1976	
Philippsburg-1 (BWR, 890 MW)	EnBW	1979	
Unterweser (BWR, 1345 MW)	E.ON	1978	
Grafenrheinfeld (PWR, 1275 MW)	E.ON	1981	31 December 2015 (closed 27 June 2015)
Gundremmingen-B (BWR, 1284 MW)	KKW Gundremmingen[c]	1984	31 December 2017
Philippsburg-2 (PWR, 1402 MW)	EnBW	1984	31 December 2019
Brokdorf (PWR, 1410 MW)	E.ON/Vattenfall[d]	1986	31 December 2021
Grohnde (PWR, 1360 MW)	E.ON	1984	
Gundremmingen-C (BWR, 1288 MW)	KKW Gundremmingen	1984	
Isar-2 (PWR, 1410 MW)	E.ON	1988	31 December 2022
Emsland (PWR, 1329 MW)	KKW Lippe-Ems[e]	1988	
Neckarwestheim-2 (PWR, 1310 MW)	EnBW	1989	

Notes pertaining to the table
PWR=Pressurized Water Reactor; BWR=Boiling Water Reactor; RWE= Rheinisch-Westfälisches Elektrizitätswerk

Sources: Atomgesetz, 31 July 2011; Atomforum Kernenergie, May 2011; IAEA-PRIS, 2012

a - Vattenfall 66,67%, E.ON 33,33%.

b - Vattenfall 50%, E.ON 50%.

c - RWE 75%, E.ON 25%.

d - E.ON 80%, Vattenfall 20%.

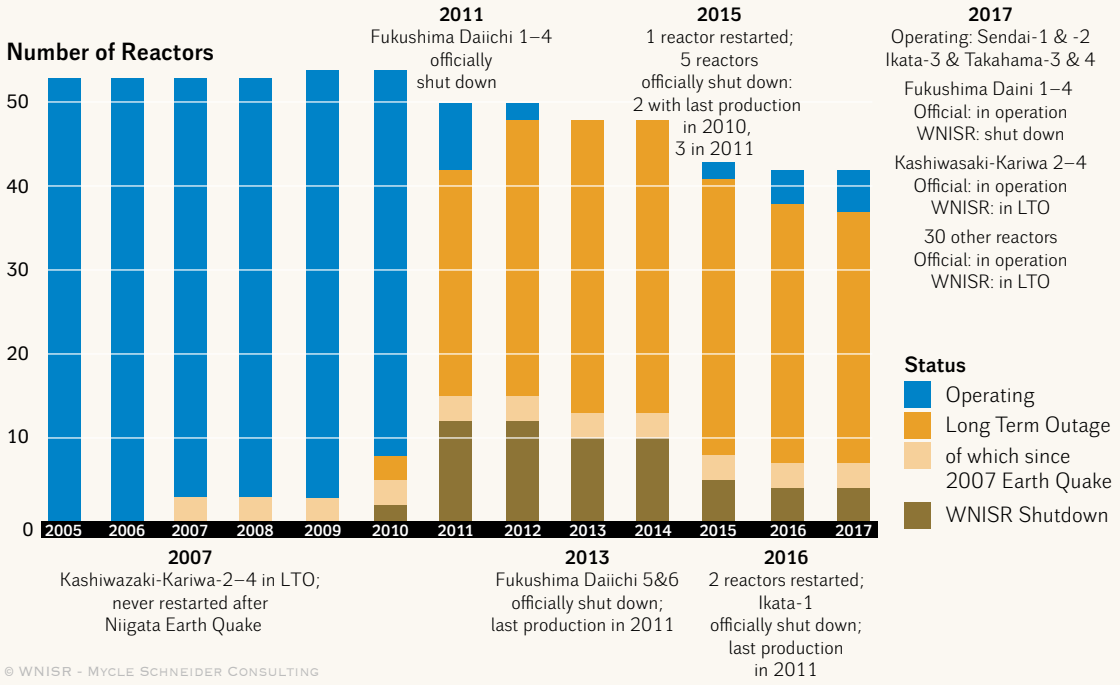
e - RWE 87,5%, E.ON 12,5%.

JAPAN FOCUS

Three reactors have restarted in Japan since 1 July 2016, bringing to five the total number in operation. In addition to the Sendai-1&2 reactors, which resumed operation in 2015, the Ikata-3 reactor restarted on 15 August 2016[90], Takahama-4 on 22 May 2017[91] and Takahama-3 on 9 June 2017.[92] In 2016, with Ikata-3 generating 2.8 TWh of electricity, total nuclear production was 14.5 TWh, supplying 2.15 percent of the nation's annual output. This is the largest share of nuclear generated electricity in Japan since 2011 (18 percent), compared with 29 percent in 2010, and the historic maximum of 36 percent in 1998.

Figure 18 | Japanese Reactor Status

Status of Japanese Reactors Officially Operational 2005 - 1 July 2017



Sources: Various sources, compiled by WNISR, 2017

The last year for Japan's nuclear industry can be characterized as making some significant progress to restarting several reactors, but also with some major setbacks for others, in particular for Tokyo Electric Power Company (TEPCO). The decision to terminate the Monju Fast Breeder Reactor in November 2016 is of both historical and strategic significance. Public opinion remains majority opposed to nuclear generation, and with retail market liberalization,

90 - *WNISR*, "Ikata-3 Restarted—Only Three Reactors Operate in Japan", 17 August 2016, see https://www.worldnuclearreport.org/Ikata-3-Restarted-Only-Three-Reactors-Operate-in-Japan.html, accessed 5 June 2017.

91 - *WNISR*, "Takahama-4 Restart in Japan After Court Injunction Was Overturned", 22 May 2017, see https://www.worldnuclearreport.org/Takahama-4-Restart-in-Japan-After-Court-Injunction-Was-Overturned.html, accessed 5 June 2017.

92 - *WNISR*, "Ikata-3 Restarted—Only Three Reactors Operate in Japan", 17 August 2016, see https://www.worldnuclearreport.org/Ikata-3-Restarted-Only-Three-Reactors-Operate-in-Japan.html, accessed 15 August 2017.

there has been a noticeable loss of market share for nuclear utilities. At the same time, the government remains committed to supporting nuclear power generation.

With five reactors in operation, as of 1 July 2017, 33 commercial reactors in Japan remain in the WNISR category of Long-Term Outage (LTO).[93] (See Figure 18 and Annex 2 for a detailed overview of the Japanese Reactor Program).

Restart Prospects

Of the 33 reactors in LTO, 20 reactors are now under review for restart by the Japanese Nuclear Regulation Authority (NRA). The next in line for restart are the Genkai-3 and 4 reactors owned by Kyushu Electric, and Ohi-3 and -4, owned by Kansai Electric Power Company (KEPCO), which are likely to be operating by March 2018, barring legal rulings. In 2016, WNISR reported that it was unlikely that more than three reactors would be operating by December 2016, which proved to be the case; this year, WNISR considers it possible that as many as seven reactors will be operating in Japan by December 2017 and nine by March 2018. Given the past six years of nuclear power plant operation, this has to be considered a significant step forward for the utilities owning these reactors. At the same time, it has to be seen in the context of total electricity generation, which, with nine reactors operating in 2018, would bring the nuclear share in the range of 6.5 percent, compared with 29 percent in 2010. Harder to assess are the prospects for any restart of BWRs during the coming few years, none having resumed operations to date. Thus, the pace of restart into 2018 and beyond is uncertain to match that witnessed in 2017.

- The Abe government remains committed to the earliest possible restart of reactors. However, outside the NRA process, there are important external factors that will continue to determine how many nuclear reactors will eventually resume operations. These include: Continuation of citizen-led lawsuits, including injunctions against restart;
- Economic factors, including a cost-benefit analysis by the utilities on the implications of restart or decommissioning;
- Local political and public opposition;
- Impact of electricity deregulation and intensified market competition.

At the same time, however, Japanese utilities are insisting, and the government has granted and reinforced, the right to refuse cheaper renewable power, supposedly due to concerns about grid stability—hardly plausible in view of their far smaller renewable fractions than in several European countries—but apparently to suppress competition. The utilities also continue strenuous efforts to ensure that the imminent liberalization of the monopoly-based, vertically integrated Japanese power system should not actually expose utilities' legacy plants to real competition. The ability of existing Japanese nuclear plants, if restarted, to operate competitively against modern renewables (as many in the U.S. and Europe can no longer do) is unclear because nuclear operating costs are not transparent. However, the utilities' almost complete suppression of Japanese wind power suggests they are concerned on this score. And as renewables continue to become cheaper and more ubiquitous, customers will be increasingly tempted by

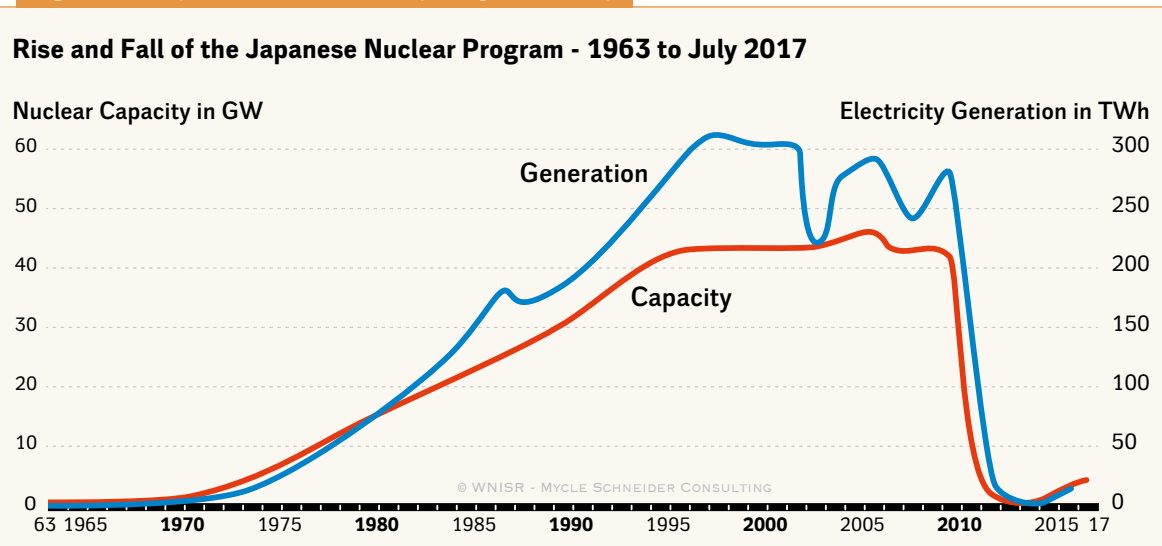
93 - M. Schneider, A. Froggatt, et. al., "WNISR 2014", 18 August 2014, see http://www.worldnuclearreport.org/WNISR2014.html, accessed 15 June 2017.

Japan's extremely high electricity prices to make and store their own electricity and to drop off the grid altogether, as is already happening, for example, in Hawaii and Australia.

Of the 20 reactors in LTO—plus one under construction (Ohma)—currently with applications outstanding before the NRA, not all will restart, with many questions and disagreements over seismic issues (including active fault status), and many plants far back in the review and screening queue. At the present rate of review, restart of three to four reactors each year from 2018 onwards remains an increasingly remote possibility, but also a challenge, with the major uncertainty that even restarted reactors will be shut down through the courts. In this sense, the future of nuclear power in Japan remains highly uncertain.

Figure 19 shows the collapse of nuclear electricity generation in Japan from 287 TWh to 14.5 TWh in 2016. While the most dramatic decline has been since the Fukushima Daiichi accident started in 2011 (3/11), in fact it is 17 years since Japan's nuclear output peaked at 313 TWh in 1998. The noticeably sharp decline during 2002-2003, amounting to a reduction of almost 30 percent, was due to the temporary shutdown of all 17 of Tokyo Electric Power's (TEPCO) reactors.[94] The shutdown was the consequence of an admission from TEPCO that its staff had deliberately falsified data for inclusion in regulatory safety inspections reports.[95] During 2003, TEPCO managed to resume operations of five of its reactors. The further noticeable decline in electrical output in 2007 was the result of the extended shutdown of the seven Kashiwazaki Kariwa reactors, following the Niigata Chuetsu-oki earthquake in 2007.[96] TEPCO was struggling to restart the Kashiwazaki Kariwa units when the Fukushima earthquake occurred.

Figure 19 | Japanese Nuclear Activity Program History



Sources: WNISR, with IAEA-PRIS, 2017

94 - Daiichi means "Number One" and Daini means "Number Two", each referring to a multi-reactor generating complex.

95 - Hiroyuki Kuroda, "Lesson Learned from TEPCO Nuclear Power Scandal", Corporate Communications Department, TEPCO, 24 March 2004, see http://www.tepco.co.jp/en/news/presen/pdf-1/040325-p-e.pdf, accessed 16 June 2017.

96 - TEPCO, "Impact of the Niigata Chuetsu-oki earthquake on the Tokyo Electric Power Company (TEPCO) Kashiwazaki Kariwa Nuclear Power Station and Countermeasures", September 2007, see http://www.tepco.co.jp/en/news/presen/pdf-1/0709-e.pdf, accessed 16 June 2017.

The Fukushima-Daiichi accidents, (see Fukushima Status Report), led to the shutdown of all 50 nuclear reactors in addition to the destruction of the four at the Fukushima-Daiichi site. Announcements in March 2015[97] and March 2016,[98] have seen a total of six nuclear reactors declared for permanent shutdown. In December 2016, the government took a long delayed but strategically highly significant decision to decommission the prototype Monju Fast Breeder reactor, which had not operated since 1995.[99] Six years on from the triple reactor meltdown at Fukushima Daiichi, the consequences of the accident continue to define the future prospects for nuclear energy in Japan.

A consistent majority of Japanese citizens, when polled, continue to oppose the continued reliance on nuclear power, support its early phase-out, and remain opposed to the restart of reactors—a recent poll in March 2017 showed 53 percent opposed to reactor operations, with those in favor declining to 26 percent compared with 30 percent in 2016.[100]

The Kumamoto earthquake that struck the island of Kyushu in mid-April 2016[101] has continued to resonate in the public discourse over the seismic risks of nuclear reactor operation, including in ongoing legal court cases against reactor restarts. The fact that the largest earthquake to hit Kyushu since 1889 took place in the region of Japan's only operating nuclear plant raised further widespread public and political opposition, including criticism of the seismic risk assessments of NRA.[102] The Kumamoto seismic events were unique in that, for the first time, two registered level-7 earthquakes on the Japanese seismic intensity scale occurred in separate municipalities, they are also the first twin earthquakes to register intensity 7, since the adoption of the Japanese scale in 1949, according to the Japan Meteorological Agency (JMA).[103]

Energy Policy

The government of Prime Minister Abe decided that a nuclear share of 20-22 percent, renewable energy of 22-24 percent, and fossil fuels 56 percent would be achieved by 2030.[104] Challenges to the proposed nuclear share were evident inside the drafting subcommittee, with dissenting expert opinions that the nuclear share did not reflect a 2014-commitment to reduce nuclear power to the extent possible.[105] To attain that nuclear share, all 26 reactors that have

97 - *WNISR*, "Japanese Utilities Confirm Closure of Five Reactors", 21 March 2015, see http://www.worldnuclearreport.org/Japanese-Utilities-Confirm-Closure.html, accessed 13 June 2017.

98 - *WNISR*, "Permanent Closure of Japanese Reactor Ikata-1", 26 March 2016, see http://www.worldnuclearreport.org/Permanent-Closure-of-Japanese-Reactor-Ikata-1.html, accessed 14 June 2017.

99 - *WNISR*, "Japanese Government Pulls the Plug on Fast Breeder Reactor Monju", 23 December 2016, see https://www.worldnuclearreport.org/Japanese-Government-Pulls-the-Plug-on-Fast-Breeder-Reactor-Monju.html, accessed 14 June 2017.

100 - *The Mainichi*, "55% oppose restarting nuclear reactors, 26% in favor: Mainichi survey", 13 March 2017, see https://mainichi.jp/english/articles/20170313/p2a/00m/0na/006000c, accessed 14 June 2017.

101 - *Bloomberg*, "Japan's Worst Quake Since 2011 Seen Delaying Nuclear Starts", 26 April 2016, see https://japansafety.wordpress.com/2016/04/27/japans-worst-quake-since-2011-seen-delaying-nuclear-starts-bloomberg/amp/, accessed 16 June 2017.

102 - *South China Morning Post*, "Activists, residents in Japan protest against restart of two Sendai nuclear reactors located less than 150km from recent quakes' epicentre", 18 April 2016, see http://www.scmp.com/news/asia/east-asia/article/1936923/activists-residents-japan-protest-against-restart-two-sendai, accessed 19 June 2017.

103 - *The Mainichi*, "Kumamoto temblors are first twin level-7 quakes on record: JMA", 21 April 2016, see http://mainichi.jp/english/articles/20160421/p2a/00m/0na/007000c, accessed 19 June 2017.

104 - CleanTech Institute, "Japan Announces Energy Mix Plan for 2030", 1 May 2015, see http://techon.nikkeibp.co.jp/english/NEWS_EN/20150501/416800/?ST=msbe, accessed 12 May 2016.

105 - *Asahi Shimbun*, "Nuclear power crucial as renewable energy too costly, ministry says", 27 May 2015.

applied for NRA review would have to be operating, plus most of those yet to be reviewed, a prospect that in reality is unattainable. A 15-percent target would require either the operation of all 26 reactors that have applied to the NRA for review, and therefore include the operation of reactors beyond their 40-year lifetime; or a combination of 40-year plus reactors together with additional reactors that have yet to apply for review.

The Japanese government will launch a revision of its Strategic Energy Plan during 2017 with the aim of a revised plan approved by the Cabinet before the end of fiscal 2017. The Ministry for Economy, Trade and Industry (METI) restated that the new plan will retain the current version's commitment to reducing dependence on nuclear energy "to the extent possible" and advocating accelerated adoption of wind, solar and other renewable energy sources. The expert panel will then pass the issue to a METI energy committee, prior to public comment and consideration by Cabinet in March 2018.

Specifically, the uncertainties in the prospects for reactor restart mean that, no matter what target percentage is set in the next strategic energy plan, the Japanese Government and utilities simply do not know how many of Japan's 33 reactors in LTO will be restarted, nor when.

The 2014 Strategic Energy Plan maintained the long-standing government policy of promoting spent nuclear fuel reprocessing and plutonium mixed oxide fuel (MOX) use in commercial reactors. In a further signal of tensions and challenges within Japan's nuclear industry, the Federation of Electric Power Companies (FEPC), which represents the nation's ten nuclear power utilities, announced on 20 November 2016 the indefinite postponement of a target date for loading plutonium MOX fuel into 16-18 reactors.[106] The plans to use MOX fuel have for the past two decades been the justification used for Japan's accumulation of plutonium through reprocessing. With the restart during the past 12 months of the Ikata-3, and more recently Takahama-3 and -4, three of the five reactors in operation in Japan are operating with MOX fuel.

Restarts

On 15 August 2016, the Ikata-3 reactor in Ehime Prefecture on the island of Shikoku was reconnected to the grid, becoming the third operational reactor in Japan after nuclear-free 2014,[107] Takahama-3 operating between January and March 2016. The 846 MW reactor had been shut down since 29 April 2011. Operator Shikoku Electric Power Company had received final approval from the Nuclear Regulation Authority (NRA) on 19 April 2016. Ikata-3 operates with 16 MOX fuel assemblies. As elsewhere throughout Japan, lawsuits were filed against operations of the Ikata plant. In the case of Unit 3, citizens filed four injunction requests in cities across the region. The injunction lawsuits filed, including at the Matsuyama District Court in 2016,[108] was given additional weight given the Kumamoto earthquake in Kyushu in April 2016, close to Shikoku and the Ikata plant. The plant is at risk from the massive Nankai Trough and the Median Tectonic Line fault belt—Japan's largest-class and longest fault zone—which

106 - *Nucleonics Week*, "Japan postpones plans to use MOX fuel", 26 November 2015.

107 - *WNISR*, "Ikata-3 Restarted—Only Three Reactors Operate in Japan", 17 August 2016, see https://www.worldnuclearreport.org/Ikata-3-Restarted-Only-Three-Reactors-Operate-in-Japan.html, accessed 15 June 2017.

108 - *The Mainichi*, "Residents to file petition for Ikata plant injunction following Kumamoto quake", 18 May 2016, see http://mainichi.jp/english/articles/20160518/p2a/00m/0na/009000c, accessed 15 June 2017.

runs near the Ikata plant. On 30 March 2017, an injunction request sought by plaintiffs in the Hiroshima District Court was turned down.[109] The three other injunction lawsuits were pending as of 1 July 2017.

As of 1 July 2017, two additional reactors restarted operations this past year. Takahama-4 was connected to the grid on 22 May 2017[110] and likewise Takahama-3 on 9 June 2017.[111] Both Takahama reactors, owned by Kansai Electric Power Company (KEPCO), are operating with a partial MOX fuel core, supplied by French company AREVA, with 24 assemblies in unit 3 and four assemblies in unit 4.

The restart of the Takahama-3 and -4 reactors followed a 28 March 2017 ruling by the Osaka High Court in western Japan, which overturned an injunction against operation of the Takahama-3 and -4 reactors.[112] Both reactors had been ordered shutdown in a landmark ruling by the Otsu District Court in Shiga prefecture on 9 March 2016 filed by 29 citizens of the prefecture, which borders Fukui prefecture, where the reactors are located.[113]

The Otsu court had ruled that fulfilling the new NRA requirements was not sufficient to secure safety at the Takahama reactors, given that the regulations were established while the investigation into the 2011 Fukushima disaster was incomplete.[114] The Shiga court had ruled that thorough survey of geological faults around the Takahama plant had yet to be conducted, and that KEPCO's claim that its reactors have a sufficient safety cushion to withstand the largest tremors projected was doubtful. KEPCO countered that the new requirements fully incorporate lessons learned from the triple meltdown at the Fukushima Daiichi nuclear plant by obliging operators to prepare for a more powerful earthquake, tsunami and other natural phenomenon that could trigger an accident.

The two Takahama reactors had been subject of two successful injunctions brought by Japanese citizens, both of which have now been overturned on appeal.

As reported in WNISR in 2016, the credibility and effectiveness of the NRA has been challenged in recent years, not least by the highly critical IAEA Integrated Regulatory Review Service (IRRS). On 7 September 2016, the NRA decided to implement by March 2020 a revised approach to reactor inspections that will make nuclear operators primarily responsible for inspections, as recommended in the IRRS report.[115] The proposed amendments to the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors were to be adopted

109 - *The Japan Times*, "Hiroshima court blocks request to halt reactor in Ehime", 30 March 2017, see http://www.japantimes.co.jp/news/2017/03/30/national/hiroshima-court-blocks-request-halt-reactor-ehime/ - .WUaPrBN95E4, accessed 15 June 2017.

110 - Kansai Electric Power Company, "Start of Power Generation at Takahama Unit No. 4", 22 May 2017, see http://www.kepco.co.jp/english/corporate/pr/2017/__icsFiles/afieldfile/2017/05/22/2017_may22_2.pdf, accessed 15 June 2017.

111 - Kansai Electric Power Company, "Start of Power Generation at Takahama Unit No. 3", 9 June 2017, see http://www.kepco.co.jp/english/corporate/pr/2017/__icsFiles/afieldfile/2017/06/09/2017_jun9_2.pdf, accessed 15 June 2017.

112 - Kansai Electric Power Company, "Decision on petition of appeal pertaining to temporary restraining order against provisional disposition order pertaining to demand of injunction preventing resumption of operation of Units 3 and 4 of Takahama Nuclear Power Plant", 28 March 2017, see http://www.kepco.co.jp/english/corporate/ir/brief/pdf/2017_mar28_2.pdf, accessed 15 June 2017.

113 - Kansai Electric Power Company, "Decision of a provisional disposition preventing the operation of Units 3 and 4 of Takahama Nuclear Power Station", 9 March 2016, see http://www.kepco.co.jp/english/corporate/pr/2016/__icsFiles/afieldfile/2016/03/09/2016_mar9_2.pdf, accessed 20 June 2017.

114 - *WNISR*, "Japan: Court Overturns Injunction Against Operation of Takahama-3 and 4", 29 March 2017, see https://www.worldnuclearreport.org/Japan-Court-Overturns-Injunction-Against-Operation-of-Takahama-3-and-4.html, accessed 15 June 2017.

115 - *NW*, "Japan regulator NRA to implement reactor inspection reforms by 2020", S&P *Platts*, Vol.57, No.36, 8 September 2016.

by March 2017 and to be considered by the Japanese Diet during 2017. The IAEA report on the NRA is unusually forthright and critical and is at variance with the repeated claims of the NRA Chair, Shunichi Tanaka, that Japanese regulatory standards are "internationally recognized as being the strictest in the world."[116]

Critical Aging and Life Extensions

A major determinant in the eventual number of reactors operated in Japan will be ageing, permanent decommissioning, and life extension decisions of nuclear power plants. As of 1 July 2017, a total of six commercial power reactors and the Monju prototype FBR (see Table 4) have officially been closed permanently, not including Fukushima. This is a significant departure from the position of utilities prior to the Fukushima Daiichi nuclear accident, when they and the Ministry for Economy, Trade and Industry (METI) were proposing operation of nuclear reactors beyond 60 years.[117] The decision to permanently shut down these reactors highlights aging issues and lack of public acceptance confronting Japan's nuclear power utilities.

Table 4 | Japanese Reactors Officially Shut Down Post-3/11

Owner	Unit	Capacity MW	Grid Connection	Official Shutdown dd/mm/yy	Last Production	Age [a]
TEPCO	Fukushima Daiichi-1 (BWR)	439	1970	-	2011	40
	Fukushima Daiichi-2 (BWR)	760	1973	-	2011	37
	Fukushima Daiichi-3 (BWR)	760	1974	-	2011	36
	Fukushima Daiichi-4 (BWR)	760	1978	-	2011	33
	Fukushima Daiichi-5 (BWR)	760	1977	19/12/13	2011	34
	Fukushima Daiichi-6 (BWR)	760	1979	19/12/13	2011	32
Kansai Electric	Mihama Unit 1 (PWR)	340	1970	17/03/15	2010	40
	Mihama Unit 2 (PWR)	500	1972	17/03/15	2011	40
Kyushu Electric	Genkai Unit 1 (PWR)	559	1975	18/03/15	2011	37
Shikoku	Ikata Unit 1 (PWR)	538	1977	25/03/16	2011	35
JAEA	Monju (FBR)	246	1995	2016	LTS [b] since 1995	-
JAPC	Tsuruga Unit 1 (BWR)	357	1969	17/03/15	2011	41
Chugoku Electric	Shimane Unit 1 (PWR)	460	1974	18/03/15	2010	37

Sources: Various sources, compiled by WNISR, 2017

a - Note that WNISR considers the age from first grid connection to last production
b - The Monju reactor was officially in LTS (IAEA-Category Long Term Shutdown) since December 1995

116 - Japan Atomic Industrial Forum, "Kansai EP Appeals Court Decision Prohibiting Restarts of Takahama NPPs", 22 April 2015, see http://www.jaif.or.jp/en/kansai-ep-appeals-court-decision-prohibiting-restarts-of-takahama-npps/, accessed 19 June 2017.

117 - T. Tsukada, Y. Nishiyama, et. al., "Research Programs On Aging Of Reactor Structural Materials At Japan Atomic Energy Research Institute", Japan Atomic Energy Research Institute, published in IAEA, "Nuclear power plant life management", proceedings of a symposium held in Budapest, 4-8 November 2002, see http://www-pub.iaea.org/mtcd/publications/pdf/csp_021c/pdf/contents.pdf; and T. Noda, K. Tajima, et al., "Current Approaches To Nuclear Power Plant Life Management In Japan", Nuclear And Industrial Safety Agency (NISA), METI, Japan Nuclear Power Plant Life Engineering Center (PLEC), Japan Power Engineering And Inspection Corporation (JAPEIC), Japan, 2002, see https://inis.iaea.org/search/search.aspx?orig_q=RN:34005329; both accessed 19 June 2017.

Before 3/11, Japan had 54 commercial nuclear reactors, including three in Long-Term Outage (LTO). As a result of the accident, the six reactor units at Fukushima Daiichi are to be decommissioned over the coming decades, which reduces the total number of reactors officially "in operation" to 42. Tokyo Electric Power Company (TEPCO) has yet to announce the permanent closure of its four Fukushima Daini reactors located 12 km south of the Fukushima Daiichi site. However, given the devastation of the accident to Fukushima Prefecture, and resultant opposition to TEPCO and nuclear power in that Prefecture and wider Japan, there is no prospect that these reactors will restart.[118] In September 2016, the Fukushima Prefectural government announced that it is planning to work with 11 municipalities to reach a collective agreement with TEPCO on assessing the safety of the Fukushima Daini reactors, the objective being the permanent shutdown of the plant.[119] WNISR has taken them off the list of operating reactors in the first edition following 3/11.

The decision to permanently shut down Ikata-1, mirrors the decision-making of other utilities in having to assess the financial implications of retrofitting the reactor to meet post-Fukushima safety standards, which, in the case of Ikata, Shikoku Electric were estimated at ¥200 billion ($1.77 billion).[120] The conclusion reached was that with a relatively small output capacity and up to four years required to complete the work, the remaining operational life of the reactor would not generate sufficient income to justify the investment. The decision reverses Shikoku's earlier position of planning for the restart of Ikata-1.

The six reactors to be decommissioned had a total installed generating capacity of 2.7 GW, equal to 5.6 percent of Japan's nuclear capacity as of March 2011. Together with the ten Fukushima units, the total rises to 16 reactors and, at the very least, 11.4 GW or 24 percent of installed nuclear capacity prior to 3/11 that has been removed from operations. The permanent closure of six reactors reduces the average age of Japan's remaining nuclear fleet, including 33 units in LTO, to 27.8 years, as of 1 July 2017 (see Figure 20).

The future nuclear generating capacity of Japan will be largely determined by decisions on operating reactors beyond 40 years. In 2016, KEPCO secured approval for the operation of Takahama-1 and -2, which were 42 and 41 years old respectively, and the Mihama-3 reactor. On 14 November 2014, the NRA had granted a ten-year life extension for Takahama-1, and on 8 April 2015 for Takahama-2.[121] Under the revised law on nuclear power plant regulations, the time limit for running a nuclear reactor is 40 years. This can be extended only once, by up to 20 years, if certain conditions are met. On 30 April 2015, KEPCO applied for a 20-year life extension for the two Takahama reactors.[122] NRA requirements were to be met by 7 July 2016 as a deadline for life-extension approvals to be granted for the Takahama units, and November 2016 for Mihama. The NRA, on 24 February 2016, announced that the Takahama

118 - Mitsuru Obe, "Tepco May Scrap Second Nuclear Plant", *The Wall Street Journal*, 4 July 2012, see http://www.wsj.com/articles/SB10001424052702304141204577506531300365556, accessed 19 June 2017.

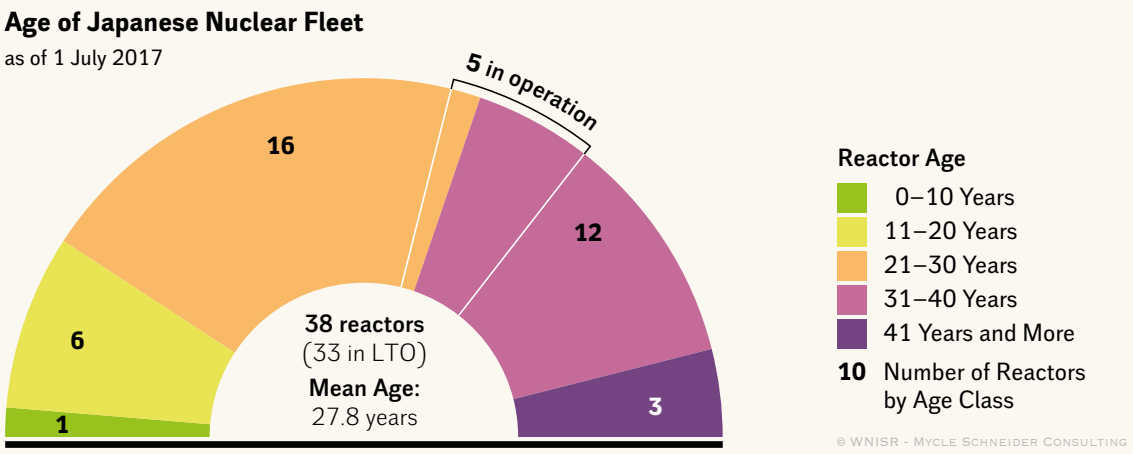
119 - S&P *Platts*, "Local governments to work together to scrutinize Tepco's Fukushima II", *NW*, Vol.57, No.41, 13 October 2016.

120 - *WNISR*, "Permanent Closure of Japanese Reactor Ikata-1", 26 March 2016, see http://www.worldnuclearreport.org/Permanent-Closure-of-Japanese-Reactor-Ikata-1.html, accessed 19 June 2017.

121 - *The Japan Times*, "Kepco asks for permission to run 40-year-old reactors for 20 more years", 1 May 2015.

122 - Ibidem.

Figure 20 | Age Distribution of Japanese Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2017

units were compatible with the 2013 safety guidelines;[123] and on 20 June 2016 the NRA, for the first time, approved a 20-year extension for the two Takahama reactors as meeting the new regulatory guidelines.[124] Welcoming the NRA approval, the President of the Japan Atomic Industrial Forum (JAIF) said: "Japan intends to provide 20% to 22% of its total generated electricity using nuclear power by 2030. Given that it is essential, in order to realize this target, not only to restart the existing plants but to have their 40-year operating limits get extended, this approval will serve as a precedent for other NPPs aiming at such extensions."[125]

On 14 April 2016, citizens filed an administrative lawsuit in the Nagoya District Court against the NRA approval of extended operation of the Takahama reactors, a case that in July 2017 is ongoing.[126] In any case, KEPCO does not expect the two Takahama units to resume operations before November 2019, at the earliest, because extensive retrofits will need to be implemented prior to restart. KEPCO has a license to operate units-1 and -2 until 2034 and 2035 respectively.

On 20 January 2017, as a result of a winter storm, the boom arm of a 112-meter tall crane collapsed at the Takahama plant, landing on the unit-2 reactor- and spent-fuel-handling-buildings.[127] KEPCO failed to notify the contractor operating the crane of a storm warning. Four large cranes are on-site for the installation on unit-2 of a shielding containment-dome. The collapse of the crane has significantly added to local opposition to plans to operate the Takahama-1 and -2 units.

123 - JAIF, "NRA Approves Takahama-1 and -2 NPPs as Compatible with New Regulatory Standards", 25 February 2016, see http://www.jaif.or.jp/en/nra-approves-takahama-1-and-2-npps-as-compatible-with-new-regulatory-standards/, accessed 20 June 2017.

124 - JAIF, "NRA Approves Extensions of Operating Periods to 60 Years for Takahama-1 and -2, the First for Aging Reactors", 22 June 2016, see http://www.jaif.or.jp/en/nra-approves-extensions-of-operating-periods-to-60-years-for-takahama-1-and-2-the-first-for-aging-reactors/, accessed 20 June 2017.

125 - Ibidem.

126 - JAIF, "Anti-nuclear Groups Sue in Nagoya District Court to Block Extended Lifetime for Takahama Units 1&2", 18 April 2016, see http://www.jaif.or.jp/en/nuclear-opponents-sue-in-nagoya-district-court-to-block-extended-lifetime-for-takahama-units-12/, accessed 20 June 2017.

127 - *The Japan Times*, "Crane falls on building with spent nuclear fuel at Takahama plant", 21 January 2017, see http://www.japantimes.co.jp/news/2017/01/21/national/crane-falls-building-spent-nuclear-fuel-takahama-plant/ - .WUc7-xN95E4, accessed 15 June 2017.

KEPCO had already opted to decommission the Mihama-1 and -2 reactors in 2015, and there were major doubts that it would proceed with plans to operate Mihama-3. In March 2016, KEPCO disclosed that the current estimate for retrofit of Mihama-3 to bring it into compliance with NRA regulations is ¥270 billion (US$2.4 billion).[128] KEPCO later revised this figure to ¥165 billion (US$1.5 billion). A significant part of this cost relates to seismic resistance measures required to meet the higher Design Basis Ground Motion.

However, KEPCO was able to secure approval from the NRA before the 30 November 2016 deadline for approval of 20-year extension. On 16 November 2016, the NRA approved a review report for Mihama-3 that is effectively an approval of the extension, after examinations of the effects of deterioration and other items.[129] The approval came in for criticism as many of the safety retrofits at the plant will only be completed during the years to January 2020, including additional fire proofing of a thousand kilometers of electric cables and conducting seismic retrofitting for safety-related systems and equipment. Mihama-3 will be permitted to operate until the end of November 2036, some sixty years since operation began.

On 7 June 2017, KEPCO management formally decided to proceed with retrofits at the Mihama-3 plant with the aim of restarting the plant in FY2020, some ten years after the reactor was shut down in April 2011 in the immediate aftermath of the Fukushima Daiichi accident.[130] The decision reflects the ongoing commitment to operating nuclear power by KEPCO, and the strategic importance of life-extension decisions. KEPCO is planning also to apply for 20-year extension for the Ohi-1 and -2 reactors, which are 39.5- and 38.7-years old respectively. JAPCO (Japan Atomic Power Company) has yet to indicate, whether it will apply for life extension for its 39-year old BWR Tokai-2 unit. The reactor remains under NRA review with major doubts as to whether it will secure approval.

Monju Shutdown

In the past year, one further reactor was declared for permanent shutdown, when the Japanese government announced on 21 December 2016 its decision to permanently shut down the 280 MWe Prototype Monju sodium-cooled Fast Breeder Reactor (FBR).[131] The decision is of considerable strategic significance given the central role fast reactor development has played in overall Japanese nuclear policy over the past four decades. While the decision has taken years to be made, and to some extent is merely the Japanese government catching up with the reality of a failed project, it also reflects the ongoing crisis in the nation's nuclear energy policy.

The reactor, located at Tsuruga in Fukui Prefecture, western Japan, and owned by the Japan Atomic Energy Agency (JAEA), was a central element in the nation's plutonium program, and was intended to form the basis for commercial deployment of fast reactors in the future. After

128 - *Nikkei Online*, "KEPCO: Nuclear Restart Plans Upset, Mihama No. 3 Closure a Possibility", 19 March 2016, (in Japanese), see http://www.nikkei.com/article/DGXLZO98651920Y6A310C1TI1000/, accessed 20 June 2017.

129 - JAIF, "NRA Approves Extension of Operating Lifetime for Mihama-3 through 2036", 17 November 2016, see http://www.jaif.or.jp/en/nra-approves-extension-of-operating-lifetime-for-mihama-3-through-2036/, accessed 16 June 2017.

130 - KEPCO, "Plan of safety improvements works at Mihama Nuclear Power Station unit 3 to allow for its operation for 60 years", 8 June 2017, see http://www.kepco.co.jp/english/corporate/ir/brief/pdf/2017_jun8_1.pdf, accessed 16 June 2017.

131 - *The Asahi Shimbun*, "Editorial: Government still refuses to face up to reality, failure of Monju project", 22 December 2016, see http://www.asahi.com/ajw/articles/AJ201612220041.html, accessed 13 June 2017.

more than two decades, Monju had operated a total of 250 days , was connected to the grid for a few months only and never reached 100 percent capacity.

Announcing the decision, Chief Cabinet Secretary Yoshihide Suga stated: "We will decommission Monju, given that it would take a considerable amount of time and expense to resume its operations."[132] The government has calculated, it will cost at least ¥375 billion (US$3.2 billion) over 30 years to fully decommission Monju,[133] on top of the 1 trillion yen (US$8.5 billion) already invested in the reactor over the past decades. It is proposed to remove the spent nuclear fuel from the reactor by 2022 and finish dismantling the facility in 2047. In June 2017, the Governor of Fukui Prefecture, which hosts the Monju FBR, finally accepted the Government's decision to decommission the reactor.[134]

After more than two decades,
Monju had operated a total of 250 days

Construction of Monju began in Chernobyl-year 1986, and criticality was achieved in April 1994, with grid connection following in August 1995. In December 1995, the reactor suffered a molten sodium coolant fire, which kept it closed until 2010. It operated on limited capacity for three months between May and August 2010, when a heavy in-vessel transfer machine fell onto the reactor vessel.

In November 2015, the NRA declared the JAEA as unfit for purpose, and that a new entity would be required to manage the reactor, or, if that proves not possible, to take the decision to permanently shut down the reactor. In November 2016, it was estimated that any restart of Monju would take eight years.[135]

The government attempted to present the Monju decision as not impacting overall nuclear policy, specifically its plans for spent-fuel reprocessing and plutonium-bearing MOX fuel use. "The nuclear fuel cycle is at the core of our energy policy," said METI Minister Hiroshige Seko.[136] METI will take over from the science ministry in overseeing the development of potentially more practical fast reactors. "We will make full use of the highly valuable knowledge and expertise acquired at Monju as we move forward with fast reactor development, (...) first by concentrating on creating a strategic roadmap," Seko said.

In November 2016, the Council on Fast Reactor Development, set up by the Government to propose options for the future of fast reactor development, agreed on the construction in Japan of a demonstration reactor—the step after the implementation of a prototype reactor like Monju. In reality, this is not a new policy, as earlier this decade the Fast Reactor Cycle Technology

132 - *Nikkei Asian Review*, "Shutting Monju reactor dampens Japan's nuclear dreams", 22 December 2016, see http://asia.nikkei.com/Politics-Economy/Policy-Politics/Shutting-Monju-reactor-dampens-Japan-s-nuclear-dreams, accessed 14 June 2017.

133 - *The Asahi Shimbun*, "Shuttering Monju reactor to take 375 billion yen and 30 years", 19 December 2016, see http://www.asahi.com/ajw/articles/AJ201612190054.html, accessed 13 June 2017.

134 - Takashi Sugimoto, "Fukui governor accepts decision to decommission Monju reactor", *The Asahi Shimbun*, 7 June 2017, see http://www.asahi.com/ajw/articles/AJ201706070036.html, accessed 13 June 2017.

135 - *NucNet*, "Eight Years Needed To Restart Japan's Monju FBR, Says Minister", 30 November 2016, see http://www.nucnet.org/all-the-news/2016/11/30/eight-years-needed-to-restart-japan-s-monju-fbr-says-minister, accessed 14 June 2017.

136 - *The Japan Times*, "Monju prototype reactor, once a key cog in Japan's nuclear energy policy, to be scrapped", 21 December 2016, see http://www.japantimes.co.jp/news/2016/12/21/national/monju-prototype-reactor-key-cog-japans-nuclear-energy-policy-scrapped/ - .WUSoJBN95E4, accessed 13 June 2017.

Development Project was launched with the aim of a design selection and construction of a demonstration 500 MW Japan Sodium Fast Reactor (JSFR) from 2015, with operation from 2025. Even before the Fukushima Daiichi accident, there were no realistic prospects for the JSFR reactor being built in the timeframe envisaged. It remains unclear, to what extent Japan will continue or extend its collaboration with France on the ASTRID demonstration fast reactor design. Japan's one remaining fast reactor, the experimental Joyo FBR in Oarai, Ibaraki, has remained shut down since 2007, and it is proposed by JAEA that it restarts operations in 2021.

Without a doubt, the decision to terminate the Monju project, long considered a failure and unlikely to ever operate successfully, could have been made years before now. That it was not was in part due to concern that it would raise questions about overall Japanese plutonium policy and have a wider negative impact on nuclear power generation itself. The decision finally has been made, but the questions remain.

New Build Projects

The situation of new-build projects is another illustration of the level uncertainty surrounding the future of nuclear power in Japan. After the 3/11 events, Japan halted work at two ABWR units, Shimane-3 and Ohma, which had been under construction since 2007 and 2010 respectively. In September 2012, METI approved the restart of construction at both sites, but there was little sign of any resumption of work. Officially, construction "partially resumed" at Ohma in October 2012 and Shimane-3 has remained "under construction and is almost complete", according to the Japan Atomic Industrial Forum (JAIF)[137] and IAEA statistics. In the case of Shimane-3, it was 94 percent complete by March 2011.[138] Since then, Chugoku Electric, the plant owner, completed a 15 m-high sea wall around Shimane-3 in January 2012, and then extended the seawall to a length of 1.5km.[139] The utility began work to install filtered vents during 2014-2015, and other modifications "pursuant to the new regulatory requirements".[140] No startup date has been declared for the reactor and while the utility is drawing up an application to the NRA for permission for change in reactor installation license, as of 1 July 2017, no application had been submitted.

In the case of Ohma, which was 40 percent complete by March 2011, the plant owner, the Electric Power Development Company (EPDC), also known as J-Power, declared that reinforced safety measures are to be implemented that take into account the lessons learned from the Fukushima accident, which include tsunami countermeasures, ensuring power supplies, ensuring heat removal functions, and severe accident responses. J-Power applied to the NRA on 16 December 2014 for review of the Ohma reactor.[141] The construction works for these mea-

137 - JAIF, "Nuclear Power Plants in Japan", 20 June 2017, see http://www.jaif.or.jp/en/npps/shimane-3/, accessed 20 June 2017.

138 - Sang-Baik Kim, Jan-Horst Keppler, "Case Studies On Project And Logistics Management In Nuclear New Built The ABWR Project at Shimane-3", NEA OECD, Nuclear Development Division, as presented at the OECD NEA Workshop on Project and Logistics Management, Paris (France), 11 March 2014, see http://docplayer.net/13785016-The-abwr-project-at-shimane-3-japan.html, accessed 20 June 2017.

139 - *NEI*, "New-build now. Part 2: Asia", 9 July 2014, see http://www.neimagazine.com/features/featurenew- build-now-part-2-asia-4313945/, accessed 20 June 2017.

140 - Chugoku Electric Power Company, "Annual Report 2015—Year ended 31 March 2015", see http://www.energia.co.jp/e/ir/report/pdf/ar15/ar15.pdf, accessed 20 June 2017.

141 - JAIF, "EPDC Submits Application for Compatibility Review for Ohma NPP", 18 December 2014, see http://www.jaif.or.jp/en/epdc-submits-application-for-compatibility-review-for-ohma-npp/, accessed 20 June 2017.

sures were scheduled to begin in November 2015 and to be completed in December 2020.[142] The budget for construction of the additional safety features is some JPY130 billion (US$1.1 billion).

However, in terms of construction of the reactor building, the Reactor Pressure Vessel (RPV), containment vessel liner and other main equipment have not been installed (in the case of the RPV a temporary storage building has been built to protect the RPV against extreme winter weather).[143] The underground concrete-structure base has been constructed, but effectively construction at the site has been suspended according to J-Power.[144]

J-Power on 9 September 2016 announced its decision to postpone its planned operating date for Ohma by two years until 2024, "due to longer-than-expected safety tests by the nuclear regulatory body."[145] This was the second postponement, with its earlier plan to start operation in 2021.

Ohma is planned to operate with a 100 percent plutonium MOX core, and is therefore of major strategic significance in terms of Japan's nuclear fuel policy, including the operation of the Rokkasho-mura reprocessing plant.[146]

Prospects for completion of construction and operation are directly linked to ongoing lawsuits, one by local citizens and another from the city of Hakodate, both of which are seeking cancellation of the project. The Hakodate city lawsuit is challenging both the central government and J-Power in the first such lawsuit in Japan.[147] The citizen lawsuit injunction concluded its hearings in spring 2017, with the technical evidence focused on seismic and volcano risks, and flaws in the ABWR design and construction given that it pre-dates the 2011 Fukushima Daiichi accident, including the capability of the plant to manage core melt. Submissions to the court challenging J-Power noted that the final design, regulatory approval and construction of the nuclear island containment barrier for Ohma have yet to be completed.[148] A court decision is expected before the end of 2017; with evidence in the Hakodate city lawsuit expected to run through 2018.

Although there remain major obstacles for both reactors, with little public information on the exact status and advancement of construction, and, in the case of Shimane-3, no communication of a planned grid-connection date, considering that some construction work is reportedly ongoing at the Shimane site, for the time being, WNISR maintains the current status of Shimane-3 as under construction, whereas it removes Ohma from its listing of reactors under construction.

142 - *WNN*, "Completion of Ohma 1 expected in 2020", 14 November 2014, see http://www.world-nuclear-news.org/NN-Completion-of-Ohma-1-expected-in-2020-1411144.html, accessed 20 June 2017.

143 - J-Power, "Ohma Nuclear Power Plant", 5 September 2016, see https://www.nsr.go.jp/data/, accessed 20 June 2017.

144 - Ibidem.

145 - *The Japan Times*, "J-Power delays plan to begin operating Oma nuclear plant until 2024", 9 September 2016, see http://www.japantimes.co.jp/news/2016/09/09/national/j-power-delays-plan-begin-operating-oma-nuclear-plant-2024/ - .WUlC3BN95E4, accessed 20 June 2017.

146 - Shaun Burnie, Frank Barnaby, et al., "Nuclear Proliferation in Plain Sight: Japan's Plutonium Fuel Cycle—A Technical and Economic Failure But a Strategic Success", *The Asia-Pacific Journal*, Vol.14, Issue 5, No.2, 1 March 2016, see http://apjjf.org/2016/05/Burnie.html, accessed 20 June 2017.

147 - *The Japan Times*, "Hakodate's Valid Nuclear Concern", Editorial, 9 April 2014, see http://www.japantimes.co.jp/opinion/2014/04/09/editorials/hakodates-valid-nuclear-concern/, accessed 20 June 2017.

148 - Large & Associates, "On Aspects Relating To The Operational Nuclear Safety Of The Ōma Nuclear Power Plant, Aomori Insufficiencies And Incompleteness Of The Design, Construction And Nuclear Safety Case Submissions Available In The Public", 21 February 2017.

SOUTH KOREA FOCUS

On the Korean Peninsula, South Korea (Republic of Korea) operates 24 reactors, one less than 2016, as a result of the permanent shutdown of the Kori-1 reactor on 18 June 2017.[149] South Korea's nuclear fleet are at the Hanbit, Hanul, Kori and Wolsong sites. Nuclear power provided a record 154.31 TWh, supplying 30.3 percent of the country's electricity in 2016, compared with the record 157.23 TWh and 31.7 percent in 2015, and down from a maximum of 53.3 percent in 1987. Three additional reactors are under construction, one of which was scheduled to start up in 2017 (Shin-Kori-4). As of 1 July 2017, fuel loading is expected in January 2018.[150] Beyond the statistics, the future direction of Korean energy policy, including nuclear power, was thrown into uncertainty with the election of President Moon Jae-in May 2017.

The closure of the 40-year-old Kori-1 reactor, was originally based on a decision made by the Ministry of Trade, Industry and Energy on 12 June 2015.[151] Plant owner Korea Hydro and Nuclear Power Co (KHNP), part of the Korea Electric Power Corporation (KEPCO) group, stated then, it would accept the government decision, and the reactor would be shut down in 2017.[152] Construction was completed in 1977 and Kori-1 began commercial operation on 29 April 1978. The reactor has been at the center of civic resistance to its continued operation, including from the nearby city of Busan.[153]

Future of Nuclear Power

The milestone of Korea shutting its first commercial reactor reflects far more than one plant closure as it was conducted under the new government of President Moon Jae-in, who was elected on a platform opposed to nuclear energy. Speaking at a highly symbolic closure ceremony at the Kori site, President Moon declared an end to the country's nuclear-oriented power-generation plan and declared that his administration will pave the way for a nuclear-free era, end plans to build new nuclear power plants and that "we will not extend the lifespan of nuclear reactors".[154] In terms of a new energy policy, Moon stated: "The government will engage more actively in fostering clearer and safer sources of energy, such as new and renewable energies and liquefied natural gas (LNG). We will also make an energy industry associated with the Fourth Industrial Revolution, a new growth engine for the national economy."[155] Implementing

149 - *WNISR*, "South Korea Marks Nuclear Policy Turn by Shutting Down Oldest Reactor", 19 June 2017, see https://www.worldnuclearreport.org/South-Korea-Marks-Nuclear-Policy-Turn-by-Shutting-Down-Oldest-Reactor.html, accessed 2 July 2017.

150 - KHNP, "Nuclear Power Construction—Shin Kori #3,4", 30 June 2017, see http://cms.khnp.co.kr/eng/content/546/main.do?mnCd=EN03020302, accessed 11 July 2017.

151 - Sohn Ji-young, "South Korea to shut down oldest nuke reactor—Kori-1 will become the nation's 1st nuclear reactor to permanently close down", *Korea Herald*, Updated 13 June 2015, see http://www.koreaherald.com/view.php?ud=20150612000846, accessed 10 July 2017.

152 - Kim Eun-jung, "S. Korea to shut down oldest reactor in 2017", *Yonhap News*, 16 June 2015, see http://english.yonhapnews.co.kr/business/2015/06/16/0501000000AEN20150616008100320.html, accessed 10 July 2017.

153 - Nuclear Safety and Security Commission (NSSC), "The NSSC Launched Safety Examination in Preparation of Permanent Shutdown of Kori Unit 1", Press Release, 24 June 2016, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=36875&pager.offset=0&board_no=501, accessed 10 July 2017.

154 - *Korea Herald*, "End of nuclear power", 19 June 2017, see http://www.koreatimes.co.kr/www/opinion/2017/06/202_231501.html, accessed 3 July 2017.

155 - Sohn JiAe, "Kori-1 nuclear reactor's shutdown marks paradigm shift to safer Korea: president", *Korea.net*, 19 June 2017, see http://www.korea.net/NewsFocus/policies/view?articleId=147260, accessed 10 July 2017.

such a policy would be a historic reversal of decades-long Korean nuclear policy. In April 2011, KEPCO presented plans to double installed nuclear capacity to nearly 43 GW by 2030 and bring the nuclear share in the power generation to 59 percent.[156] Korean energy policy is currently heavily based on fossil fuels and nuclear power. With coal at 35 percent, nuclear at about 32 percent, LNG 19 percent, oil 10 percent, new renewables provided only 1.5 percent of the country's total electricity generation in 2016.

President's Moon opposition to nuclear energy reflects a wider societal shift triggered by the Fukushima Daiichi accidents, but also subsequent falsification and corruption scandals that forced the shutdown of multiple reactors.[157] In October 2013, the government confirmed that 100 people, including a top former state utility official, had been indicted on corruption charges in relation to the falsification scandal (see previous WNISR editions for details).

Reflecting the shift in public and political opinion against nuclear power, in 2012, Park Won Soon, Mayor of Seoul, initiated a program entitled "One Less Nuclear Power Plant" with the official target by the end of 2014 to "save away" through energy efficiency and renewable energy roll-out the equivalent amount of energy generated by a nuclear power plant[158]. The target was achieved six months early and "Phase 2" of the Plan stipulates the saving/substitution of the equivalent of another two reactors by 2020. In 2013, the Seoul Metropolitan Government appointed a high-level Seoul International Energy Advisory Council (SIEAC), comprising leading international energy experts, to assist in the design of innovative clean energy policy.[159]

If President Moon's policy is applied, reactors reaching their 40-year operating lifespans will be shut down, the two first ones being Wolsong-1 in 2022 and Kori-2 in 2023, followed by Kori-3 in 2024, Kori-4 and Hanbit-1 in 2025, and Hanbit-2 and Wolsong-2 in 2026. A critical issue will be whether such a policy will be implemented by his successor, besides the two first ones. Given the fixed five-year term presidents serve in South Korea, Moon will vacate his position in 2022.

The first direct impact on Korea's nuclear industry after the election of President Moon came at a 27 June 2017 Cabinet meeting, where it was decided to suspend construction of the APR 1400 MW Shin-Kori-5 and-6 reactors. "The new administration named a halt to construction of the Shin-Kori-5 and -6 reactors as an election pledge as a part of its post-nuclear power policies," said Office of Government Policy Coordination director Hong Nam-ki.[160] The decision came one year after the Nuclear Safety and Security Commission (NSSC) approved by a majority the construction permits for Shin-Kori-5 and -6. Though preparation work has begun at the site, actual construction of the reactor buildings has not begun, though it is widely cited as 28 percent complete as of end of May 2017. As of 1 July 2017, no first concrete had been pou-

156 - Ki Hak Kim, "Fueling the Sustainable Future", 6 April 2011.

157 - Korean Institute of Nuclear Safety, "Safety Focus—CFSI (Counterfeit, Fraudulent, Suspect Item) Investigation", Undated, see http://www.kins.re.kr/en/ourwork/cfsi.jsp, accessed 10 July 2017.

158 - Roughly 2 MTOE (million tons of oil equivalent), calculated on the primary energy side.

159 - For a list of SIEAC Members and background see https://www.ieac.info. SIEAC is coordinated by Mycle Schneider.

160 - Jung In-hwan, Kim Sung-hwan, "Construction to be suspended on fifth and sixth Shin-Kori nuclear reactors", *The Hankyoreh*, 28 June 2017, see http://www.hani.co.kr/arti/english_edition/e_business/800632.html, accessed 10 July 2017.

red for the base mat of the reactor building. A formal halt to work at the site has been decided at a KHNP Board meeting on 14 July 2017.[161]

As part of the decision-making process on the future of the Shin-Kori reactors, the government will form a public debate committee, including ten neutral members, which is to meet over three months. Though not tasked with final decision-making authority, it will draw up plans for public opinion consultation. The final decision will be made by a citizen jury.[162]

Construction continues on the APR1400 Shin-Hanul-1 and -2 units, which are scheduled to begin operation in April 2018 and February 2019 respectively. However, in late May 2017, KHNP suspended design work for Shin-Hanul-3 and -4, until the new government clarifies its nuclear policy, while it committed to continue the licensing process for the two reactors.[163]

The Government is also considering the early closure of Korea's second-oldest reactor Wolsong-1, which will be 40 years old in December 2022. In February 2015, the NSSC voted in favor of plant-life extension for Wolsung-1.[164] Two of the nine commissioners abstained from voting. The operator of the CANDU-6 reactor, KHNP, replaced all pressure tubes and calandria tubes during extended shutdown between 2009 and 2011. The reactor has been shut down since November 2012, when its operating license expired. The Korea Institute of Nuclear Safety (KINS) concluded in October 2014 that the reactor could operate until 2022, and that it complied with the revised Nuclear Safety Act, including against major natural disasters. KHNP has invested 560 billion won (US$59 million) in upgrades.[165] The reactor restarted in June 2015.

On 12 September 2016, south east Korea experienced its most severe earthquake since records began in 1978. The Gyeongju seismic event measured 5.8 with the epicenter 28 kilometers from the Wolsong nuclear plant. KHNP manually shutdown the four CANDU-6 Wolsong reactors at the site immediately after the earthquakes. The ground force experienced at the Wolsong site was 0.0981 gal, with the design basis for the reactors at 0.2 gal. KHNP shut them as a "precautionary" measure.[166] The Wolsong site also hosts the newer OPR-1000 PWR Shin-Wolsong-1 and -2, which were designed to withstand 2.0 gal or a magnitude 6.5 earthquake. After completing safety checks, KHNP reported in late October 2016, that they had detected no damage to components or structures at the CANDU-6 reactors. The NSSC conducted its own review and concluded on 17 November 2016 that the CANDU-6 Wolsong plant was not affected by the earthquake.[167] The Wolsong-1 to -4 reactors were reconnected to the grid between 6 and 8 December 2016, after securing final approval from the NSSC on 5 December.

161 - Park Ji-Won,"Construction of two new nuclear power plants in Ulsan to be temporarily halted for safety concerns", *Arirang News*, 14 July 2017, see http://www.arirang.co.kr/News/News_View.asp?nseq=206368, accessed 27 July 2017.

162 - Ibidem.

163 - *Asian Power*, "Korea Hydro & Nuclear Power halts works for new Shin Hanul nuclear reactors", 29 May 2017, see http://asian-power.com/project/news/korea-hydro-nuclear-power-halts-works-new-shin-hanul-nuclear-reactors, accessed 3 July 2017.

164 - NSSC, "The Commissioners Decided to Approve Continued Operation of Wolsong Unit 1 in the 35th Meeting", Press Release, 27 February 2015, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=17977&pager.offset=10&board_no=501, accessed 10 July 2017.

165 - Park Han-na, "Restart of aging nuclear reactor sparks controversy", *Korea Herald*, 27 February 2015, see http://www.koreaherald.com/view.php?ud=20150227000740, accessed 10 July 2017.

166 - *NW*, "Four south Korean reactors still shut more than a month after earthquake", 27 October 2016.

167 - NSSC, "NPPs were Not Affected by 3.5-Magnitude Earthquake Occurred Near Boryeong", Press Release, 13 November 2016, see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=414l6&pager.offset=40&board_no=501, accessed 8 July 2017.

Operation of Wolsung-1 has been a major controversy over recent years, in particular following the Fukushima Daiichi accidents, with uncertainty as to whether it would have its license extended. Over 30 years, since the reactor started operating in 1983, the nuclear plant was shut down 39 times due to malfunctions.[168] The main political opposition party at the time, the New Politics Alliance for Democracy (NPAD), stated the decision was unacceptable in terms of public safety, with polling in Gyeongju showing 60 percent of those surveyed wanted the reactor permanently closed.[169]

The seismic event, together with over 500 aftershocks, warnings from the Korean Meteorological Administration that a magnitude 6.0 could occur any time due to the presence of active faults, and the shutdown of the Wolsong plant led to further public opposition to nuclear power in general and Wolsong specifically. Many ruling and opposition politicians, including those based near the Gyeongju area, backed by the anti-nuclear movement, called for the Wolsong complex to be permanently shut.

UNITED KINGDOM FOCUS

In 2016, the United Kingdom operated 15 reactors, which provided 65.1 TWh or 20.4 percent of the country's electricity, down from a maximum of 26.9 percent in 1997.

The 12 first-generation Magnox plants, with 26 reactors, had all been retired by the end of 2016. The U.K.'s seven second-generation nuclear stations, each with two Advanced Gas-cooled Reactors (AGR), are also at or near the end of their design lives. However, owner EDF Energy is planning to extend the lifetimes of all the AGRs, and announced between December 2012 and February 2016 that it planned to seek a 7-year extension to 2023 for Hinkley Point B and Hunterston B, a 5-year extension to 2024 for Heysham-1 and Hartlepool and a 10-year extension to 2030 for Dungeness, Heysham-2 and Torness.170 The newest reactor, Sizewell-B, is the only PWR in the U.K. and was completed in 1995. The history of the UK's reactor startups and shutdowns can be seen in Figure 21. The average age of the U.K. fleet stands at 33.4 years (see Figure 22).

In 2006, the Labour Government of Tony Blair started to organize the framework of a new-build program, when he said that the issues were 'back on the agenda with a vengeance'. [171] In July 2011, the Government released the National Policy Statement (NPS) for Nuclear Power Generation.[172] The eight "potentially suitable" sites considered in the document for deployment "before the end of 2025" are exclusively current or past nuclear power plant sites in England or Wales, except for one new site, Moorside, adjacent to the fuel-chain facilities at Sellafield.[173]

168 - Park Han-na, "Restart of aging nuclear reactor sparks controversy", *Korea Herald*, 27 February 2015, see http://www.koreaherald.com/view.php?ud=20150227000740, accessed 10 July 2017.

169 - Kim Eun-jung, "(3rd LD) Nuclear watchdog extends operation of 32-year-old reactor", *Yonhap New*, 27 February 2015, see http://english.yonhapnews.co.kr/national/2015/02/27/52/0302000000AEN20150227000453315F.html, accessed 10 July 2017.

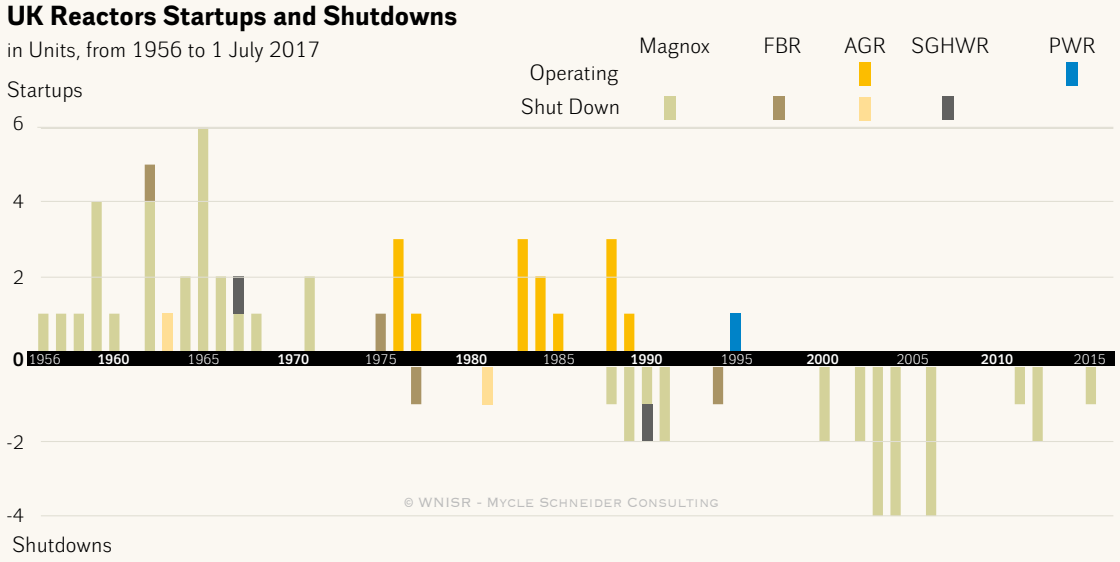
170 - *WNN*, "EDF Energy extends lives of UK AGR plants", 16 February 2016, see http://www.world-nuclear-news.org/C-EDF-Energy-extends-lives-of-UK-AGR-plants-1602164.html, accessed 27 April 2017.

171 - *BBC*, "Blair backs nuclear power plans", 16 May 2006, see http://news.bbc.co.uk/1/hi/uk_politics/4987196.stm, accessed 4 April 2017.

172 - Department of Energy & Climate Change (DECC), "National Policy Statement for Nuclear Power Generation", U.K. Government, July 2011.

173 - Bradwell, Hartlepool, Heysham, Hinkley Point, Oldbury, Sizewell, Sellafield, and Wylfa.

Figure 21 | U.K. Reactor Startups and Shutdowns



Sources: IAEA-PRIS, WNISR, 2017

Northern Ireland and Scotland[174] are not included. No reactor is now likely to be commissioned prior to 2025, due to financial and corporate structural problems with reactor vendors.

EDF Energy, majority-owned by French state-utility EDF, was given planning permission to build two reactors at Hinkley Point in April 2013. In October 2015, EDF and the U.K. Government[175] announced updates to the October 2013 provisional agreement of commercial terms of the deal for the £16 billion (US$20 billion) overnight cost of construction of Hinkley Point C (HPC).[176] The estimated price of construction has since risen and now stands at £19.6 billion (US$25.3 billion), up from the £18bn (US$23.2 billion) quoted in 2016. EDF says the £1.5bn (US$1.9 billion) increase results mainly "from a better understanding of the design adaptated [adapted] to the requirements of the British regulators, the volume and sequencing of work on site and the gradual implementation of supplier contracts". EDF maintains the official construction target date as "mid-2019" and the "initial delivery objective for Unit 1 at the end of 2025".[177]

The key points of the deal were a Contract for Difference (CfD), effectively a guaranteed real electricity price for 35 years, which, depending on the number of units ultimately built, would be £89.5–92.5/MWh, in 2012 values (US$115–120/MWh), with annual increases linked to the retail price index. The cost of this support scheme has rocketed, the UK National Audit Office suggesting that the additional 'top-up' payments, required through the CfD, have increased from £6.1 billion (US$$_{2013}$9.9 billion) in October 2013 to £29.7 billion (US$$_{2016}$41.2 billion) in

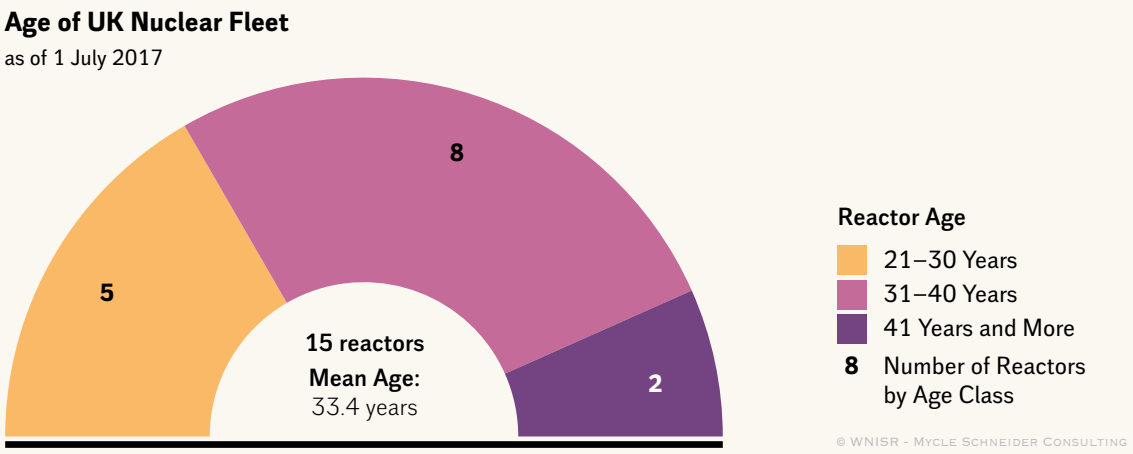
174 - The Scottish government is opposed to new-build and said it would not allow replacement of the Torness and Hunterston plants once they are shut down (probably in 2016 and 2023, respectively). Only 18 percent of the Scottish people supported new-build in a pre-Fukushima poll; see *The Scotsman*, "Only 18% of Scots Say 'Yes' to New Nuclear Power Stations", 27 September 2010.

175 - DECC, "Hinkley Point C to power six million UK homes", Press Release, U.K. Government, 21 October 2015, see https://www.gov.uk/government/news/hinkley-point-c-to-power-six-million-uk-homes, accessed 18 June 2016.

176 - The 2013 and 2015 figures are all in 2012 money unless otherwise specified.

177 - EDF, "Clarifications on Hinkley Point C project", Press Release, 3 July 2017.

Figure 22 | Age Distribution of U.K. Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2017

March 2016, due to falling wholesale electricity prices. The National Audit Office (NAO) also stated that "the [Government] Department's deal for HPC has locked consumers into a risky and expensive project with uncertain strategic and economic benefits."[178] The NAO pointed to a key factor behind the Government's ongoing support for Hinkley, in that it is less about energy policy and more about the Government's perceived role in the world and its reputation, when they stated: "In September 2016, HM Treasury highlighted how the value-for-money case for HPC had weakened. But it concluded that the legal, reputational, investor and diplomatic ramifications of not proceeding meant it was, on balance, better to continue with the deal." The basic problem with Hinkley is that there is no exit strategy for the U.K. Government or the project partners.

There was an expectation that construction would be primarily funded by debt (borrowing) backed by U.K. sovereign loan guarantees, expected to be about £17 billion (US$26.9 billion). However, in October 2015, EDF claimed it expected to finance its part of the finance from equity (own funds), suggesting it would be "more efficient".[179] EDF announced in November 2015 its intention to sell non-core assets worth up to €10 billion (US$11.4 billion) to help finance Hinkley.[180] In December 2016, the EDF board approved its partial sale of the high voltage network (RTE) to the state bank Caisse des Depots – expected to be 49.9 percent share on the basis of an indicative value of €8.2 billion (US$9 billion) for 100 percent of RTE's equity.[181] While the sale of its Polish assets, was delayed by the Polish Government, citing security of

178 - Department for Business, Energy & Industrial Strategy, "Hinkley Point C", Report by the Comptroller and Auditor General, National Audit Office (NAO), 12 June 2017, Session 2017-18, 23 June 2017, see https://www.nao.org.uk/wp-content/uploads/2017/06/Hinkley-Point-C.pdf, accessed 11 July 2017.

179 - Emily Gosden, "New nuclear plant at Hinkley Point to begin construction 'within weeks'", *The Telegraph*, 21 October 2015, see http://www.telegraph.co.uk/news/earth/energy/nuclearpower/11945485/Nuclear-go-ahead-construction-of-new-plant-to-begin-within-weeks.html, accessed 11 May 2016.

180 - Michael Stothard, "EDF looks to sell €10 bn of assets to boost balance Sheet", *Financial Times*, 18 October 2015, see http://www.ft.com/cms/s/0/fcd6a462-7578-11e5-a95a-27d368e1ddf7.html, accessed 4 April 2017.

181 - Geert De Clercq, Benjamin Mallet and Ingrid Melander, "EDF's board approves partial sale of its grid unit RTE", *Reuters*, 14 December 2016, see http://uk.reuters.com/article/us-edf-rte-idUKKBN1432UJ, accessed 4 April 2017.

supply concerns, to enable a consortium of Polish State run firms to bid for the French owed assets.[182]

In June 2016, following the U.K. public voting to leave the EU in a referendum, a new government was formed, headed by Prime Minister Teresa May. In the following month, the government announced that it would undertake a new review of Hinkley. The project was finally approved in September 2016, with the government having a 'special share', that would give it a veto over future ownership, if there are national security concerns.

The expected composition of the consortium owning the plant had changed from October 2013 to October 2015. In 2013, it was expected to comprise EDF (up to 50 percent), two Chinese companies, CGN (China General Nuclear Power Corporation) and CNNC (China National Nuclear Corporation) (up to 40 percent), and AREVA (up to 10 percent), with up to 15 percent still to be determined. In October 2015, the effective bankruptcy of AREVA made their contribution impossible, the Chinese stake had fallen to 33.5 percent and the other investors had not materialized leaving EDF with 66.5 percent. The October 2015 announcement mentioned only CGN leaving the impression CNNC had dropped out, but in May 2016, CNNC made it clear they expected to participate in the 33.5 percent Chinese stake.[183]

One other new element was that the Chinese stake in the follow-on Sizewell C project would be reduced to 20 percent, leaving EDF with 80 percent. Given the problems EDF is having financing Hinkley, this makes the Sizewell project appear implausible. However, EDF is allowing CGN to use the Bradwell site it had bought as back-up, if either the Hinkley or Sizewell sites proved not to be viable. CGN plans to build its own technology, the Hualong One (or HPR-1000) at this site.[184] In January 2017, the U.K. Government requested that the regulator begin the Generic Design Assessment of the HPR 1000 reactor. Work was begun later that month and is expected to be complete in 2021.[185]

The EDF-CGN consortium is not the only proposed reactor builder and NuGen, in June 2014, finalized a new ownership structure with Toshiba-Westinghouse (60 percent) and Engie (40 percent), as Iberdrola sold their shares. The group plans to build three Toshiba-Westinghouse-designed AP1000 reactors at the Moorside site, with units proposed to begin operating in 2024.[186] However, after a major financial collapse, Westinghouse filed for Chapter 11 bankruptcy protection in the USA in March 2017. This is having a disastrous impact on the parent company Toshiba, which has seen its share value halving since December 2016, when the extent of Westinghouse's problems came to light.[187] The perilous state of the project

182 - EnergyMarketPrice, "Poland hopes to accomplish the sale of EDF's Polish assets in the second quarter 2017", 10 February 2017, see http://www.energymarketprice.com/energy-news/poland-hopes-to-accomplish-the-sale-of-edf-s-polish-assets-in-the-second-quarter-2017, accessed 4 April 2017.

183 - *The Times*, "Chinese give Hinkley Point nuclear project a boost", 9 May 2016.

184 - EDF, "Agreements in place for construction of Hinkley Point C nuclear power station", Press Release, 21 October 2015, see https://www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/news-views/agreements-in-place, accessed 4 April 2016.

185 - Office for Nuclear Regulation (ONR), Natural Resources-Wales, Environment Agency, "Assessing new nuclear reactor designs—Generic Design Assessment Periodic Report: November 2016 – January 2017", March 2017, see http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-nov16-jan17.pdf, accessed 4 April 2017.

186 - *NucNet*, "Toshiba Finalises Controlling Stake in UK Nuclear Company NuGen", 30 June 2014, see http://www.nucnet.org/all-the-news/2014/06/30/toshiba-finalises-controlling-stake-in-uk-nuclear-company-nugen, accessed 4 April 2017.

187 - Kana Inagaki, "Westinghouse files of Chapter II bankruptcy protection", *Financial Times*, 29 March 2017, see https://www.ft.com/content/ba9d8e42-de63-320e-b29c-70dcf19e1f28, accessed 4 April 2017.

also led to Engie selling its remaining 40 percent to Toshiba-Westinghouse for US$138 million, who were contractually obliged to buy them at the pre-determined price.[188] In late April 2017, the national press reported that Toshiba was preparing to mothball the project, warning suppliers of spending cuts and ordering seconded staff to return to their employees.[189]

The U.K. Government is now actively trying to encourage other investors or vendors to become involved at Moorside, with Korea's KEPCO, a nationally owned utility and reactor vendor, being targeted as a potential partner. However, it seems unlikely that KEPCO would be willing to build Westinghouse's AP1000 reactors and so, if they are engaged, a new reactor design licensing process for their own technology would be required. If Westinghouse doesn't find a buyer, it leaves the Moorside project stalled. In amongst all the economic chaos, the U.K. Office of Nuclear Regulation approved the AP1000 reactor design on 30 March 2017.[190] The probability of KEPCO's involvement in any overseas project was further eroded by the May 2017 election of President Moon, who stated in June 2017: "We will scrap the nuclear-centered polices and move toward a nuclear-free era. We will eliminate all plans to build new nuclear plants."[191] It is difficult to imagine that President Moon would allow the 51-percent state-owned company to invest in nuclear new-build abroad.

The other company involved in nuclear new-build is Horizon Nuclear, which was bought by the Japanese company Hitachi from German utilities E.ON and RWE for an estimated price of £700 million (US$1.2 billion). The company has submitted its Advanced Boiling Water Reactor (ABWR) design for technical review, whilst making it clear that its continuation in the project will depend on the outcome of the EDF negotiations with the Government.[192] The ABWR, planned for the Wylfa and Oldbury sites, passed the justification procedure in January 2015, and the Generic Design Assessment (GDA) is expected to be completed by December 2017.[193] In April 2017, Horizon Nuclear applied for a site license at the Wylfa location. If everything did go according to plan, the reactor would start up in 2025.[194]

The constant decline in energy *and* electricity consumption in the U.K. does not favor the economic case for nuclear new-build. Annual final electricity consumption in 2016 was little different to that in 2015 (0.1 percent higher), with generation similar to the level of two decades ago. Meanwhile, renewables' share of electricity generation reached 24.4 percent in 2016, and outpaced nuclear power's contribution of 20.4 percent.[195]

188 - Marcus Leroux, "French investor deals new blow to nuclear project", *The Times*, 5 April 2017.

189 - John Collingridge, "Toshiba mothballs Cumbrian nuclear power project", *Sunday Times*, 30 April 2017.

190 - Office for Nuclear Regulation (ONR), "Design acceptance for the AP1000 reactor", 30 March 2017, see http://news.onr.org.uk/2017/03/design-acceptance-for-the-ap1000-reactor/, accessed 2 August 2017.

191 - Hojun Hwang, "Korea's first nuclear power reactor turned off for good", *Arirang*, 20 June 2017, see http://www.arirang.co.kr/News/News_View.asp?nseq=205377, accessed 22 June 2017.

192 - Ambrose Evans-Pritchard, "Hitachi reluctant about UK nuclear reactor plan", *The Telegraph*, 14 April 2013, see http://www.telegraph.co.uk/finance/newsbysector/energy/9993564/Hitachi-reluctant-about-UK-nuclear-reactor-plan.html, accessed 30 July 2017.

193 - ONR, Natural Resources-Wales, Environment Agency, "Assessing new nuclear reactor designs—Generic Design Assessment Progress Report—November 2016 – January 2017", see http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-nov16-jan17.pdf, accessed 4 April 2017.

194 - *WNN*, "Horizon clears justification hurdle", 28 January 2015, see http://www.world-nuclear-news.org/NN-Horizon-clears-justification-hurdle-2801151.html, accessed 4 April 2017.

195 - Department for Business, Energy & Industrial Strategy, "National Statistics—Energy Trends section 5: Electricity", U.K. Government, March 2017, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/604090/Electricity.pdf, accessed 4 April 2017.

Brexatom

In June 2016, in a national referendum the U.K. population voted to leave the European Union. This has considerable implications for the energy and electricity sectors in the EU27 and the U.K. However, what came as a surprise to some, was that the UK Government announced on 26 January 2017 in its European Union (Notification of Withdrawal) Bill, that the UK would also be leaving the Euratom Treaty.

The Treaty established the Atomic Energy Community (Euratom), whose primary function was to support the development of nuclear power and has remained, largely, unreformed and consequently a separate legal entity. The Treaty has a wide range of responsibilities, including the verification of the non-proliferation of nuclear materials designated as non-military, under a trilateral treaty between Euratom, the IAEA and the U.K. Government and the setting of nuclear safety and radiation protection standards for workers, the public and the environment. To support the development of nuclear power, Euratom operates its own research and development program, has set up a nuclear specific loan facility and created a Supply Agency to ensure adequate access to nuclear materials, and is effectively controlling all nuclear material in the EU.

There has been a growing call from the nuclear industry and its supporters for the UK to remain in Euratom, as they fear that an abrupt exit will lead to a 'cliff edge' potentially causing major disruption to business across the whole nuclear fuel system.[196]

The UK's departure from the EU and Euratom Treaty will also have a political impact on the nuclear sector within the EU27, as the UK has been one of its most active supporters in the EU. Furthermore, the complications around Brexatom put a spotlight onto the Euratom Treaty, whose legal status and many of its functions are out of step with the modern EU and may once again lead to calls for its abolishment.

196 - NIA, "Exiting Euratom—The UK's Withdrawal from Euratom", Nuclear Industry Association, 3 May 2017, see https://www.niauk.org/wp-content/uploads/2017/05/Exiting-Euratom_May17.pdf, accessed 11 July 2017.

UNITED STATES FOCUS

With 99 commercial reactors currently operating as of 1 July 2017, the U.S. possesses the largest nuclear fleet in the world. The past year has witnessed dramatic developments centered around historic-builder Westinghouse's filing for bankruptcy. Construction of two AP1000 reactors at V.C. Summer in South Carolina was terminated on 31 July 2017,[197] with a decision expected in August as to whether to continue or end construction of two other AP1000's at Vogtle in Georgia. These major setbacks have merely confirmed the near zero prospects of any new construction in the U.S. into foreseeable future.[198]

The 482 MW Fort Calhoun pressurized water reactor in Nebraska, was permanently shut down on 24 October 2016, due to poor economics.[199] As in recent years, announcements were made of further closure of existing reactors. The Nuclear Energy Institute (NEI), the advocacy organization for the U.S. nuclear industry, projects "15-to-20 plants at risk of shut-down over the next five-to-10 years".[200] Independent analysts think many more plants are at risk of being shut down.[201] At the same time, several utilities reversed decisions to close reactors after they secured state level financial support. Therefore, while it is inevitable that the size of the U.S. nuclear fleet will continue to decline for the foreseeable future, the decline could be slowed down by directly subsidizing threatened operating plants.

The U.S. reactor fleet provided 805TWh in 2016[202], a slight increase over the 798 TWh in 2015, but still below the record year of 2010 with 807.1 TWh. Nuclear plants provided 19.7 percent of U.S. electricity in 2016, a slight increase over 2015, and about 3 percentage points below the highest nuclear share of 22.5 percent, reached in 1995.

With only two reactors under construction and only one new reactor started up in 20 years, the U.S. reactor fleet continues to age, with a mid-2017 average of 37.1 years, amongst the oldest in the world: 40 units have operated for more than 40 years (see Figure 23).

In the past year, one new nuclear reactor started up—the Tennessee Valley Authority's (TVA) 1150 MW Watts Bar-2. More than four decades after construction began,[203] the reactor on 3 June 2016 became the first commercial reactor to be connected to the grid in the U.S. since

197 - SCANA, "South Carolina Electric & Gas Company To Cease Construction And Will File Plan Of Abandonment Of The New Nuclear Project", 31 July 2017, see https://www.scana.com/docs/librariesprovider15/pdfs/press-releases/07312017-sce-amp-g-to-cease-construction-and-will-pursue-abandonment-of-the-new-nuclear-project---scana-reaffirms-earnings-guidance.pdf?sfvrsn=0, accessed 3 August 2017.

198 - *WNISR*, "Utilities Abandon V. C. Summer AP10 Reactor Construction Following Westinghouse Bankruptcy", 2 August 2017, see https://www.worldnuclearreport.org/Utilities-Abandon-V-C-Summer-AP1000-Reactor-Construction-Following-Westinghouse.html, accessed 4 August 2017.

199 - OPPD, "Fort Calhoun Station now officially offline" 24 October 2016, Omaha Public Power District, see https://oppdthewire.com/fort-calhoun-station-ceases-operations/, accessed 3 May 2017.

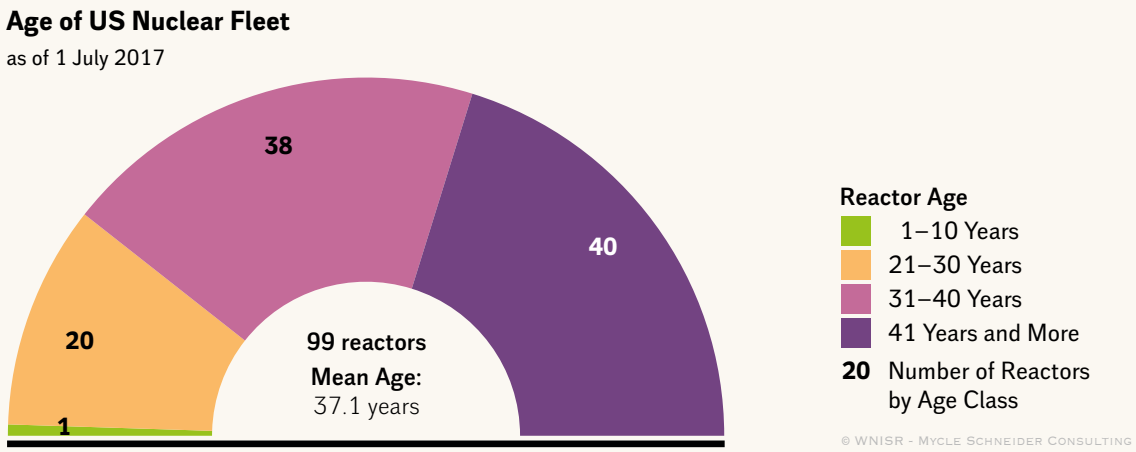
200 - Wayne Barber, "NEI warns more nuclear power plant retirements on the way", *Electric Light & Power*, 23 May 2016, see http://www.elp.com/articles/2016/05/nei-warns-more-nuclear-power-plant-retirements-on-the-way.html, accessed 6 August 2017.

201 - Mark Cooper, "Renaissance In Reverse—Competition Pushes Aging U.S. Nuclear Reactors To The Brink Of Economic Abandonment", Institute for Energy and the Environment, Vermont Law School, 18 July 2013, see http://will.illinois.edu/nfs/RenaissanceinReverse7.18.2013.pdf, accessed 6 August 2017.

202 - U.S. Energy Information Administration (U.S. EIA), "Electricity Data Browser—Net Generation, monthly", see https://www.eia.gov/electricity/data/browser/, accessed 3 May 2017.

203 - *WNISR*, "Watts Bar-2 (US): Grid Connection 43 Years After Construction Start—Shutdown 2 Days Later", 8 June 2016, see https://www.worldnuclearreport.org/Watts-Bar-2-US-Grid-Connection-43-Years-After-Construction-Start-Shutdown-2.html, accessed 24 May 2017.

Figure 23 | Age Distribution of U.S. Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2017

Watts Bar-1 in 1996.[204] After a number of technical incidents, TVA announced that commercial operation of the unit began on 19 October 2016.[205] However, whilst operating at just 16 percent power, the reactor shut down again on 23 March 2017, when the main condenser experienced a structural failure.[206] The plant is expected to remain shut down until summer 2017.[207]

In the year to December 2016, the Nuclear Regulatory Commission (NRC) issued 20-year license renewals for six nuclear plants: Braidwood-1 & -2, LaSalle-1 and -2, Grand Gulf-1, and Fermi-2.[208] Only one nuclear plant applied for a license renewal (Waterford-3). As of 1 July 2017, 84 of the 99 operating U.S. units had received a license extension with a further nine applications under review, and one additional unit expected to submit an application during 2017.[209] In December 2015, the NRC put out a draft document describing "aging management programs" that might allow the NRC to grant nuclear power plants operating licenses for "up to 80 years".[210]

204 - IAEA, "Power Reactor Information System (PRIS) Database", 2016, see http://www.iaea.org/programmes/a2/, accessed 18 June 2016.

205 - TVA, "Watts Bar Unit 2 Complete and Commercial", 19 October 2016, see https://www.tva.com/Newsroom/Watts-Bar-2-Project, accessed 3 May 2017.

206 - NRC, "Preliminary notification of even or unusual Occurrence PNO-II-17-002— Shutdown due to condenser failure", 23 March 2017, see https://www.nrc.gov/docs/ML1708/ML17082A621.pdf, accessed 24 May 2017.

207 - Peter Maloney, "TVA Watts Bar-2 nuke to shut until summer amid safety culture concerns", *Utility Dive*, 8 May 2017, see http://www.utilitydive.com/news/tva-watts-bar-2-nuke-to-shut-until-summer-amid-safety-culture-concerns/442109/, accessed 24 May 2017.

208 - NRC, "Status of License Renewal Applications and Industry Activities", Updated 4 January 2017, see https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html, accessed 4 May 2017.

209 - Entergy Operations, "Updated Schedule of Submittal of Future License Renewal Application—River Bend Station–Unit 1", Docket No. 50-458, License No. NPF-47, 18 August 2016, see https://www.nrc.gov/docs/ML1625/ML16252A330.pdf, accessed 4 May 2017.

210 - NRC, "Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report – Draft Report for Comment (NUREG-2191, Volume 1)", 15 December 2015, see https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2191/v1/, accessed 3 May 2017.

Securing Financing, Shutdowns and Reversing Shutdowns

The past year witnessed continuing efforts by nuclear utilities to find mechanisms to secure financial support for their ailing reactor fleet. The NRC's exploration of a path to further extend nuclear reactors operating lifetimes is in direct contradiction to the signals from the electricity markets, which has been to rather accelerate shutting down old reactors. For a long time, the nuclear industry has argued that reactors might be expensive, but once built and paid for, the operating costs are low and thus nuclear plants will generate electricity cheaply. Thus, for example, then U.S. Secretary of Energy, Ernest Moniz, wrote in 2011: "Nuclear power enjoys low operating costs, which can make it competitive on the basis of the electricity price needed to recover the capital investment over a plant's lifetime".[211] In recent years, that claim has been continuously undermined as electric utility after electric utility has decided to close operational nuclear reactors even though their licenses would allow them to operate for a decade or more beyond the newly planned shutdown date. In essence, the costs associated with maintaining aged reactors have been rising, while market prices are falling. In addition, low gas prices from hydraulic fracturing (fracking) have resulted in gas-fired generating stations producing cheaper electricity. The result is clear: nuclear power has great difficulties to compete in the current U.S. electricity marketplace.

In its "Annual Briefing for the Financial Community" delivered on 9 February 2017, Maria G. Korsnick, the Nuclear Energy Institute's (NEI) president and chief executive stated that the U.S. "faces two challenges of immediate concern: preserving as much of its base load infrastructure as possible, which includes existing nuclear capacity, and creating the policy conditions under which companies will develop and build new nuclear capacity."[212] NEI reported that for nuclear power in the U.S. in 2016, annual expenditures at the average nuclear reactor (i.e., the various annual expenditures associated with running a nuclear reactor in the U.S., averaged for the whole fleet) came to US$33.93MWh, with single unit plants averaging US$41.39.[213] Note that these numbers are for reactors whose construction costs have been paid off. These figures should also be seen in the context of recent bids for new solar photovoltaic projects (see Chapter Nuclear Power vs. Renewable Energy Deployment).[214]

Underscoring the market challenge facing nuclear- and coal-based generators is the situation in **Texas**. While there are no indications of planned closure of the twin reactor units at Comanche Peak, or the other twin unit at South Texas, the owner Luminant has depreciated the value of the Comanche Peak plant from US$2.2 billion to US$949 million. "Power prices are now at historic lows and when Comanche Peak makes less revenue, its value as an income producing asset must follow", explains Luminant.[215] The Electric Reliability Council of Texas (ERCOT), the state's independent system operator, reports a significantly weakened market between 2014 and 2017, with power prices dropping due to "unsustainably low levels

211 - Ernest Moniz, "Why We Still Need Nuclear Power", Energy Initivative, MIT, *Foreign Affairs*, November-December 2011, see https://www.foreignaffairs.com/articles/2011-10-17/why-we-still-need-nuclear-power, accessed 25 May 2017.

212 - NEI, "NEI to Wall Street: Nuclear Energy Is a Cornerstone of American Infrastructure—Nuclear Plants Are Irreplaceable National Assets", News Release, 9 February 2017, see https://www.nei.org/News-Media/Media-Room/News-Releases/NEI-to-Wall-Street-Nuclear-Energy-Is-a-Cornerstone, accessed 3 May 2017.

213 - NEI, "Nuclear Costs in Context", August 2017, see https://www.nei.org/CorporateSite/media/filefolder/Policy/Papers/Nuclear-Costs-in-Context.pdf?ext=.pdf, accessed 6 August 2017.

214 - Ibidem.

215 - *Nucleonics Week*, "Luminant, Texas county more than $1 billion apart on Comanche Peak's value", 1 September 2016.

and crippling profitability for generators" according to Standard & Poor's (S&P) Global Ratings released in March 2017.[216] The principal driver being low natural gas prices and increased installed wind capacity, with wind turbines now producing over 15 percent of the state's electricity.

ERCOT's annual state of the market report issued in June 2016 noted: "The generation-weighted average price for the four nuclear units—approximately 5GW of capacity—was US$24.56 per MWh in 2015. (...) Assuming that operating costs in ERCOT are similar to the U.S. average, considering only fuel and operating and maintenance costs indicates that nuclear generation was not profitable in ERCOT during 2015."[217]

Unlike the older plants of the north-east and mid-west, which have been in the spotlight due to unfavorable economics, Comanche Peak reactor units 1&2 have been operating since 1990 and 1993 respectively, while South Texas reactor units 1&2 from 1988 and 1989 respectively. As Luminant reported, "Comanche Peak is among the lowest-cost nuclear generators in the U.S., based on its total cost of about US$26/MWh... Selling or shutting Comanche Peak is not a possibility."[218] There is no indication that such a commitment is inaccurate, but there are clearly questions arising about the long-term viability of even some of the U.S. newest reactors. As S&P concluded: "The effects of low natural gas prices continue to fall disproportionately on coal- and nuclear-fired generation," the report reads. "These assets have continued to be punished..."[219]

NEI reports that "average generating costs have decreased from peak of US$39.75/MWh in 2012 to US$35.5/MWh in 2015",[220] but it is uncertain, if this decline is going to continue into the future. The decline so far is largely due to two reasons. The first is that fuel costs have declined, in turn due to the fall in uranium prices by more than half and enrichment prices by more than two thirds. The other reason for the decrease in operational costs is that utilities have reduced capital expenditures (major repairs), but this cannot continue indefinitely, as the age of the fleet is increasing. The response from the nuclear industry and nuclear utilities has been to either shut down several nuclear reactors and/or to call for government intervention into the market in some fashion to support continued operations of distressed nuclear plants. Indeed, in February 2016, the American Nuclear Society (ANS) felt compelled to publish a toolkit of various ways by which states can intervene to ensure that utilities can keep struggling nuclear plants operating without losing money.[221]

216 - Rod Walton, "S&P expects continued struggles for ERCOT and Texas generators", *Electric Light & Power*, 15 March 2017, see http://www.elp.com/articles/2017/03/s-p-expects-continued-struggles-for-ercot-and-texas-generators.html, accessed 23 May 2017.

217 - *Electric Light & Power*, "S&P expects continued struggles for ERCOT and Texas generators", 15 March 2017, see http://www.elp.com/articles/2017/03/s-p-expects-continued-struggles-for-ercot-and-texas-generators.html, accessed 8 August 2017.

218 - *Nucleonics Week*, "Luminant, Texas county more than $1 billion apart on Comanche Peak's value", 1 September 2016.

219 - Rod Walton, "S&P Report Underlines Financial Concerns about ERCOT Generators", *Electric Light & Power*, 21 March 2017, see http://www.elp.com/Electric-Lighkt-Power-Newsletter/articles/2017/03/s-p-report-underlines-deep-concerns-about-ercot-s-future-financial-strength.html, accessed 23 May 2017.

220 - NEI, "Nuclear by the Numbers", 9 February 2017, see https://www.nei.org/CorporateSite/media/filefolder/Policy/Wall Street/Nuclear_by_the_Numbers.pdf?ext=.pdf, accessed 3 May 2017.

221 - Special Committee on Nuclear in the States, "Nuclear in the States Toolkit Version 1.0: Policy Options for States Considering the Role of Nuclear Power in Their Energy Mix", ANS, February 2016, see http://nuclearconnect.org/issues-policy/nuclear-policy-in-the-states, accessed 23 May 2017.

As reported in WNISR2016, the leading example of how utilities have tried and in certain cases succeeded in obtaining substantial extra revenues to maintain profitability of their nuclear fleet has been in the state of **Illinois**. In the past few years, some of plants owned by Exelon, the largest nuclear operator in the U.S., have failed to clear the capacity market auctions, especially in the PJM interconnection (Pennsylvania-New Jersey-Maryland Interconnection LLC), a regional transmission organization that coordinates the movement of wholesale electricity in 13 States on the East coast, South East and Midwest plus the District of Columbia.[222] Other nuclear plants within the PJM Control Area have also failed to clear the capacity market auctions. The story is similar in the Midcontinent Independent System Operator (MISO) interconnection, which covers part of Illinois and 14 other states.

The capacity market involves power plants committing to having a certain amount of generating capacity ready for delivering power upon demand and receiving a payment for that capacity. In the capacity market auctions, the plants that are ready to commit reliable power at the lowest cost are chosen first. Once the projected demand for the future has been met, the plants that are offering to supply power at higher costs are said to have not cleared the market.

The response of utilities with nuclear plants to their inability to clear auctions has been to blame the structure of the markets rather than their own high costs. Joseph Dominguez, Exelon's senior vice president for governmental and regulatory affairs and public policy, told NEI that "(...) the market does not sufficiently recognize the significant value that nuclear plants provide in terms of reliability and environmental benefits".[223] Independent assessments do not support that claim, which has so far taken at least 14 forms.[224]

In July 2015, the Federal Energy Regulatory Commission (FERC) approved PJM's restructuring proposals that would allow it to increase payments to utilities that can more reliably deliver power. Despite higher prices, in August 2015, Exelon announced that three of its nuclear plants, "Oyster Creek, Quad Cities and Three Mile Island [...] did not clear in the PJM capacity auction for the 2018-19 planning year".[225] The company also announced that "a portion of the Byron nuclear plant's capacity did not clear the auction".[226]

In 2016, Exelon teamed up with subsidiary Commonwealth Edison Company or ComEd, and proposed "a larger bill that would make sweeping changes to the state's ene rgy system" and add "a surcharge onto electricity bills that would make the nuclear plants profitable".[227] Analysts estimated the proposed "changes would amount to a total rate hike of US$7.7 billion

222 - PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia; see PJM "About PJM—Who We Are", Undated, see http://www.pjm.com/about-pjm/who-we-are.aspx, accessed 26 May 2017.

223 - NEI, "Exelon on the 2014 PJM Capacity Market Auction", interview with Joseph Dominguez, Senior Vice President for Governmental and Regulatory Affairs and Public Policy, Exelon Corp., 12 June 2014, see https://www.nei.org/News-Media/News/News-Archives/Exelon-on-the-2014-PJM-Capacity-Market-Auction, accessed 23 May 2017.

224 - Amory B. Lovins, "Do coal and nuclear generation deserve above-market prices?", *The Electricity Journal*, Vol.30, Issue 6, July 2017, see http://dx.doi.org/10.1016/j.tej.2017.06.002, accessed 6 August 2017.

225 - Exelon Corporation, "Exelon Announces Outcome of 2018-19 PJM Capacity Auction", *Business Wire*, 24 August 2015, see http://www.businesswire.com/news/home/20150824005330/en/Exelon-Announces- Outcome-2018-19-PJM-Capacity-Auction, accessed 23 May 2017.

226 - Sonal Patel, "Two Exelon Nuclear Plants Fail to Clear PJM Auction", *POWER Magazine*, 25 May 2016, see http://www.powermag.com/two-exelon-nuclear-plants-fail-to-clear-pjm-auction/, accessed 23 May 2017.

227 - Kim Geiger, "Exelon makes another try for energy changes that critics call bailout", *Chicago Tribune*, 27 May 2016, see http://www.chicagotribune.com/news/local/politics/ct-illinois-com-ed-exelon-bill-20160527-story.html, accessed 23 May 2017.

over 10 years that would be paid by government, businesses and consumers... [and] that Exelon and ComEd would reap US$1 billion in guaranteed profits from the plan over a decade", including "a subsidy of as much as US$2.6 billion over that time".[228] While on the one hand, Exelon was seeking subsidies from government and customers, on the other hand, it has been presenting itself as profitable to Wall Street.[229]

Exelon announced on 2 June 2016 the planned closure of the single reactor unit at Clinton and two-unit Quad Cities, unless the state implemented subsidies for nuclear power.[230] The two stations are said to have lost a combined US$800 million during the past seven years, despite being two of Exelon's best-performing plants. Subsequently a provision of the Illinois Future Energy Jobs Act passed the state legislature on 7 December 2016, establishing a Zero Emissions Credits (ZEC) program that provided financial support to certain in-state nuclear generators that have become uncompetitive in wholesale markets. The ZEC price may be above current rates to provide financial support to a power generator. Through this program, the Exelon-owned Clinton and Quad Cities nuclear plants would be eligible for ZECs. On 14 February 2017, the Electric Power Supply Association (EPSA) and generators filed a complaint in the U.S. District Court of the Northern District of Illinois opposing the proposed ZEC's for Exellon, stating that "bailing out uneconomic power plants is a bad deal for Illinois ratepayers, who will see their electric bills go up across the state".[231] Litigation continues.

The availability of the ZEC program in Illinois led Exelon to reverse its decision to permanently shut the Clinton nuclear plant scheduled for 1 June 2017 and its two-unit Quad Cities on 1 June 2018. Exelon had filed an application with the NRC for termination of its operating license for Clinton, subsequently withdrawn.[232] Exelon began receiving ZEC income for its Illinois plants as of 1 June 2017.

Several other states with at-risk nuclear plants, possibly including **Connecticut**[233], **Pennsylvania and New Jersey**, could be asked later this year to pass similar ZEC legislation to aid other nuclear plants.

The future of Three Mile Island (TMI) appears to hang in the balance, with Exelon and industry supporters pushing for nuclear supporting ZEC in the Pennsylvania legislature,[234] likely to be proposed later in 2017. In Exelon's most recent SEC filing described TMI as the facility "at

228 - Ibidem.

229 - Steve Daniels, "Exelon tells Wall St. one thing about profits while peddling a different tale in Springfield", *Crain's Chicago Business*, 30 April 2016, see http://www.chicagobusiness.com/article/20160430/ISSUE01/304309995/exelon-tells-wall-st-one-thing-about-profits-while-peddling-a-different-tale-in-springfield, accessed 23 May 2017.

230 - Anthony Watt, Dennis Moran, and Gerold Shelton, "Q-C nuclear plant will stay open; House, Senate pass Exelon bill", *Dispatch • Argus, QCOnline.com*, Updated 5 December 2017, see http://www.qconline.com/news/local/q-c-nuclear-plant-will-stay-open-house-senate-pass/article_a83a9aea-26a0-5575-a847-6008f971aeb9.html, accessed 15 May 2017.

231 - Keith Goldberg, "Nuke Plant Subsidies Flout FERC, Power Cos. Say", Law360, 15 February 2017, see https://www.law360.com/articles/892374/ill-nuke-plant-subsidies-flout-ferc-power-cos-say, accessed 15 May 2017.

232 - NRC, "[Docket No. 50–461; NRC–2016–0207] Exelon Generation Company LLC; Clinton Power Station, Unit 1—License amendment application; withdrawal by applicant", Federal Register Vol.82, No.4, 6 January 2017, see https://www.federalregister.gov/documents/2017/01/06/2017-00045/exelon-generation-company-llc-clinton-power-station-unit-1, accessed 15 May 2017.

233 - Draft legislation for ZECs in Connecticut was disclosed in January 2017 that if adopted would be available for the two unit Millstone reactors operated by Dominion. Peter Maloney, "Connecticut lawmakers prepare legislation to support Millstone nuclear plant", *Utility Dive*, 10 February 2017, see http://www.utilitydive.com/news/connecticut-lawmakers-prepare-legislation-to-support-millstone-nuclear-plan/435876/, accessed 23 May 2017.

234 - Marie Cusick "Lawmakers mull support for nuclear industry", *StateImpact Pennsylvania*, 26 April 2017, see https://stateimpact.npr.org/pennsylvania/2017/04/26/lawmakers-mull-support-for-nuclear-industry/, accessed 15 May 2017.

the greatest risk of early retirement due to current economic valuations and other factors."[235] Exelon's executive vice president of governmental and regulatory affairs and public policy stated: "We've operated for the past six years at a loss."[236] In May 2017, Exelon announced that the TMI and Quad Cities reactors had not cleared the auction for the period 2020-21.[237] It is the third straight year where TMI did not clear PJM base residual auctions. "As long as state and federal energy policies fail to adequately compensate nuclear energy's many environmental and economic benefits, we will continue to experience challenges to the profitability of many of the nation's nuclear facilities, including TMI." said Exelon.[238]

One state where the legislative approach seems to have nearly worked during 2016 was Connecticut, where Dominion Energy instigated a special hearing by the state legislature's Energy and Technology Committee.[239] As a result, the Connecticut Senate passed legislation that would have changed the market structure in the state and would have protected Dominion's Millstone plant. However, the bill failed to come to the vote and "died" in Connecticut's House of Representatives.[240]

In October 2015, Entergy Corporation announced that it would close down the Pilgrim nuclear plant in **Massachusetts** because the 43-year-old plant was "simply no longer financially viable" and that it had already informed ISO New England, the regional transmission organization that Pilgrim would not be part of the next electricity auction.[241] In April 2016, Entergy announced the closing date of the plant as 31 May 2019.[242] There is no indication that Entergy will reverse its decision on closure, with plans filed in March 2017 with the NRC related to moving spent fuel from the reactors pool to dry storage.[243]

In **New York State**, Entergy announced in November 2015 that "market conditions require us to... close the FitzPatrick nuclear plant".[244] Even New York Governor Andrew Cuomo's order in December 2015 calling on "the State Department of Public Service to design and enact a new Clean Energy Standard mandating that 50 percent of all electricity consumed in New York by

235 - Wallace McKelvey, "Three Mile Island, like much of nuclear industry, is on the brink", *PennLive*, Updated 30 April 2017, see http://www.pennlive.com/politics/index.ssf/2017/04/nuclear_power_three_mile_islan_1.html, accessed 15 May 2017.

236 - Ad Crable, "Three Mile Island nuclear plant again fails key power auction, decision whether to close 'to be made soon'", *LancasterOnline*, 24 May 2017, see http://lancasteronline.com/news/local/three-mile-island-nuclear-plant-again-fails-key-power-auction/article_e12d94f8-4080-11e7-8297-034697ee2fd0.html, accessed 24 May 2017.

237 - Exelon, "Exelon Announces Outcome of 2020-2021 PJM Capacity Auction", Press Release, 24 May 2017, see http://www.exeloncorp.com/newsroom/pjm-auction-results-release-2017, accessed 24 May 2017.

238 - Ad Crable, "Three Mile Island nuclear plant again fails key power auction, decision whether to close 'to be made soon'", *LancasterOnline*, 24 May 2017, see http://lancasteronline.com/news/local/three-mile-island-nuclear-plant-again-fails-key-power-auction/article_e12d94f8-4080-11e7-8297-034697ee2fd0.html, accessed 24 May 2017.

239 - Mark Pazniokas, "Nuclear power's future in Connecticut is on the table", *The Connecticut Mirror*, 23 March 2016, see http://ctmirror.org/2016/03/23/nuclear-powers-future-in-connecticut-is-on-the-table/, accessed 25 May 2017.

240 - Judy Benson, "Bill that would have protected Millstone from energy market dips dies in House", *The Day*, Updated 6 May 2016, see http://www.theday.com/article/20160505/NWS01/160509539, accessed 23 May 2017.

241 - David Abel, "Pilgrim Nuclear Power Station in Plymouth to shut down by 2019", *Boston Globe*, 13 October 2015, see https://www.bostonglobe.com/metro/2015/10/13/entergy-close-pilgrim-nuclear-power-station-nuclear-power-plant-that-opened/fNeR4RT1BowMrFApb7DqQO/story.html, accessed 6 August 2017.

242 - David Abel, John R. Ellement, "Pilgrim nuclear power plant now has a closing date", *Boston Globe*, 14 April 2016, see https://www.bostonglobe.com/2016/04/14/pilgrim-nuclear-power-plant-close-may/FRXGHcfMrk3nSngdYueMML/story.html, accessed 6 August 2017.

243 - Justin Saunders, "Entergy Takes Next Steps for Pilgrim Closure", *CapeCod.com*, 13 March 2017, see http://www.capecod.com/newscenter/entergy-takes-next-steps-for-pilgrim-closure/, accessed 23 May 2017.

244 - Aaron Larson, "Entergy Announces Closure of FitzPatrick Nuclear Power Plant", *POWER Magazine*, 2 November 2015, see http://www.powermag.com/entergy-announces-closure-of-fitzpatrick-nuclear-power-plant/, accessed 25 May 2017.

2030 result from clean and renewable energy sources", which also included an order "to develop a process to prevent the premature retirement of safe, upstate nuclear power plants during this transition",[245] did not change Entergy's decision.

Exelon, which also operates nuclear plants in New York, took a page out of Entergy's book and threatened to shut the Ginna and Nine Mile Point-1 reactors unless the state approves "a compensation plan for nuclear generators" that would "require all companies that sell electricity in the state to buy power from upstate nuclear plants at potentially above-market rates".[246]

Having announced in November 2015 that the Fitzpatrick nuclear plant was not financially viable,[247] with permanent closure scheduled for January 2017,[248] on 9 August 2016, Exelon announced that it had reached an agreement with Entergy to assume ownership and continued operation of the plant.[249] The announcement came one week after New York's Public Services Commission (NYPSC) approved the state's Clean Energy Standard,[250] featuring ZECs that would benefit FitzPatrick, as well as Exelon's Nine Mile Point unit 1&2 and Ginna. Earlier in 2016, Exelon had stated that, without support, it would shut the Ginna plant because "projected market revenues are insufficient to support the Ginna facility's continued operation."[251] The availability of ZECs for Ginna appeared to reverse Exelon's plan for closure.[252]

On 3 March 2017, the NRC issued an order approving the direct transfer of the operating license for the FitzPatrick nuclear power plant from its current owner and operator, Entergy Corporation, to Exelon Generation,[253] effective 31 March 2017.[254] The US$110-million sale of the single-unit plant had been approved by the NYPSC in November 2016[255] and by the Federal Energy Regulatory Commission (FERC) in December 2016.[256]

245 - Andrew Cuomo, "Letter to Audrey Zibelman, CEO, New York State Department of Public Service", Governor, Executive Chamber, State of New York, 2 December 2015, see https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/Renewable_Energy_Letter.pdf, accessed 25 May 2017.

246 - Jim Ostroff, "Exelon to shut Nine Mile Point-1, Ginna reactors if New York fails to OK compensation plan", *Platts*, 14 June 2016, see https://www.platts.com/latest-news/electric-power/washington/exelon-to-shut-nine-mile-point-1-ginna-reactors-21708658, accessed 6 August 2017.

247 - Entergy, "Clear vision, clear progress—2015 Integrated Report", see http://www.entergy.com/content/investor_relations/pdfs/Entergy_2015_Integrated_Report.pdf, accessed 3 May 2017.

248 - ANS, "NRC approves sale of FitzPatrick from Entergy to Exelon", April 2017, see http://www.ans.org/pubs/magazines/nn/y_2017/m_4, accessed 3 May 2017.

249 - Exelon, "Exelon to Assume Ownership and Operation of Entergy's James A. Fitzpatrick Nuclear Power Plant in Upstate New York", 9 August 2016, see http://www.exeloncorp.com/newsroom/exelon-to-assume-ownership-and-operation-of-fitzpatrick-nuclear-power-plant, accessed 3 May 2017.

250 - New York State Energy Research and Development Authority, "Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard", NY Public Serviced Commission, 1 August 2016, see http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=15-e-0302, accessed 8 August 2017.

251 - *NW*, "FitzPatrick to shut if plan for credits thwarted, says entergy spokeswoman", 27 October 2016.

252 - Exelon, "New York's Clean Energy Standard at Work: Ginna's Refueling Outage Powers Local Economy", 24 April 2017, see http://www.exeloncorp.com/newsroom/ginna-refueling-outage-powers-local-economy, accessed 15 May 2017.

253 - U.S.NRC, "NRC Approves License Transfer of FitzPatrick Nuclear Plant", 3 April 2017, see https://www.nrc.gov/docs/ML1706/ML17062A563.pdf, acccessed 3 May 2017.

254 - Exelon, "James A. FitzPatrick Nuclear Power Plant Joins Exelon Generation Nuclear Fleet", 31 March 2017, see http://www.exeloncorp.com/newsroom/fitzpatrick-joins-exelon-generation-nuclear-fleet, accessed 3 May 2017.

255 - PSC, "PSC Announces New York's Approval of Sale of the James A. FitzPatrick Nuclear Power Plant—Sale of FitzPatrick Keeps Greenhouse Emissions Low for all New Yorkers", 17 November 2016, see https://www3.dps.ny.gov/pscweb/webfileroom.nsf/Web/1F5545164D43A5AF8525806E0068D467/$File/pr16077.pdf?OpenElement, accessed 3 May 2017.

256 - Federal Energy Regulatory Commission (FERC), "Order Authorizing Proposed Transaction—Entergy Nuclear FitzPatrick, LLC ; Exelon Generation Company, LLC—Docket No. EC16-169-000", 7 December 2016, see www.ferc.gov/CalendarFiles/20161207174450-EC16-169-000.pdf, accessed 7 August 2017.

The New York PSC ZEC plan requires that assigned nuclear power plants participate in the program through two six-year periods and sell the ZECs to the New York State Energy Research and Development Authority. In total, the ZEC is estimated to be worth US$8 billion over a 12-year period from 1 April 2017. For the nuclear reactors in New York State, the PSC agreed a ZEC rate of US$17.48/MWh during the period from 1 April to 31 March 2019. Future levels remain to be set, and the State Assembly may press the NYPSC to determine it not administratively as now but competitively.

ZECs paid to designated nuclear generators would otherwise increase with time, tentatively reaching US$29.15/MWh for the period from 1 April 2027 to 31 March 2029. Moody's Investor Services 8 August 2016 estimated that with a "current wholesale power price in the forward market for 2017" of about US$35/MWh and US$3.50/MWh estimated for capacity payments that year, the US$17.48/MWh "subsidy will equal about a 45 percent price increase."[257] With the purchase of FitzPatrick, Moody's said that Exelon "could receive another US$120 million pretax cash flow from [the credits], or about US$75 million of after-tax cash flow" in the first two years. These are indeed very large subsidies.

In response to the NYPSC Clean Energy Standard ZEC, a coalition of five electricity generators and the Electric Power Supply Association (EPSA) on 19 October 2016 filed a lawsuit in a New York State court calling for the halting of the "unlawful" plan. The lawsuit states that "seeking to change the results of FERC's market-based auction system, the PSC issued the ZEC order to bail out four uneconomic upstate nuclear power plants and keep them in the market for at least 12 more years" via the ZECs; the coalition continued. "Unless enjoined or eliminated, these credits will result in New York's captive ratepayers paying the owners an estimated US$7.6 billion over 12 years."[258] Such litigation will serve as a litmus test for the viability of the ZEC model in Illinois and Ohio.

Entergy's other nuclear plant in New York State is the Indian Point nuclear power plant, which has been more profitable because of the higher power prices in nearby New York City. However, operations at Indian Point are being challenged on two crucial environmental requirements—a coastal zone management certification and a water permit application.[259] While Entergy has declared that it is exempt from needing the coastal zone management certification, New York State disagrees. The two parties continued through 2016 to battle it out in the Court of Appeals.[260]

On 9 January 2017, agreement was announced for the permanent closure of the two reactor units at Indian Point, which lies 30 miles (48 km) north of Manhattan, New York.[261] The agreement mirrors an arrangement reached between PG&E (Pacific Gas & Electric Co.) and

257 - *NW*, "FitzPatrick to shut if plan for credits thwarted, says entergy spokeswoman", 27 October 2016.

258 - Jeannine Anderson, "Generators sue New York PSC over financial support for nuclear plants", *Public Power Daily*, American Public Power Association, 25 October 2016, see http://www.publicpower.org/Media/daily/ArticleDetail.cfm?ItemNumber=46934, accessed 9 August 2017.

259 - Frans Koster, "Could Indian Point Fall Victim to Economics?", *NIW*, 10 June 2016.

260 - Michael Randall, "Entergy faces new obstacle to renewing licenses at Indian Point nuclear plant", *Times Herald-Record*, 12 November 2015, see http://www.recordonline.com/article/20151112/NEWS/151119779, accessed 25 May 2017.

261 - Indian Point Energy Center, "Entergy, NY Officials Agree on Indian Point Closure in 2020-2021—Decision driven by sustained low power prices", Entergy, Press Release, 9 January 2017, see http://www.safesecurevital.com/entergy-ny-officials-agree-on-indian-point-closure-in-2020-2021/, accessed 15 May 2017; for complete transcript of the agreement signed 9 January 2017, see *Riverkeeper*, "Indian Point Agreement", see https://www.riverkeeper.org/wp-content/uploads/2017/01/Indian-Point-Closure-Agreement-January-8-2017.pdf, accessed 15 May 2017.

stakeholders, including environment groups, over the planned closure of the two reactors at Diablo Canyon in California announced in 2016.[262] In the case of Indian Point, long opposed on safety grounds by groups in and around New York City, as well as the Governor of New York State, the early shutdown is part of a settlement under which the State has agreed to drop legal challenges and support renewal of the operating licenses for Indian Point.[263] Entergy filed a license renewal application for both Indian Point operating units in April 2007, which were subsequently subject to sustained challenge from citizens groups over the past ten years.[264] Entergy invested over US$1 billion in the two reactors in recent years.[265] According to the agreement, Indian Point Unit 2 will shut down no later than 30 April 2020 and Unit 3 no later than 30 April 2021.

Entergy also announced on 8 December 2016 its intention to permanently shut down the Palisades reactor, following the early termination of the Power Purchase Agreement (PPA).[266] Under the current plan, and assuming regulatory approval of the request to terminate the PPA in 2018, Palisades will be refueled during 2017 and operate through the end of that fuel cycle, then permanently shut down on 1 October 2018. "Market conditions have changed substantially, and more economic alternatives are now available to provide reliable power to the region. The transaction is expected to result in US$344 million in savings", said Entergy.[267] The Palisades reactor, one of the oldest in the U.S. fleet, has long been under contention on safety grounds, specifically its extensive neutron radiation embrittlement of the Reactor Pressure Vessel (RPV), the most severe on record in the U.S.[268]

In **New Jersey**, identical bills were introduced in the Senate[269] and General Assembly that would require the state Board of Public Utilities to conduct a study concerning the feasibility and benefits of adopting an energy policy that includes a ZEC program, with the requirement that the assessment be completed within one year. The Public Service Enterprise Group (PSEG), the utility that operates the Salem reactor units 1&2, Salem-2 and Hope Creek

262 - PG&E "In Step With California's Evolving Energy Policy, PG&E, Labor and Environmental Groups Announce Proposal to Increase Energy Efficiency, Renewables and Storage While Phasing Out Nuclear Power Over the Next Decade", News Release, 21 June 2016, see https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20160621_in_step_with_californias_evolving_energy_policy_pge_labor_and_environmental_groups_announce_proposal_to_increase_energy_efficiency_renewables_and_storage_while_phasing_out_nuclear_power_over_the_next_decade, accessed 15 May 2017.

263 - Indian Point Energy Center, "Entergy, NY Officials Agree on Indian Point Closure in 2020-2021—Decision driven by sustained low power prices", Entergy, Press Release, 9 January 2017, see http://www.safesecurevital.com/entergy-ny-officials-agree-on-indian-point-closure-in-2020-2021/, accessed 15 May 2017; for complete agreement, see Riverkeeper, "Indian Point Agreement", signed 9 January 2017, see https://www.riverkeeper.org/wp-content/uploads/2017/01/Indian-Point-Closure-Agreement-January-8-2017.pdf, accessed 15 May 2017.

264 - Vivian Yee, Patrick McGeehan, "Indian Point Nuclear Power Plant Could Close by 2021", *New York Times*, 6 January 2017, see https://www.nytimes.com/2017/01/06/nyregion/indian-point-nuclear-power-plant-shutdown.html?_r=0, accessed 15 May 2017.

265 - Tom Kauffman, "Indian Point 3's Operating License is Alive and Well", NEI, 10 December 2015, see http://neinuclearnotes.blogspot.jp/2015/12/indian-point-3s-operating-license-is.html, accessed 15 May 2017.

266 - Entergy, "Palisades Power Purchase Agreement to End Early", News Release, 8 December 2016, see http://www.entergynewsroom.com/latest-news/palisades-power-purchase-agreement-end-early/, accessed 15 May 2017.

267 - Ibidem.

268 - Beyond Nuclear, "Beyond Nuclear warns NRC against weakening RPV embrittlement/PTS safety regulations at Palisades", 30 October 2014, see http://www.beyondnuclear.org/safety/2014/10/30/beyond-nuclear-warns-nrc-against-weakening-rpv-embrittlement.html, accessed 15 May 2017.

269 - Senate, "State of New Jersey—217th Legislature—An Act requiring the Board of Public Utilities to conduct a study concerning zero emission credits", introduced 6 March 2017, see http://www.njleg.state.nj.us/2016/Bills/S3500/3061_I1.HTM, accessed 23 May 2017.

reactor unit in New Jersey, is actively supporting the establishment of ZECs in the state.[270] On 28 April 2017, PSEC warned that, while cash flow is currently positive for the reactor units, they are projected to turn negative in 2020, and that "if those assets are not earning their cost of capital over the long term or if they turn cash flow negative, we'll retire them,"[271] The New Jersey Department of Environmental Protection in 2016 allowed PSE&G Power, the operator and, along with Exelon, owner of the two units at Salem, to continue operating the reactors without building cooling towers, which environmentalists had long advocated to stop the plants destructive impact on the ecosystem of Delaware Bay.[272]

In 2016, PSE&G Power was granted an early site permit by the NRC Atomic Safety Licensing Board (ASLB)[273] for a new reactor to be located at a site adjacent to two existing facilities in Salem County. PSE&G originally applied for a permit in 2010, but there are no immediate plans to proceed with construction.

Another plant under financial stress is the Davis Besse reactor in **Ohio**, long considered at risk of shutdown due to economic factors.[274] Its operator FirstEnergy proposed a power-purchase agreement with the Public Utilities Commission of Ohio, which approved a special eight-year arrangement in March 2016.[275] The arrangement would have required FirstEnergy's Ohio customers to subsidize the continued operations of Davis Besse and the Sammis coal-based thermal plant. However, in April 2016, the Federal Energy Regulatory Commission (FERC) blocked the power purchase agreement.[276]

Through 2016, FirstEnergy continued to lobby for the establishment of Zero Emission Nuclear (ZEN) legislation that would support their Davis-Besse and Perry reactors, which could be worth an estimated US$300 million a year to the reactors. A FirstEnergy spokesperson stated that "I don't think these units will keep running far into the future."[277] FirstEnergy Solutions, the company's unregulated subsidiary that owns the competitive generation, is at risk of federal bankruptcy court protection, with FirstEnergy Nuclear Operating Co. also a candidate for Chapter 11 bankruptcy reorganization. In February 2017, it was reported that FirstEnergy would either seek a new owner for the two nuclear plants or close them in 2018.[278]

270 - PSEG, "Preserving Nuclear Energy: A New Jersey Resource—A PSEG Position Paper", May 2017, see https://www.pseg.com/family/power/nuclear/pdf/nj_nuclear_brochure.pdf, accessed 23 May 2017; also Robert Walton, "PSEG CEO Izzo calls for efficiency, rate reform and nuclear supports in New Jersey", *Utility Dive*, 6 June 2017, see http://www.utilitydive.com/news/pseg-ceo-izzo-calls-for-efficiency-rate-reform-and-nuclear-supports-in-new/444027/, accessed 6 June 2017.

271 - Michael McAuliffe, "PSEG executive sees nuclear unit cash flow turning negative in 2020", *NW*, *Platts*, 4 May 2017.

272 - Tom Johnson, "DEP Says Salem Nuclear Good to Go Without Cooling Towers", *NJ Spotlight*, 13 June 2016, see http://www.njspotlight.com/stories/16/06/12/dep-says-salem-nuclear-good-to-go-without-cooling-towers/, accessed 25 May 2017.

273 - Atomic Safety and Licensing Board, "In the Matter of PSEG POWER, LLC and PSEG NUCLEAR, LLC (Early Site Permit Application)—Docket No. 52-043-ESP", U.S.NRC, 26 April 2016, see https://www.nrc.gov/docs/ML1611/ML16117A383.pdf, accessed 25 May 2017.

274 - Mark Cooper, "Power Shift: The Deployment of a 21st Century Electricity Sector and the Nuclear War To Stop It", Institute for Energy and the Environment, Vermont Law School, June 2015, see http://www-assets.vermontlaw.edu/Assets/iee/Power_Shift_Mark_Cooper_June_2015.PDF, accessed 25 May 2017.

275 - John Funk, "FirstEnergy's Davis-Besse, Sammis power plants make money after all: FirstEnergy profits show", *Cleveland.com*, 27 April 2016, see http://www.cleveland.com/business/index.ssf/2016/04/firstenergys_davis-besse_sammi.html, accessed 25 May 2017.

276 - Gavin Bade, "FERC blocks Ohio power plant subsidies for AEP and FirstEnergy", *Utility Dive*, 28 April 2016, see http://www.utilitydive.com/news/ferc-blocks-ohio-power-plant-subsidies-for-aep-and- firstenergy/418297/, accessed 16 June 2016.

277 - NW, "Firstenergy calling for zero-emission credit program for Ohio nuclear units", 23 February 2017.

278 - Andrew Cass, "FirstEnergy looking to sell or shutter Perry Nuclear Power Plant", *The News Herald*, 24 February 2017, see http://www.news-herald.com/article/HR/20170224/NEWS/170229620, accessed 15 May 2017.

One further possible lifeline for FirstEnergy, as well as plants nationwide, is the Federal Government. Energy Secretary Rick Perry in a 14 April 2017 memorandum to staff ordered a departmental review of the electricity grid, targeting federal regulations and support for renewable energy that he says could imperil baseload power in the future,[279] with a request it be completed by mid-June 2017, this was subsequently postponed with no issue date as of 1 July 2017.[280] The review aims to assess, whether federal policies have negatively impacted the electric grid's supply of baseload power or the reliable electricity supply generated by large-scale power plants generally fueled by coal, natural gas or nuclear sources. A leaked draft version of the report dated 26 June 2017 concluded[281] that the vast majority of nuclear plant closures are due to "unfavorable market conditions" and the "most unfavorable condition is that the marginal cost of generation for many nuclear plants is higher than the cost of most other generators in the market." FirstEnergy in late April 2017 indicated that it could delay its plans to sell or shut down its merchant coal and nuclear units until the Department of Energy (DOE) completes its review.[282] However, FirstEnergy currently retains plans to exit its competitive generating business by mid-2018, meaning it could also close or sell its two Beaver Valley reactor units.

The single unit Fort Calhoun reactor in **Nebraska** was permanently shut down on 24 October 2016, due to poor economics.[283] Located 19 miles north of Omaha, the reactor was operated by Omaha Public Power District (OPPD) through an agreement with Exelon Generation. The reactor began operation in 1973, and received a license extension in 2002 from the Nuclear Regulatory Commission (NRC) to operate until 2033. Fort Calhoun had struggled since the 2014 debut of the day-ahead market in the Southwest Power Pool (SPP) and in May 2016 the President of OPPD told its Board that its continued operation was not financially sustainable.[284]

The reason offered for its shutdown reveal the problems confronting nuclear power plants in the U.S. In April 2016, the Chairman of Board of OPPD called for potential scenarios regarding future power resources; it turned out that in all scenarios, Fort Calhoun did not meet the requirements of the lowest cost portfolio and that "other carbon-free options are more economic".[285] On 17 June 2016, the OPPD Board voted unanimously to shut down the reactor by the end of the year; the decision was, in the words on one board member, "simply an economic decision".[286] Exelon had taken over the running of the plant in 2012 under a 20-year,

279 - Devin Henry, "Perry orders Energy Department study of electric grid", *The Hill*, 17 April 2017, see http://thehill.com/policy/energy-environment/329142-perry-orders-energy-department-study-of-electric-grid, accessed 23 May 2017.

280 - U.S.NEI, "DOE's Perry Orders Study on Grid Reliability, Market Distortions", 19 April 2017, see https://www.nei.org/News-Media/News/News-Archives/DOE-s-Perry-Orders-Study-on-Grid-Reliability,-Mark, accessed 23 May 2017.

281 - Joe Romm, "Coal and nuclear are uneconomic—more bombshells from Perry's draft grid study", *Think Progress*, 17 July 2017, see https://thinkprogress.org/draft-doe-study-bombshell-9221a62afefd/, accessed 5 August 2017.

282 - *Nucleonics Week*, "First Energy looks to government for generation plant solution: CEO", 4 May 2017.

283 - *The Wire*, "Fort Calhoun Station now officially offline", OPPD, 24 October 2016, see http://oppdthewire.com/fort-calhoun-station-ceases-operations/, accessed 22 May 2017.

284 - Argus, "Fort Calhoun reactor may shut by year-end", 31 May 2016, see http://www.argusmedia.com/pages/NewsBody.aspx?id=1249396&menu=yes, accessed 25 May 2017.

285 - Aaron Larson, "Fort Calhoun May Close by Year End, Joining List of Premature Nuclear Power Plant Retirements", *POWER Magazine*, 12 May 2016, see http://www.powermag.com/fort-calhoun-may-close-by-year-end-joining-list-of-premature-nuclear-power-plant-retirements/, accessed 16 June 2016.

286 - Cole Epley, "'Simply an Economic Decision': OPPD to Close Fort Calhoun Nuclear Plant by End of 2016", *Omaha World-Herald*, 17 June 2016, see http://www.omaha.com/money/simply-an-economic-decision-oppd-to-close- fort-calhoun-nuclear/article_3fe6ce02-3352-11e6-a426-a7596287dd59.html, accessed 25 May 2017.

US$400 million contract with OPPD. Generation costs and output at Fort Calhoun indicated a cost to OPPD of about US$71/MWh, compared with a market price of US$20.[287]

Since 2013, reactor utilities in the U.S. have declared 16 reactors for permanent shutdown, (three during the past 12 months); with the decision on three of these reactors having subsequently been reversed due to the availability of state ZEC legislation (Fitzpatrick in New York, Clinton and Quad Cities 1 & 2 in Illinois); six have been shut down (Crystal River 3 in Florida, San Onofre 2 and 3 in California, Kewaunee in Wisconsin, Vermont Yankee in Vermont, and the latest being in October 2016 with Fort Calhoun in Nebraska); of the remaining reactors declared for permanent closure there seems no prospect that the decisions will be reversed for Palisades in Michigan, Indian Point 2&3, Pilgrim in Massachusetts, Oyster Creek in New Jersey, and Diablo Canyon 1 & 2 in California. The shutdown agreement of the Diablo Canyon nuclear plant provides a model for other reactors in the U.S. As Amory Lovins has concluded, the Diablo decision, "unlike previous nuclear shutdowns, some of which were too abrupt for immediate replacement with carbon-free resources, PG&E's nuclear output will be phased out over 8–9 years, replaced timely and cost-effectively by efficiency and renewables. That means no more fossil fuel burned nor carbon emitted, all at less cost to ratepayers."[288] The number of shutdowns will grow further, even with further ZEC legislation adopted. Most at risk include the Perry and Davis Besse reactors unless they can secure ZECs, and a decision on the two-unit Prairie Island reactors in Minnesota expected in the coming year due to estimated retrofit costs of US$500 million required before 2020.[289]

Table 5 | Early Shutdowns of U.S. Reactors 2009–2025

Reactor	Owner	Decision Date	Shutdown Date (last electricity generation)	Age at Shutdown (in years)	NRC 60-Year License Approval
Oyster Creek	Exelon	8 December 2010	December 2019	50	Yes
Crystal River-3	Duke Energy	5 February 2013	26 September 2009	32	Application withdrawn
San Onofre-2&-3	SCE/SDG&E	7 June 2013	January 2012	29 / 28	No application
Kewaunee	Dominion Energy	22 October 2012	7 May 2013	39	Yes
Vermont Yankee	Entergy	28 August 2013	29 December 2014	42	Yes
Pilgrim	Entergy	13 October 2015	31 May 2019	47	Yes
Diablo Canyon -1&-2	PG&E	21 June 2016	November 2024 & August 2025	40	Suspended
Fort Calhoun	OPPD	26 August 2016	24 October 2016	43	Yes
Palisades	Entergy	8 December 2016	1 October 2018	47	Yes
Indian Point-2&-3	Entergy	9 January 2017	No later than 30 April 2020 / 30 April 2021	47 / 44	Under review

Notes : SCE: Southern California Edison; SDG&E: San Diego Gas & Electric; PG&E: Pacific Gas & Electric Company; OPPD: Omaha Public Power District

Sources: Various, compiled by WNISR, 2017

287 - Cole Epley, "OPPD announces official closing date for Fort Calhoun nuclear plant: Oct. 24", *Omaha World-Herald*, 31 August 2016, see http://www.omaha.com/money/oppd-announces-official-closing-date-for-fort-calhoun-nuclear-plant/article_b8cf2e6f-ce65-56fb-9a0b-cb7ad80f8ce4.html, accessed 22 May 2017.

288 - Amory B. Lovins, "Closing Diablo Canyon Nuclear Plant Will Save Money And Carbon", *Forbes*, 22 June 2016, see https://www.forbes.com/sites/amorylovins/2016/06/22/close-a-nuclear-plant-save-money-and-carbon-improve-the-grid-says-pge/ - 3dcbdc9e5093, accessed 5 August 2017.

289 - Robert Walton, "Xcel Energy faces almost $500M in Prairie Island nuke upgrades", *Utility Dive*, 21 March 2017, see http://www.utilitydive.com/news/xcel-energy-faces-almost-500m-in-prairie-island-nuke-upgrades/416019/, accessed 25 May 2017.

New Reactor Construction

> *"We're the largest nuclear company in the world that's privately owned, and we're going to show why that's a good thing, and get these plants done."*[290]
>
> Danny Roderick then Westinghouse CEO, October 2015

On 29 March 2017, Westinghouse Electric Company, a subsidiary of Japanese Toshiba group and the largest historic builder of nuclear power plants in the world, filed for Chapter 11 bankruptcy protection in the U.S. Bankruptcy Court for the Southern District of New York.[291] The insolvency has resulted from a number of factors, most recently, the enormous cost increases and time delays at the four AP1000 reactors under construction at the Alvin W Vogtle plant in Georgia and V.C. Summer in South Carolina. The AP1000 reactor projects are managed by Chicago Bridge and Iron (CB&I) Stone and Webster, a subsidiary of Westinghouse Electric Company LLC, which was purchased by Toshiba in 2006.

The cost overruns on these projects are the principal cause of US$6.2 billion in losses declared by Westinghouse parent company Toshiba. As Westinghouse's website puts it somewhat more discreetly, the "company is seeking to undertake a strategic restructuring as a result of certain financial and construction challenges in its U.S. AP1000 power plant projects".[292]

In response to the bankruptcy filing, Southern Company, the parent company of GeorgiaPower, the owner of the Vogtle plant, stated: "We will continue to take every action available to us to hold Westinghouse and Toshiba accountable for their financial responsibilities under the engineering, procurement and construction agreement and the parent guarantee."[293] As a practical matter, Toshiba may be unable to cover its obligations.

Vogtle and V.C. Summer AP1000 Projects

On 9 February 2012, for the first time in nearly three and a half decades, the NRC granted a Construction and Operating License (COL) for the Vogtle-3 and -4 units. One week later, a coalition of environmental organizations filed a lawsuit against the decision.[294] On 30 March 2012, South Carolina Electric & Gas received the second COL for units 2 and 3 at its Summer site. In an unprecedented move, Gregory B. Jaczko, Chairman of the NRC, voted against the opinion

290 - Phil Chaffee, "Westinghouse's Strategy in CB&I Stone & Webster Acquisition", *NIW*, 30 October 2015.

291 - U.S. Bankruptcy Court, "Case 1:17-bk-10778—Westinghouse International Technology LLC— Bankruptcy Petition #: 17-10778-mew", Southern District of New York (Manhattan), 29 March 2017, see https://www.inforuptcy.com/filings/nysbke_273415-1-17-bk-10778-westinghouse-international-technology-llc - docket_text, accessed 27 May 2017.

292 - Westinghouse, "Westinghouse Announces Strategic Restructuring", 29 March 2017, see http://www.westinghousenuclear.com/About/News/View/WESTINGHOUSE-ANNOUNCES-STRATEGIC-RESTRUCTURING, accessed 5 August 2017.

293 - Tom Hals, Emily Flitter, and Makiko Yamazaki, "How two cutting edge U.S. nuclear projects bankrupted Westinghouse", *Reuters*, 4 May 2017, see http://www.reuters.com/article/us-toshiba-accounting-westinghouse-nucle-idUSKBN17Y0CQ, accessed 27 May 2017.

294 - Mindy Goldstein et al., "Before the Nuclear Regulatory Commission—Petitioners' motion to stay the effectiveness of the Combined License for the Vogtle electric generating plant units 3 and 4 pending judicial review", Docket Nos. 52-0 25 & 52-026, 16 February 2012, see http://www.beyondnuclear.org/storage/2012-02-16_Stay_Motion%20Vogtle%20COL.pdf, accessed 9 August 2017.

of the four other Commissioners, stating that the decision was being taken "as if Fukushima never happened".[295] Jaczko subsequently resigned from his NRC position.

Construction of Vogtle-3 officially began in March 2013,[296] with unit 4 following in November 2013.[297] The original cost estimate for the two AP1000 reactors at Plant Vogtle was US$14 billion. In December 2015, Georgia Power confirmed that the estimated total costs were now US$21 billion,[298] about 50 percent above initial estimates. By June 2017, one estimate for project completion put the cost at US$29 billion.[299]

Vogtle units 3&4 are jointly owned by Georgia Power (45.7 percent, the parent company being Southern Company), Oglethorpe Power Corporation (30 percent), Municipal Electric Authority of Georgia (22.7 percent) and Dalton Utilities (1.6 percent). A report for the Georgia Public Service Commission (G-PSC) in June 2014 warned that projected startup of unit-3 had slipped from April 2016 to January 2018.[300] In April 2015, the NRC reported that "revised estimates for substantial completion… now stand at June 2019 and June 2020. Primary reasons for the delays included issues with submodule design and fabrication."[301]

At V.C. Summer, units 2 & 3 construction began on 11 March 2013,[302] and 4 November 2013[303] respectively, with startup dates projected for Unit 2 for 2017 and for Unit 3 late 2017 or early 2018.[304] Both reactors are owned by South Carolina Electric & Gas Company (SCE&G)[305] and South Carolina Public Service Authority (Santee Cooper). In a May 2016 filing SC&G reaffirmed that the first new reactor is targeted for "substantial completion" (not operation) in August 2019 and the second unit in August 2020.[306] On 14 February 2017, Westinghouse provided SCE&G with revised in-service dates of April 2020 and December 2020 for Units 2 and 3, respectively.[307]

295 - *MSNBC*, "U.S. licenses first nuclear reactors since 1978", 9 February 2012.

296 - *WNISR*, "Construction Start at Vogtle Reactor in the US", 16 March 2013, see https://www.worldnuclearreport.org/Construction-Start-at-Vogtle.html, accessed 27 May 2017.

297 - *WNISR*, "Construction Start on US Vogtle Unit 4", 25 November 2013, see https://www.worldnuclearreport.org/Construction-Start-on-US-Vogtle.html, accessed 27 May 2017.

298 - The Southern Alliance for Clean Energy, "Plant Vogtle's Price Tag Climbs to $21 Billion as Commission Experts Predict Further Delays and Cost Increases for Southern Company's Proposed Reactors", News Release, 11 December 2015, see http://www.ncwarn.org/2015/12/plant-vogtles-price-tag-climbs-to-21-billion-as-commission-experts-predict-further-delays-and-cost-increases-for-southern-companys-proposed-reactors-news-release-from-the-souther/, accessed 7 August 2017.

299 - Darrell Proctor, "Cost Overruns at Vogtle Expected to Soar", *POWER Magazine*, 19 June 2017, see http://www.powermag.com/cost-overruns-at-vogtle-expected-to-soar/, accessed 5 August 2017.

300 - *Associated Press*, "Monitor warns of delays building Plant Vogtle", published in *Athens Banner-Herald*, 23 June 2014, see http:/m.onlineathens.com/local-news/2014-06-23/monitor-warns-delays-building-plant-vogtle, accessed 7 August 2017.

301 - NRC, "Quarterly Nuclear Power Deployment Summary—April 2015", April 2015.

302 - *WNISR*, "Summer, South Carolina: First Construction Start in 36 Years in the US", 12 March 2013, see https://www.worldnuclearreport.org/Summer-South-Carolina-First.html, accessed 27 May 2017.

303 - *WNISR*, "Construction Start at V.C. Summer Reactor Unit 3", 14 November 2013, see https://www.worldnuclearreport.org/Construction-Start-at-VC-Summer.html, accessed 27 May 2017.

304 - *WNN*, "Second Summer AP1000 under construction", 6 November 2013, see http://www.world-nuclear-news.org/NN-Second-Summer-AP1000-under-construction-0611134.html, accessed 7 August 2017.

305 - SCE&G is a regulated public utility and the principal subsidiary of SCANA Corporation, an energy-based holding company.

306 - SCANA, "Petition of South Carolina Electric & Gas Company for Updates and Revisions to Schedules Related to the Construction of a Nuclear Base Load Generation Facility at Jenkinsville, South Carolina", Public Service Commission of South Carolina, 26 May 2016, see https://dms.psc.sc.gov/Attachments/Matter/5e9e64a6-9db1-4086-9341-b1b7325bca7d, accessed 28 May 2017.

307 - SCANA, "SCANA Receives Reaffirmation from Westinghouse Regarding Completion of V.C. Summer New Nuclear Project", 14 February 2017, see https://www.scana.com/docs/librariesprovider15/pdfs/press-releases/02142017-scana-receives-reaffirmation-from-westinghouse-regarding-completion-of-vc-summer-new-nuclear-project.pdf?sfvrsn=0, accessed 28 May 2017.

In October 2016, after a review of the project, Westinghouse and the reactor owners SC&G agreed on a new contract with a higher projected cost of US$14 billion, about 43 percent higher than the total US$9.8 billion price tag announced in 2008.[308] In May 2017, the cost of the project was being reported as "approaching US$16 billion".[309]

According to SCE&G, planned cash requirements for the V.C. Summer reactor project to completion in April and December 2020 respectively are a total of US$5.3 billion. Construction costs projected by SCE&G in 2017 are US$1.9 billion, US$1.7 billion in 2018, and US$1.1 billion through 2020.[310] As with Vogtle, there were no prospects that the V.C. Summer reactors would be completed on the latest schedule.

Construction

In 2015, the WNA reported that the AP1000 design "uses modular construction techniques, enabling large structural modules to be built at factories and then installed at the site. This means that more construction activities can take place at the same time, reducing the time taken to build a plant as well as offering economic and quality control benefits."[311]

The reality has turned out to be very different.

Even before formal reactor construction began at the Vogtle site, the NRC determined that in excavating and preparation for laying of the reactors' basemat, a Severity Level (SL) IV violation of NRC requirements had occurred.[312] The violations included non-compliant backfill material, and the failure to test as required waterproof membranes, which are required to meet Seismic Category component standard, important in coping with seismic loads and the Safe Shutdown Earthquake (SSE) designation. These problems set back construction start by nine months. These problems were compounded over the next four years, as regulatory and internal inspections at Lake Charles revealed multiple problems associated with the effort to construct modular parts to fit the new Westinghouse design, NRC records show.[313]

The construction of the Vogtle and V.C. Summer reactors were already in severe difficulty long before the declaration of bankruptcy by Westinghouse.

308 - K. Chad Burgess "Petition of South Carolina Electric & Gas Company for Updates and Revisions to Schedules Related to the Construction of a Nuclear Base Load Generation Facility at Jenkinsville, South Carolina", SCANA, Before the Public Service Commission of South Carolina, 26 May 2016, see https://dms.psc.sc.gov/Attachments/Matter/5e9e64a6-9db1-4086-9341-b1b7325bca7d, accessed 28 May 2017.

309 - Peter Maloney, "Westinghouse will not object to unsealing contract for V.C. Summer nuclear project", *Utility Dive*, 22 May 2017, see http://www.utilitydive.com/news/westinghouse-will-not-object-to-unsealing-contract-for-vc-summer-nuclear-pr/443180/, accessed 29 May 2017.

310 - SCANA, "Fourth Quarter and Full Year 2016", 16 February 2017.

311 - WNA, "Major module installed at Summer 3", 8 July 2015, see http://www.world-nuclear-news.org/NN-Major-module-installed-at-Summer-3-0807154.html, accessed 27 May 2017.

312 - U.S.NRC, "Southern Nuclear Operating Company Vogtle Electric Electric Generating Plant Units 3 and 4–NRC Inspection Report 05200011/2011-009 and Notice of Violation", 16 September 2011, see https://www.nrc.gov/docs/ML1125/ML11259A159.pdf, accessed 27 May 2017.

313 - Tom Hals, Emily Flitter, "How two cutting edge U.S. nuclear projects bankrupted Westinghouse", *Reuters*, 4 May 2017, see http://www.reuters.com/article/us-toshiba-accounting-westinghouse-nucle-idUSKBN17Y0CQ, accessed 7 August 2017.

“ It’s going beautifully, and we’re on schedule ”

Tom Fanning, Southern CEO, October 2016[314]

Vogtle[315]

While Georgia Power claimed in 2016 that Plant Vogtle was 60-percent complete, in terms of construction milestones, the actual full-plant construction was only 36 percent complete as of September 2016, a point admitted by Georgia executives to the PSC (Public Service Commission).[316] [317]

The December 2016 quarterly progress report by the Georgia PSC, obtained by *EnergyWire*,[318] (one public version, the other classified as ‘Highly Confidential Trade Secret EPC Information’), cast major doubts on the latest estimated completion dates of the Vogtle reactors, with future long-term activities identified by “staff as high risk for delay.” Although both versions of the report were heavily redacted, it confirmed that “there have been continued delays from the November 2016 Integrated Project Schedule (“IPS”) to the December 2016 IPS for many Unit 3 and 4 activities” and that “that all of the paths to Unit 3 completion are under schedule stress and will likely incur additional delays.”[319]

If the decision is taken to continue with construction (see below) and even with a dramatic improvement in construction rates from an estimated 40-percent complete as of 31 March 2017, a more credible completion date for Plant Vogtle would be 2023. But this date remains highly speculative, and is on the basis of maintaining the current nine percent annual construction completion rate, with no further delays, which given the track record of the project must be in doubt.

Additional construction delays, and therefore further additional major costs, for completion of Plant Vogtle, are inevitable. The cost of one year delay in the project has been reported to the PSC in Georgia as ‘hundreds of millions of dollars”.[320] While the AP1000 units at Vogtle are scheduled to begin commercial operation in June 2019 and June 2020 respectively, in reports by the PSC staff in 2016 and independent monitors have said those dates are not likely to be met:

314 - Kristi E. Schwartz, “Evidence mounts that Vogtle project won’t start up in 2020”, *Energy Wire*, *E&E News*, 8 February 2017, see https://www.eenews.net/energywire/stories/1060049693/, accessed 28 May 2017.

315 - All documents related to the construction monitoring are available on the website of the Public Service Commission, see http://www.psc.state.ga.us/factsv2/Docket.aspx?docketNumber=29849.

316 - Scott Judy, “Turnaround Eludes Nuclear Power Plant Vogtle”, *Engineering News-Record*, 18 January 2017, see http://www.enr.com/articles/41134-turnaround-eludes-nuclear-power-plant-vogtle, accessed 7 August 2017.

317 - Travis Highfield, “Plant Vogtle construction continues despite setbacks, cost overrun”, *The Augusta Chronicle*, 13 February 2016, see http://chronicle.augusta.com/news-metro/2016-10-18/plant-vogtle-construction-continues-despite-setbacks-cost-overrun, accessed 7 August 2017.

318 - Kristi E. Schwartz, “Evidence mounts that Vogtle project won’t start up in 2020”, *E&E News*, 8 February 2017, see https://www.eenews.net/energywire/2017/02/08/stories/1060049693, accessed 28 May 2017.

319 - Georgia PSC, “Vogtle 3 and 4 Nuclear Project Monthly Report—Public Disclosure”, December 2016, see https://www.eenews.net/assets/2017/02/08/document_ew_02.pdf, accessed 28 May 2017.

320 - Georgia PSC, “7th VCM August 2012-February 2013—Direct Testimony of William R Jacobs”, p11.

> We conclude that the Company has not demonstrated to staff that the current COD (Commercial Operation Dates) have a reasonable chance of being met. It is our opinion that there is a very strong likelihood of further delays for CODs for both Units.[321]

Describing the risk of further delays as "acute", the current annual construction rate of 9.2 percent would have to be tripled to 27 percent in 2017, if the stated completion date was to be met. In fact, the construction rate *declined* from August 2016.

The risk of additional project capital and financing costs due to additional schedule delays beyond the current forecasted delayed CODs remains a significant risk to increase Project cost... the Project continued to incur substantial schedule delays, in particular on Unit 3.[322]

In early May 2017, Georgia Power officials admitted to the Georgia PSC that the project slipped at least four months behind schedule in the second half of 2016, and has fallen farther behind this year.[323]

Following the Westinghouse bankruptcy filing, Georgia Power on 12 May 2017 announced that with Westinghouse they had reached in principle, a new service agreement, which "allows for the transition of project management from Westinghouse to Southern Nuclear and Georgia Power once the current engineering, procurement and construction contract is rejected in Westinghouse's bankruptcy proceeding."[324]

The interim assessment agreement set to expire originally on 12 May remained in place until 3 June 2017 while the new service agreement was finalized and all approvals obtained. During this time, work was to continue at the site and an orderly transition of project management will begin. Georgia Power executives have said they expect Westinghouse to terminate an engineering, procurement and construction, or EPC, contract on the two AP1000 units as soon as an interim agreement to provide construction management services lapses. On 9 June 2017, an agreement was reached in which Toshiba promised to pay Georgia Power US$3.68 billion beginning in October 2017 through January 2021.[325]

The early date for completing the analysis of the Vogtle project slipped further, when Southern Company officials stated that they hoped to have their evacuation completed "by August, or late summer [2017]".[326]

321 - See submission from Southern Alliance for Clean Energy (SACE), including Review of the Proposed Revisions of Expenditures Pursuant to Georgia Power Company's Certificate of Public Convenience and Necessity for Plant Vogtle Units 3 and 4, Fifteenth Semi-Annual Construction Monitoring Report, Docket 29849, 15th VCM, 13 February 2017, citing Direct Testimony of Routger and Jacobs, p23; Tr 155

322 - Georgia Public Service Commission, "15th VCM August 2016-February 2017—Direct Testimony of Steven D Roetger and William R Jacobs, Jr.", 17 November 2016.

323 - Russell Grantham, "Southern Company: 'Weeks' before we'll know cost of Plant Vogtle", *The Atlanta Journal-Constitution*, 11 May 2017, see http://www.ajc.com/business/southern-company-weeks-before-know-cost-plant-vogtle/xKz0Ih0COdYqqTCJAfxDQN/, accessed 29 May 2017.

324 - Georgia Power, "New service agreement reached for Vogtle nuclear expansion—Interim assessment agreement extended through June 3, work continues at site", Press Release, 12 May 2017, see http://www.prnewswire.com/news-releases/new-service-agreement-reached-for-vogtle-nuclear-expansion-300457135.html, accessed 28 May 2017.

325 - Darrell Proctor, "Toshiba Agrees to $3.68 Billion Deal to Aid Vogtle Nuclear Construction", *POWER Magazine*, 12 June 2017, see http://www.powermag.com/toshiba-agrees-to-3-68-billion-deal-to-aid-vogtle-nuclear-construction/, accessed 5 August 2017.

326 - Matt Kempner, "Southern Co. CEO: More time needed for new Vogtle plan", *Atlanta Journal Constitution*, 24 May 2017, see http://www.myajc.com/business/southern-ceo-more-time-needed-for-new-vogtle-plan/5tKTIa1WpXKx95F5qPyWeL/, accessed 29 May 2017.

V.C. Summer

In 2014, SCE&G revised the completion date for the reactors to 15 December 2017 and 15 December 2018 for V.C. Summer units 2&3 respectively.[327] The latest estimates are April and December 2020,[328] even before the Westinghouse bankruptcy these lacked credibility. The construction status of the V.C. Summer plant was at 33.7 percent complete as of February 2017.[329]

In March 2017, Kevin Marsh, CEO of SCANA, parent company of SCE&G, stated: "Our commitment is still to try to finish these plants. That would be my preferred option. The least preferred option, I think realistically, is abandonment".[330] In March 2017 SCANA announced that during the coming 30 days it would evaluate options for the project, including:

- continuing with the construction of both new units;
- focusing on the construction of one unit, and delaying the construction of the other;
- continuing with the construction of one and abandoning the other; and
- abandoning both units.[331]

On 29 April 2017, that assessment period on the future of the project was extended to 26 June 2017. SCANA by this time was admitting that "from a prudency perspective, we have to evaluate, whether or not mothballing one (reactor) or abandoning one would be in our best interests," said Steve Byrne, chief operating officer of SCANA. "If only one nuclear reactor could be completed, SCANA would convert the other into a gas reactor."[332]

Quality-Control Failures, Disputes and Acquisitions

The Westinghouse bankruptcy is in part a consequence of the multiple regulatory, quality control, construction failures during the past seven years in relations to the AP1000 projects. These have also contributed to the cascade of disputes between the contractors and Westinghouse, leading to acquisitions and legal challenges that have compounded the construction delays at Vogtle and V.C. Summer.

The most significant delays have been due to the 'innovative' design and the challenges created by the untested approach to manufacturing and building reactors. The AP1000 manufacturing method of using prefabricated parts when the supplier was unable to guarantee quality control

327 - Adam Russell, "Another Vogtle debacle? Cost overruns, delays and construction woes bedevil V.C. Summer reactor project in S.C.", Friends of the Earth U.S., 16 January 2014, see http://www.foe.org/news/archives/2014-01-another-vogtle-debacle-cost-overruns-delays-and-construction-woes-at-reactor, accessed 8 August 2017.

328 - Roddie Burris, "SCE&G gets new commitment from Westinghouse to finish V.C. Summer nuclear project", *The State*, 14 February 2017, see http://www.thestate.com/news/business/article132748809.html - storylink=cpy, accessed 7 August 2017.

329 - David Wren, "SCANA exec: Nuclear plant completion could hinge on extension of federal tax credits", *The Post and Courier*, 27 April 2017, see http://www.postandcourier.com/business/scana-exec-nuclear-plant-completion-could-hinge-on-extension-of/article_2bf6d520-2b83-11e7-a557-4b77cf88f39c.html, accessed 29 May 2017.

330 - Sam Fretwell, "SCANA, Santee Cooper to reassess reactors after Westinghouse bankruptcy", *The State*, 29 March 2017, see http://www.thestate.com/news/local/article141420014.html, accessed 27 May 2017.

331 - *WNN*, "Scana to evaluate Summer options", 30 March 2017, see http://www.world-nuclear-news.org/C-Scana-to-evaluate-Summer-options-3003177.html, accessed 28 May 2017.

332 - Michael Smith, "SCANA, Santee Cooper extend V.C. Summer deal; Project Vogtle files objection", *Aiken Standard*, 29 April 2017, see http://www.aikenstandard.com/news/scana-santee-cooper-extend-v-c-summer-deal-project-vogtle/article_f4ddbe5c-2c34-11e7-8f6c-e3fb3ec75fe8.html, accessed 5 August 2017.

and compliance with NRC regulations clearly has been costly failure. These have led to major conflicts between contractors and client.

In October 2015, Westinghouse signed a purchase agreement to acquire CB&I Stone & Webster Inc., the nuclear construction and integrated services businesses then owned by CB&I.[333] Westinghouse CEO Danny Roderick said the agreement "supports our company's strategic global growth framework, and expands our capabilities".[334] Westinghouse and its affiliates became the sole contractor for construction of Vogtle-3 and -4, owned by Georgia Power, and V.C. Summer-2 and -3 reactors. Westinghouse later entered into an agreement with Fluor Corp. as the construction subcontractor. Westinghouse paid nothing up front, but agreed to accept all liabilities related to cost overruns at Vogtle and V.C. Summer that Shaw was building in partnership with Westinghouse. The deal was meant to get the two power plant projects back on schedule.

CB&I subsequently charged that Westinghouse reneged on promises to wipe out all the construction company's liabilities tied to the Vogtle and V.C. Summer projects. The dispute relates to the value of the net working capital of the CB&I nuclear construction business. However, the nuclear power plant construction unit's liabilities affect not just the net working capital calculations, but also the valuation of the unit. Toshiba initially estimated the 'goodwill' resulting from the purchase of CB&I Stone and Webster at around US$87 million, which has now morphed into several billions of dollars. Clearly, as an intangible asset, the goodwill estimated by Toshiba was massively overvalued failing to take into account the rising cost of materials and goodwill to complete Vogtle and V.C. Summer, leading to the company's assets worth being less than expected. In April 2016, Toshiba reported the write down of goodwill as likely to be US$2.3 billion, now revised downward further by several billion.[335] On 5 December 2016, the Delaware Chancery Court ruled in favor of Westinghouse and dismissed the filing of CB&I, and found that the parties' purchase agreement required an independent auditor to resolve the dispute.[336] CB&I filed an appeal on 7 December 2016.[337]

Uncertainty Over V.C. Summer and Plant Vogtle

> *"If I'd known any of this a decade ago we would have gone a different way"*
>
> Stan Wise, Georgia Public Service Commission, May 2017.

The outcome for Vogtle and V.C. Summer U.S. AP1000 projects through June 2017 remained uncertain, with abandonment of an explicit option. In the case of the Vogtle unit 3&4 project

333 - Aaron Larson, "CB&I Out, Fluor In at Vogtle and V.C. Summer Nuclear Power Plant Construction Projects", *POWER Mag.*, 28 October 2015, see http://www.powermag.com/cbi-out-fluor-in-at-vogtle-and-v-c-summer-nuclear-power-plant-construction-projects/, accessed 28 May 2017.

334 - Ibidem.

335 - *WNN*, "Toshiba expects $2.3 billion write-down on Westinghouse", 26 April 2016, see http://www.world-nuclear-news.org/C-Toshiba-takes-2.3-billion-write-down-on-Westinghouse-2604165.html, accessed 28 May 2017.

336 - Matt Chiappardi, "Chancery Sends $2B Westinghouse Merger Fight To Auditor", *Law360*, 2 December 2016, see https://www.law360.com/articles/868511/chancery-sends-2b-westinghouse-merger-fight-to-auditor, accessed 28 May 2017.

337 - Michael Greene, "Chicago Bridge & Iron Appeals Dismissal of Westinghouse Suit", 7 December 2016, see https://www.bna.com/chicago-bridge-iron-n73014448199/, accessed 28 May 2017.

in Georgia, Stan Wise, chairman of the state's Public Service Commission, pointed out that it is "possible...that Plant Vogtle just doesn't get finished at all. It's a real hit and a real blow to something that we felt like was going to be the very best possible energy choice for Georgia maybe even into the next century".[338] But he also went on to talk about the changes in the energy landscape since the Vogtle plan was initially approved, "with natural gas getting very cheap, and technologies like solar power and batteries improving" and declaring: "If I'd known any of this a decade ago we would have gone a different way". Plant Vogtle and V.C. Summer were the first new US nuclear power projects to be licensed and begin construction in more than 30 years.[339]

Factors Determining the Future of Vogtle and V.C. Summer

There are a number of critical factors that determine the future of the Vogtle and V.C. Summer projects. These include: securing financial guarantees from Toshiba, including the effect of Westinghouse bankruptcy proceedings; securing federal Production Tax Credits; and the position of the Georgia and South Carolina Public Services Commissions and public opinion.

Westinghouse / Toshiba Guarantees

Toshiba is the guarantor of certain Westinghouse obligations under the contracts with Southern Co (and SCE&G). Toshiba is expected to set aside roughly 670 billion yen (US$6.02 billion) as provisions for guarantees for the fiscal year ended 31 March 2017.[340]

Another dispute also arose with Westinghouse, according to court documents filed by Georgia Power in which they objected to the Westinghouse debtor-in-possession, or DIP, bankruptcy loan because it calls for attaching liens to Westinghouse's intellectual property necessary to complete two AP1000 reactors.[341] Attaching liens to intellectual property critical to building the reactors could jeopardize the entire project, "if the DIP Lenders are granted liens on the Intellectual Property, the possibility would exist that the DIP Lenders would later foreclose on the Intellectual Property... it could seriously disrupt or even potentially halt construction of the Project," according to court papers filed by the Vogtle owners.[342] That is true even though none of the money in the bankruptcy finance package can be used on reactor construction, according to Georgia Power.[343] Westinghouse's bankruptcy financing is provided by affiliates of Apollo Global Management LLC.

338 - Molly Samuel, "Contractor Bankruptcy Could Be Trouble For Georgia Power", *WABE*, 24 March 2017, see http://news.wabe.org/post/contractor-bankruptcy-could-be-trouble-georgia-power, accessed 28 May 2017.

339 - *WNN*, "Vogtle receives final loan guarantees", 25 June 2015, see http://www.world-nuclear-news.org/NN-Vogtle-receives-final-loan-guarantees-2506157.html, accessed 27 May 2017.

340 - Soichi Inai, "Westinghouse risks still shadow Toshiba", *Nikkei Asian Review*, 23 May 2017, see http://asia.nikkei.com/Spotlight/Toshiba-in-Turmoil/Westinghouse-risks-still-shadow-Toshiba, accessed 29 May 2017.

341 - A liens is an official order that allows a party to keep the property of a person who owes them money until it has been paid. In the U.S. the term lien generally refers to a wide range of encumbrances and would include other forms of charge.

342 - Michael Smith, "SCANA, Santee Cooper extend V.C. Summer deal; Project Vogtle files objection", *Aiken Standard*, 29 April 2017, see http://www.aikenstandard.com/news/scana-santee-cooper-extend-v-c-summer-deal-project-vogtle/article_f4ddbe5c-2c34-11e7-8f6c-e3fb3ec75fe8.html, accessed 28 May 2017.

343 - Peg Brickley, "Southern's Georgia Power Objects to Westinghouse Bankruptcy Loan—Update", *Dow Jones Newswire, Fox Business*, 27 April 2017, see http://www.foxbusiness.com/features/2017/04/27/southerns-georgia-power-objects-to-westinghouse-bankruptcy-loan-update.html, accessed 29 May 2017.

The V.C. Summer project does not have the same issue, as the owners have been in the process of escrowing the AP1000 intellectual property and software since March 2017. A May 2017 Barclays Capital analysis noted that "(Vogtle) Project owners are negotiating with Toshiba on a schedule for payments on that guarantee should Westinghouse declare it cannot meet the obligation of the EPC contract".[344] As noted, a US$3.68 billion agreement was reached in June 2017 between Toshiba and Georgia Power to be paid through 2021.

In the case of V.C. Summer, on 27 July 2017 agreement was reached between SCANA Corp and Santee Cooper with Toshiba for payment of US$2.168 billion to be paid from October 2017 through 2022.[345]

In both cases, the guarantees offered by Toshiba could be rejected by a bankruptcy court or the amount set aside by Toshiba may not be sufficient.

Federal Loan Guarantees

In February 2010, the U.S.DOE announced that it had awarded, on a conditional basis, US$8.3 billion in title XV11 federal loan guarantees to underwrite the construction costs of Vogtle-3 and -4.[346] The loans would be spread among three of the four owners of the project: Georgia Power (US$3.4 billion) Oglethorpe Power (US$3.1 billion) and MEAG Power (US$3.8 billion).[347] Under the terms of the agreement, the loan guarantees will allow the owners of the project to borrow at below-market Federal Financing Bank rates with the assurance of the U.S. Government. Final approval for the loan guarantee was announced in February[348] and June 2014.[349] The DOE loan guarantees were awarded without making the recipient companies pay a project subsidy cost. Title XVII of the Energy Policy Act of 2005, which established the loan guarantee program, requires that the government receive "from the borrower a payment in full for the cost of the obligation," yet the DOE awarded the guarantee for Plant Vogtle without charging the fee.[350]

As noted by NEI in 2010, "although the loan guarantees are not loans, they are the next best thing; the government-owned Federal Financing Bank takes on the risk of defaulting on the loan. The utilities do have to negotiate a fee with the bank to offset the risk of default."[351]

344 - William Freebairn,"Vogtle partners seeking accelerated payment from Toshiba of guarantees", *Platts, NW*, Vol.58, No.20, 18 May 2017.

345 - Tom Hals, "Toshiba reaches $2.2 billion deal over SCANA's South Carolina nuclear project", *Reuters*, 27 July 2017, see https://www.reuters.com/article/us-toshiba-accounting-westinghouse-scana-idUSKBN1AC3DN, accessed 5 August 2017.

346 - Ibidem.

347 - Loan Programs Office, "VOGTLE", U.S.DOE, Undated, see https://energy.gov/lpo/vogtle, accessed 28 May 2017.

348 - U.S.DOE, "At Vogtle, Big Results with Nuclear Power", 20 February 2014, see https://energy.gov/articles/vogtle-big-results-nuclear-power, accessed 28 May 2017.

349 - U.S.DOE, "Energy Department Issues Remaining $1.8 Billion in Loan Guarantees for Vogtle Advanced Nuclear Energy Project", 24 June 2014, see https://energy.gov/articles/energy-department-issues-remaining-18-billion-loan-guarantees-vogtle-advanced-nuclear, accessed 28 May 2017.

350 - Ben Schreiber, "Friends of the Earth statement on nuclear loan guarantee", Friends of the Earth, 22 April 2014, see http://www.foe.org/news/archives/2014-04-friends-of-the-earth-statement-on-nuclear-loan-guara, accessed 28 May 2017.

351 - *NEI*, "Vogtle shareholders get an edge", 23 February 2010, see http://www.neimagazine.com/news/newsvogtle-shareholders-get-an-edge-updated, accessed 28 May 2017.

The loan guarantees allowed Vogtle's owners to finance a substantial portion of their construction costs at interest rates well below market rates, and to increase their debt fraction, which significantly reduces overall financing costs.

In justification for the loan guarantee to Vogtle, the Obama administration stated that "the Vogtle project represents an important advance in nuclear technology, other innovative nuclear projects may be unable to obtain full commercial financing due to the perceived risks associated with technology that has never been deployed at commercial scale in the U.S. The loan guarantees from this draft solicitation would support advanced nuclear energy technologies that will catalyze the deployment of future projects that replicate or extend a technological innovation."[352]

The impact of the Westinghouse bankruptcy and the evaluations of the options for the Vogtle project, raises the prospect of repayment of the US$8.3 billion loan to Southern.[353]

Tax Credits

"It is very, very important to the viability," said Jimmy Addison, SCANA's executive vice president and chief financial officer. "We have impressed upon everyone that has a vested interest in South Carolina and in nuclear in America that... the timeliness of this is very important to this evaluation."[354]

A critical factor that will determine the future of the Vogtle and V.C. Summer is the availability of Production Tax Credits (PTCs) of US$0.018 per kWh for the first 6,000 MW of capacity for the first eight years of the reactor operation. This PTC is capped at US$125 million per year per 1,000 MW of capacity. The PTC was included as part of the Energy Policy Act of 2005, and currently requires a unit to have an in-service date before 1 January 2021.

The owners of the Vogtle and V.C. Summer plants were desperate to secure Federal PTCs. In the case of Vogtle, they are worth US$800 million; according to SCANA, the tax credits would offset about US$2.2 billion of the current US$14 billion in projected V.C. Summer construction costs, with the money going to ratepayers, but only if the reactors are online by the end of 2020.[355]

It is not by coincidence that even as the scheduled startup dates for the reactors have been pushed back they still on paper currently meet the PTC's deadline. "Lobbyists for the two utilities have made securing an extension of the deadline a top priority this year, and executives have said they believe there is political support for enacting that change."[356]

352 - Loan Programs Office, "Fostering the Next Generation of Nuclear Energy Technology", U.S.DOE, 29 September 2014, see https://energy.gov/lpo/articles/fostering-next-generation-nuclear-energy-technology, accessed 28 May 2017.

353 - Peter Maloney, "Westinghouse bankruptcy puts $8.3B in federal loan guarantees for Vogtle plant at risk", *Utility Dive*, 3 April 2017, see http://www.utilitydive.com/news/westinghouse-bankruptcy-puts-83b-in-federal-loan-guarantees-for-vogtle-pl/439508/, accessed 29 May 2017.

354 - David Wren, "SCANA exec: Nuclear plant completion could hinge on extension of federal tax credits", *The Post and Courier*, 27 April 2017, see http://www.postandcourier.com/business/scana-exec-nuclear-plant-completion-could-hinge-on-extension-of/article_2bf6d520-2b83-11e7-a557-4b77cf88f39c.html, accessed 29 May 2017.

355 - Sammy Fretwell, "Could losing tax break sink SCE&G's nuclear project?", *The State*, 22 May 2017, see http://www.thestate.com/news/local/article151956352.html, accessed 28 May 2017.

356 - William Freebairn,"Vogtle partners seeking accelerated payment from Toshiba of guarantees", *Platts, NW*, Vol.58, N.20, 18 May 2017.

However, an extension of the deadlines for PTCs was not included in an omnibus spending bill approved by Congress on 2 May 2017 and might now have to wait for inclusion in proposed tax legislation.[357] "It's over US$2 billion," said Dukes Scott, director of the S.C. Office of Regulatory Staff. "That's going to be crucial to the decision-making." There is little chance of passing legislation that includes PTCs any time soon.[358]

Costs to Customers and the Position of the Public Services Commissions

The Georgia PSC has backed the Plant Vogtle project from the start, including awarding generous Combined Works In Progress (CWIP), where all construction costs incurred by Georgia Power are passed directly on to the customer. The Vogtle project and CWIP has long been criticized by groups in Georgia as uneconomic and detrimental to the customers and electricity needs of the State of Georgia. The original construction schedules were criticized as unachievable long before the start of construction though such critiques were dismissed by both the utility and the PSC.[359] It did not help that the financing and decision-making has lacked transparency. While detailed information about the project's cost and schedule is provided to the PSC, complaints were already filed in 2010, that the utilities had classified almost all the cost and schedule information as trade secret.

The Georgia Nuclear Energy Financing Act, signed into law in 2009, allows regulated utilities to recover from their customers the financing costs associated with the construction of nuclear generation projects—years before those projects begin producing benefits for ratepayers. Of Georgia Power's estimated US$6.1 billion Vogtle costs, US$1.7 billion is financing costs. The utility began recovering these financing costs from its customers starting in 2011. For 2011, that translates to Georgia Power electric bills going up by an average of US$3.73 per month. Georgia Power estimates that this monthly charge will escalate so that by 2018, a Georgia Power residential customer using 1,000 kWh per month will see their bill go up by US$10 per month, or approximately US$120 per year, due to Vogtle-3 and -4. Utilities like CWIP because it gives them an interest-free loan from their customers rather than market-rate debt and equity financing. However, CWIP increases their risk, because price elasticity and political dissatisfaction will both have longer to work before the plant is ultimately finished (if it is) and put in the ratebase (to the extent it is). Georgia's special law is considered by the builders to relieve them of all cost-overrun or imprudent-investment risk, but even if it did (which will be up to the courts), the state regulator has many other tangible ways to express its displeasure if it feels a regulated utility has been unwise, imprudent, or deceitful.

In the case of V.C. Summer, in June 2016 the South Carolina Office of Regulatory Staff (ORS) reported that the pay-in-advance nuclear construction charge was 16 percent of retail bills. As

357 - Emma Dumain, "S.C. congressional delegation loses fight to get nuclear tax credit in government spending bill", *The Post and Courier*, 2 May 2017, see http://www.postandcourier.com/news/s-c-congressional-delegation-loses-fight-to-get-nuclear-tax/article_c68a5cde-2f42-11e7-ba6f-977391a7c898.html, accessed 29 May 2017.

358 - U.S. Senate and House of Representatives, "A Bill—To amend the Internal Revenue Code of 1986 to modify the credit for production from advanced nuclear power facilities", 115th Congress, 1st Session, see https://www.scott.senate.gov/sites/default/files/images/MCG17173.pdf, accessed 28 May 2017.

359 - Max Chang, David White, et al., "Big Risks, Better Alternatives—An Examination of Two Nuclear Energy Projects in the U.S.", Synapse Energy Economics, 6 October 2011, Commissioned by the Union of Concerned Scientists, see http://www.cleanenergy.org/wp-content/uploads/UCSBigRisksBetterAlternativesOCT2011.pdf, accessed 29 May 2017.

of May 2016, SCE&G customers have had eight price increases, and SCE&G has raised electricity prices nearly 20 percent since 2009 to fund the nuclear project.[360]

Any future costs sought by the owners of Vogtle and V.C. Summer to be covered under CWIP would need PSC approval. Already challenged on the projects viability since before construction of the plants, public criticism of the failure of the PSCs in Georgia and South Carolina to act prudently has only increased in recent years, and has escalated since the bankruptcy filing of Westinghouse. "The project is under the microscope now, and elected officials may not be willing to make customers foot the bill when things don't go as planned."[361]

State regulators will also have to agree to the utility's taking over as general contractors with a construction company, such as Bechtel or Fluor, serving as a subcontractor, "which will require a new allocation of risk, since the construction contractors, unlike Westinghouse, would not offer a fixed-price contract for completion," according to analysis from Barclays Capital.[362]

President Trump on Nuclear Power

During his election campaign President Trump made clear his support for nuclear power, as he stated: "Nuclear power is a valuable source of energy and should be part of an all-the-above program for providing power for America long into the future". However, even at the time there were signals that his support might be conditional, as in his campaign energy-plan proposals, it said that he will ensure government does not favor one energy generator over another and will allow the energy marketplace to determine the best mix of domestic energy sources.[363] While, the "An America First Energy Plan", on the White House Web Site, does not mention nuclear power at all, instead focusing on the need for shale gas and clean coal.[364] Then during the June 2017 Energy Week, President Trump spoke at the Department of Energy, when he said on nuclear power: "We will begin to revive and expand our nuclear energy sector—which I'm so happy about—which produces clean, renewable and emissions-free energy". However, in order to do this, he announced "a complete review of U.S. energy policy will help us find new ways to revitalize this crucial energy source".[365] This was a disappointment to many, and as a Republican energy strategist said: "For anyone who knows nuclear, there's no doubt about

360 - David Wren, "SCANA exec: Nuclear plant completion could hinge on extension of federal tax credits", *The Post and Courier*, 27 April 2017, see http://www.postandcourier.com/business/scana-exec-nuclear-plant-completion-could-hinge-on-extension-of/article_2bf6d520-2b83-11e7-a557-4b77cf88f39c.html , accessed 29 May 2017.

361 - Aaron Larson, "Southern Company Could Delay Plant Vogtle Decision Until Late Summer", *POWER Magazine*, 24 May 2017, see http://www.powermag.com/southern-company-could-delay-plant-vogtle-decision-until-late-summer/, accessed 28 May 2017.

362 - William Freebairn,"Vogtle partners seeking accelerated payment from Toshiba of guarantees", *Platts, Nucleonics Week*, Vol.58, No.20, 18 May 2017.

363 - NEI, "Clinton, Trump Both Support Nuclear Energy", 19 October 2016, Nuclear Energy Institute, see https://www.nei.org/News-Media/News/News-Archives/Clinton,-Trump-Both-Support-Nuclear-Energy, accessed 18 August 2017.

364 - The White House, "An America First Energy Plan", undated, see https://www.whitehouse.gov/america-first-energy, accessed 18 August 2017.

365 - President Trump, "Remarks by President Trump at the Unleashing American Energy Event", 29 June 2017, see https://www.whitehouse.gov/the-press-office/2017/06/29/remarks-president-trump-unleashing-american-energy-event, accessed 18 August 2017.

what needs to be done. It's a question of doing it—not talking about it."[366] One month later construction was halted at the V.C. Summer nuclear power plant.

Termination of V.C. Summer project

On 31 July 2017, Santee Cooper and SCANA Corporation announced that they were halting construction of the V. C. Summer project.[367] Both corporations attributed their decisions primarily to the expected cost and time overruns, if the project had been completed. Santee Cooper said that its analysis showed "the project would not be finished until 2024, four years after the most recent completion date provided by Westinghouse, and would end up costing Santee Cooper customers a total of $11.4 billion".[368] Likewise SCANA's evaluation of "the project costs and schedules" led it to conclude "that completion of both Units would be prohibitively expensive". The announcement caused an increase in the share prices of SCANA and financial analysts upgraded its stocks. The suspension of V.C. Summer recalls the history of 40 other stranded nuclear reactor projects in the United States, whose construction started in the 1970s, and which were abandoned between 1977 and 1989, as can be seen from the Global Nuclear Power Database.[369] The V.C. Summer project now joins the ranks of the forty nuclear new-build projects—including 12 Westinghouse reactors—that were abandoned in the U.S. between 1977 and 1989 at various stages of construction (see Global Nuclear Power Database for details).[370] With a decision on the fate of the Vogtle project later in 2017, former NRC commissioner Peter Bradford put the V.C. Summer decision in context: "There never was an actual 'nuclear renaissance', just the 31 paper applications on file at the Nuclear Regulatory Commission by early 2009. Now nearly all but two are cancelled, leaving a trail of economic waste in their wake. The intent of the renaissance dream was to show that new reactor designs and an expedited licensing process from which the public was largely excluded would produce reactors that could be completed 'on time and on budget' as well as at competitive costs. The expectation was that private financing, without subsidy from customers and taxpayers, would then become available to nuclear power. That dream is now in ruins. The Westinghouse bankruptcy and subsequent events in South Carolina make the lessons so clear that even the most ardent nuclear propagandists probably can no longer shout them down."[371]

366 - Jennifer A. Dlouhy, "Trump's Plans for a Nuclear Revival Will Begin With a Study", *Bloomberg*, 29 June 2017, see https://www.bloomberg.com/news/articles/2017-06-29/trump-s-plans-for-a-nuclear-revival-will-begin-with-a-study, accessed 18 August 2017.

367 - SCANA, "South Carolina Electric & Gas Company To Cease Construction And Will File Plan Of Abandonment Of The New Nuclear Project", 31 July 2017, see https://www.scana.com/docs/librariesprovider15/pdfs/press-releases/07312017-sce-amp-g-to-cease-construction-and-will-pursue-abandonment-of-the-new-nuclear-project---scana-reaffirms-earnings-guidance.pdf, accessed 5 August 2017.

368 - *WNISR*, "Utilities Abandon V. C. Summer AP1000 Reactor Construction Following Westinghouse Bankruptcy", 2 August 2017, see https://www.worldnuclearreport.org/Utilities-Abandon-V-C-Summer-AP1000-Reactor-Construction-Following-Westinghouse.html, accessed 5 August 2017.

369 - *WNISR*/*Visionscarto*/*Bulletin of the Atomic Scientists*, "Global Nuclear Power Database", 2017, see http://thebulletin.org/global-nuclear-power-database, accessed 5 August 2017.

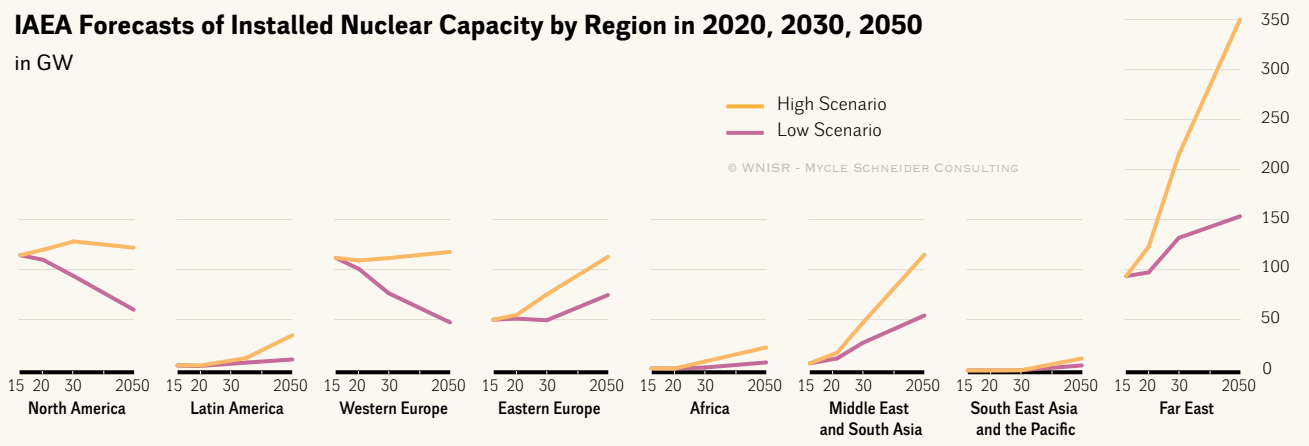
370 - *WNISR*, "Westinghouse: Origins and Effects of the Downfall of a Nuclear Giant", 2 April 2017, see https://www.worldnuclearreport.org/Westinghouse-Origins-and-Effects-of-the-Downfall-of-a-Nuclear-Giant.html, accessed 29 May 2017.

371 - *Vermont Business Magazine*, "Vermont Law School's Cooper on demise of V.C. Summer: Nuclear power is uneconomic", 4 August 2017, see http://www.vermontbiz.com/news/2017/august/04/vermont-law-schools-cooper-demise-vc-summer-nuclear-power-uneconomic, accessed 5 August 2017.

POTENTIAL NEWCOMER COUNTRIES

Nuclear power's contribution to the global electricity mix has declined over the past two decades, as the world's power consumption has increased, while nuclear production has largely stagnated and other sources have shown strong growth rates. Despite this, several international energy organizations forecast that nuclear power production, globally, will increase in the coming decades. For example, the IEA's World Energy Outlook suggests that by 2040 the total power output from nuclear will increase by about 50 percent.[372] This would be a remarkable, and somewhat unlikely, achievement, especially given the very low level of construction in the traditional markets of Western Europe and North America and their aging nuclear fleets. This is highlighted in Figure 24, which is based on data published by the IAEA in their 2016 predictions for global nuclear development. These assume that in North America, in their low nuclear scenario, a halving of current nuclear capacity by 2050 and even in their high scenarios an increase of only around 10 percent, while Western Europe would decrease by over 50 percent and remain approximately constant in these two scenarios.[373]

Figure 24 | IAEA Forecasts of Installed Nuclear Capacity



Source: IAEA, 2016

The IAEA assumes that to meet their prediction of more than doubling of current capacity in the higher nuclear scenario, considerable new construction will occur in existing countries, such as China, South Korea and India, but also envisages significant capacity in newcomer countries.

The WNA suggests that there are just 20 countries in which nuclear power is being planned for the first time, with an additional 20, where the nuclear option is under consideration. This is small compared to renewable energy, as at end of 2015, targets had been established

372 - IEA, "World Energy Outlook", International Energy Agency, November 2016.

373 - IAEA, "Energy, Electricity and Nuclear Power Estimates for the Period up to 2050", 2016, see http://www-pub.iaea.org/books/IAEABooks/11120/Energy-Electricity-and-Nuclear-Power-Estimates-for-the-Period-up-to-2050, accessed 25 April 2017.

in 173 countries at the national or state/provincial level.[374] The WNA further categorizes those countries in which nuclear power is being planned into five separate groups:

- Power reactors under construction: UAE, Belarus.
- Contracts signed, legal and regulatory infrastructure well-developed or developing: Lithuania, Turkey, Bangladesh, Vietnam (but deferred).
- Committed plans, legal and regulatory infrastructure developing: Jordan, Poland, Egypt.
- Well-developed plans but commitment pending: Thailand, Indonesia, Kazakhstan, Saudi Arabia, Chile; or commitment stalled: Italy.
- Developing plans: Israel, Nigeria, Kenya, Laos, Malaysia, Morocco, Algeria.

This section of the report will look at the countries in which WNA considers nuclear power programs are being developed.

UNDER CONSTRUCTION

Construction started in November 2013 at **Belarus**'s first nuclear reactor at the Ostrovets power plant, also called Belarusian-1. Construction of a second 1200 MWe AES-2006 reactor started in June 2014. In November 2011, the Russian and Belarusian governments agreed that Russia would lend up to US$10 billion for 25 years to finance 90 percent of the contract between Atomstroyexport and the Belarus Directorate for Nuclear Power Plant Construction. In July 2012, the contract was signed for the construction of the two reactors for an estimated cost of US$10 billion, including US$3 billion for new infrastructure to accommodate the remoteness of Ostrovets in northern Belarus.[375] The project assumes liability for the supply of all fuel and repatriation of spent fuel for the life of the plant. The fuel is to be reprocessed in Russia and the separated wastes returned to Belarus. In August 2011, the Ministry of Natural Resources and Environmental Protection of Belarus stated that the first unit would be commissioned in 2016 and the second one in 2018.[376] However, these dates were revised, and when construction started, it was stated that the reactors would not be completed until 2018 and 2020.[377] In May 2016, the startup months were specified as November 2018 and July 2020 respectively.[378] As of April 2016, the two units were said by deputy energy minister Mikhail Mikhadyuk to be 38 percent complete.[379] In August 2016, the reactor pressure vessel slipped and fell two meters before hitting the ground, during installation. This lead to an eight-month delay, while it was replaced. The reactor is now only expected to be completed at the end of 2019.[380]

374 - REN21, "Renewables 2016—Global Status Report", Renewable Energy Policy Network for the 21st Century, 2016.

375 - *NIW*, "Belarus, Aided by Russia and Broke, Europe's Last Dictatorship Proceeds With NPP", 28 September 2012.

376 - V.V. Kulik, "Letter to the European Commission", Deputy Minister, Ministry of Natural Resources and Environmental Protection of the Republic of Belarus, dated 9 August 2011.

377 - *WNN*, "Ostrovets plant meets construction safety rules", 7 November 2014, see http://www.world-nuclear-news.org/NN-Ostrovets-plant-meets-construction-safety-rules-07111401.html, accessed 25 April 2017.

378 - *WNN*, "Reactor vessel assembly completed for second Belarusian unit", 26 May 2016, see http://www.world-nuclear-news.org/NN-Reactor-vessel-assembly-completed-for-second-Belarusian-unit-26051601.html, accessed 25 April 2017.

379 - *NEI*, "Progress continues at Belarus NPP", 20 April 2016, see http://www.neimagazine.com/news/newsprogress-continues-at-belarus-npp-4870105/, accessed 25 April 2017.

380 - *NIW*, "Briefs—Belarus", 7 April 2017.

The official cost of the project has increased by 26 percent, to 56 billion Russian Roubles – in 2001 prices (US$$_{2001}$1.8 billion).[381] However, the falling exchange rate of the rouble against the dollar significantly affects the dollar price of the project.

The project is the focus of international opposition and criticism, with formal complaints from the Lithuanian government.[382] Belarus has been found to be in non-compliance with some of its obligations concerning the construction of the plant, according to the meeting of the Parties of the Espoo Convention.[383] In April 2017, an accord was signed by all parties in the Lithuanian Parliament noting that all necessary measures should be taken to stop the construction of Ostrovets and "at least to ensure that the electricity produced in this nuclear power plant will not be allowed into Lithuania nor will it be allowed to be sold on the Lithuanian market under any circumstances".[384]

According to media reports, at the surprise initiative of Swedish MP Kent Harstedt, on 5 July 2017, a draft resolution brought forward by Lithuanian parliamentarians critical of the Ostrovets project was removed from the agenda at the Organization for Security and Cooperation (OSCE) in Europe's Parliamentary Assembly.[385]

Currently, Belarus is a net importer of electricity—in 2015 it received 3.6 TWh from Russia and Ukraine, a fall from 3.8 TWh the previous year.[386] When generating, both nuclear units could produce at least double this amount, so domestic power plants will have to be closed, or output restricted, or consumption or power exports increased. This latter option, which would also bring important revenue to Belarus, may not be possible as the Lithuanian and Polish Governments are said to be refusing to buy electricity from the Belarus nuclear power plant due to safety concerns over the reactor.[387] The Lithuanian Government, along with the other Baltic States is seeking to decouple its markets from Russia and synchronize its system with Poland.

In the **United Arab Emirates** (UAE), construction is ongoing at the Barakah nuclear project, 300 km west of Abu Dhabi, where there are four reactors under construction. At the time of the contract signing in December 2009 with Korean Electric Power Corp., the Emirates Nuclear Energy Corp (ENEC), said that "the contract for the construction, commis-

381 - *Charter 97*, "Astravets NPP Becomes 12 billion more expensive in one day", 30 December 2016, see https://charter97.org/en/news/2016/12/30/236059, 18 April 2017.

382 - *Bloomberg*, "Lithuania Urges Belarus to Halt Nuclear Project on Safety Issues", 20 August 2013, see http://www.bloomberg.com/news/2013-08-20/lithuania-urges-belarus-to-halt-nuclear-project-on-safety-issues.html, accessed 25 April 2016.

383 - UNECE, "Parties to UNECE treaties adopt declaration on applying environmental assessment procedures to nuclear energy issues", United Nations Economic Commission for Europe, Press Release, 13 June 2014.

384 - Lithuanian Parliament, "Accord between the Parliamentary Political Parties of the Republic of Lithuania on Joint Actions Against the Unsafe Nuclear Power plant in Astraveyets", April 2017.

385 - *Baltic Course*, "Lithuanians' OSCE resolution on Belarus' NPP blocked in 'painful blow from Sweden'", 6 July 2017, see http://www.baltic-course.com/eng/energy/?doc=130997, accessed 7 August 2017.

386 - Belarus News, "Belarus' electricity import down by 26.3% to 2.8bn kWh in 2015", 27 January 2016, see http://eng.belta.by/economics/view/belarus-electricity-import-down-by-263-to-28bn-kwh-in-2015-88511-2016/, accessed 25 April 2017.

387 - *Your Nuclear News*, "Lithuania praises Poland for stand against Belarusian NPP", Your Industry News, 31 March 2017, see http://www.yournuclearnews.com/lithuania+praises+poland+for+stand+against+belarusian+npp_141135.html, accessed 27 April 2017.

sioning and fuel loads for four units equalled approximately US$20 billion, with a high percentage of the contract being offered under a fixed-price arrangement".[388]

The orginal financing plan for the project was thought to include US$10 billion from the Export-Import Bank of Korea, US$2 billion from the Ex-Im Bank of the U.S., US$6 billion from the government of Abu Dhabi, and US$2 billion from commerical banks.[389] However, it now transpires that the total cost of the project is at least €24.4 billion (US$28.2 billion). The financing for this was US$16.2 billion Abu Dhabi's Department of Finance, equity financing US$4.7 billion, US$2.5 billion through a loan from the Export-Import Bank of Korea, with loan agreements from the National Bank of Abu Dhabi, First Gulf Bank, HSBC (Hongkong and Shanghai Banking Corporation Limited) and Standards Charter making up the remainder.[390] In October 2016, KEPCO (Korea Atomic Energy Research Institute) took an 18 percent equity stake in the project company that owns the four reactors, with ENEC, holding the remaining 82 percent.[391]

an extension for the start-up of nuclear operations for Unit 1, from 2017 to 2018, to ensure sufficient time for international assessments and adherence to nuclear industry safety standards

In July 2010, a site-preparation license and a limited construction license were granted for four reactors at Barakah, 53 kilometers from Ruwais.[392] A tentative schedule published in late December 2010, and not publicly altered since, suggested that Barakah-1 would start commercial operation in May 2017 with unit 2 operating from 2018, unit 3 in 2019, and unit 4 in 2020. Construction of Barakah-1 officially started on 19 July 2012, of Barakah-2 on 28 May 2013, Barakah-3 on 24 September 2014 and unit 4 on 30 July 2015.[393] In May 2016, ENEC stated that Barakah-1 is about 87 percent complete, with Barakah-2, -3 and -4 at 68 percent, 47 percent and 29 percent respectively.[394] As late as October 2016, Korean press was reporting unit 1 to be still scheduled for completion by May 2017.[395] Then, in May 2017, *Reuters* suggested that the start-up of the first reactor was delayed, potentially until the end of 2017, due to a lack of locally trained and licensed domestic personnel.[396] In May 2017, ENEC announced the it had "completed

388 - ENEC, "UAE Selects Korea Electric Power Corp, as Prime Team as Prime Contractor for Peaceful Nuclear Power", Emirates Nuclear Energy Corporation, 27 December 2009, see https://www.enec.gov.ae/news-and-events/news/uae-selects-korea-electric-power-corp-as-prime-team-as-prime-contractor-fo/, accessed 25 April 2017.

389 - Sang-Baik Kim, Jan-Horst Keppler, "Case Studies On Financing And Electricity Price Arrangements—The Barakah Nuclear Power Plants, The United Arab Emirates", Organization for Economic Development and Co-operation (OECD), Nuclear Energy Agency (NEA), Nuclear Development Division, OECD NEA Workshop on Electricity Prices and Nuclear New Build, Paris, 19 September 2013, see http://www.oecd-nea.org/ndd/workshops/wpne/presentations/docs/4_2_KIM_ Barakah presentation.pdf, accessed 29 March 2016.

390 - *NIW*, "Kepco takes 18% of Barakah", 21 October 2016.

391 - *NEI*, "Kepco and Enec set up joint venture for Barakah NPP", 25 October 2016, see http://www.neimagazine.com/news/newskepco-and-enec-set-up-joint-venture-for-barakah-npp-5647366/, accessed 25 April 2017.

392 - *ArabianBusinesss.com*, "ENEC Welcomes Regulator's License Approval", 11 July 2010.

393 - ENEC, "ENEC completes major work and testing at Barakah Units 1 Nuclear Energy Plant", 16 February 2016, see http://www.enec.gov.ae/media-centre/news/content/enec-completes-major-work-and-testing-at-barakah-unit-1-nuclear-energy-plan, accessed 24 April 2016.

394 - *NIW*, "United Arab Emirates", 20 May 2016.

395 - Lee Hyo-sik, "KEPCO to operate UAE nuclear plant for 60 years", The Korea Times, 20 October 2016, see http://www.koreatimes.co.kr/www/news/biz/2016/10/123_216466.html, accessed 25 April 2017.

396 - Jane Chung, Geert De Clercq, "UAE delays launch of first nuclear power reactor", *Reuters*, 4 May 2017, see http://www.reuters.com/article/us-kepco-emirates-nuclearpower-exclusive-idUSKBN1801ZD, accessed 10 May 2017.

initial construction activities for Unit 1" and the "handover of all systems for commissioning"; the plant as a whole would be 81 percent complete, with Barakah-1 at 95 percent finished. At the same time, ENEC stated: "The timeline includes an extension for the start-up of nuclear operations for Unit 1, from 2017 to 2018, to ensure sufficient time for international assessments and adherence to nuclear industry safety standards, as well as a reinforcement of operational proficiency for plant personnel."[397]

Korean press sources report that there have been a number of serious accidents at the construction site, resulting in deaths of workers. An assessment undertaken by Bechtel, on behalf of KEPCO indicated that its "contractors largely failed to ensure worker safety".[398]

The UAE released a long-term energy plan in February 2017, which proposes that by 2050 renewable energy will provide 44 percent of the country's electricity, with natural gas 38 percent, "clean fossil fuels" 12 percent and nuclear 6 percent.[399] The nuclear share is in line with expected output from the Barakah nuclear power plant, so it seems that no further nuclear power plants are envisaged. During the construction of Barakah, the costs of renewables globally, and in the region, have fallen considerably. In 2016, the bidder was chosen for an 800 MW photovoltaic (PV) plant, with a price of US$2.99c/KWh, which was the first time in the country that the cost of renewable generation was below a conventional fossil fuel plant.[400]

CONTRACTS SIGNED

In November 2011, the **Bangladesh** Government's press information Department said that it was prepared to sign a deal with the Russian Government for two 1000 MW units to be built by 2017-18 at a cost of US$1.5-2 billion.[401] Since then, although negotiations have reportedly been ongoing, the start-up date has been continually postponed and the expected construction cost has risen.

In January 2013, Deputy Finance Minister of Russia Sergey Storchak and Economic Relations Division (ERD) Secretary of Bangladesh Abul Kalam Azad signed the agreement on the Extension of State Export Credit for financing the preparatory stage work for the nuclear power plant at Rooppur (or Ruppur).[402] The site was chosen as early as in the 1960s, when the country was part of Pakistan, on the banks of the largest river in the country; over the decades, the river has shifted from its original trajectory and new land had to be acquired in

397 - ENEC, "ENEC Announces Completion of Initial Construction Work for Unit 1 of Barakah Nuclear Energy Plant & Progress Update Towards Safety-led Operations", 5 May 2017, see https://www.enec.gov.ae/enec-announces-completion-of-initial-construction-work-barakah-unit-1-progress-update/, accessed 21 July 2017.

398 - Lee Hyo-sik, "KEPCO hit by safety lapses at UAE nuke plant site", *Korean Times*, 22 February 2017, see http://www.koreatimes.co.kr/www/biz/2017/02/367_224498.html, accessed 25 April 2017.

399 - LeAnne Graves and Thamer Al Subaihi, "UAE turns green with new power plan 2050", *The National*, UAE Edition, 10 January 2017, see http://www.thenational.ae/uae/uae-turns-green-with-new-power-plan-2050, accessed 18 April 2017.

400 - *TradeArabia*, "Power Generation target for Mena: 440GW by 2020", 24 April 2017, see https://www.tradearabia.com/news/OGN_323940.html, accessed 27 April 2017.

401 - Srinivas Laxman, "Bangladesh & Russia Sign N-Plant Deal For Two Reactors At Rooppur", *Asian Scientist*, 4 November 2011, see https://www.asianscientist.com/2011/11/topnews/rooppur-nuclear-power-project-bangladesh-russia-sign-nuclear-agreement-2011/, accessed 26 April 2017.

402 - Energy Bangla, "Bangladesh, Russia sign nuclear power pact", 17 January 2013.

the last year.[403] The deal was only for US$500 million[404] to cover the site preparatory work.[405] In October 2013, a ceremony was held for the formal start of the preparatory stage,[406] with formal construction then expected to begin in 2015. At the time of the ceremony, the cost of construction was revised upwards and it was suggested that each unit would cost US$1.5–2 billion.[407] These cost estimates tripled in April 2014, when a senior official at the Ministry of Science and Technology was quoted as suggesting the price was more likely to be US$6 billion.[408] In 2015, the Bangladeshi Finance Minister was quoted as saying the project was then expected to cost US$13.5 billion.[409] However, even this is not likely to be the final cost with suggestions that this is not a fixed price contract, but a "cost-plus-fee" contract, and "the vendor has the right to come up with any cost escalation (plus their profit margin) to be incorporated into the contract amount" and that the eventual cost of generating power would be "at least 60 percent higher than the present retail cost" of electricity in Bangladesh.[410]

In December 2015, an agreement was said to be signed between the Bangladesh Atomic Energy Commission and Rosatom for 2.4 GW of capacity, with work expected to begin in 2016 and operation to start in 2022 and 2023.[411] According to the deal, Russia would provide 90 percent of the funds on credit at an interest rate of Libor plus 1.75 percent. Bangladesh will have to pay back the loan in 28 years with a 10-year grace period. As in other countries, Russia has offered to take back the spent fuel. Site preparation is reportedly 80 percent complete.[412] In late May 2016, negotiations were concluded over the US$12.65 billion project, with Russia making available US$11.385 billion.[413] In late June, the Atomic Energy Regulatory Authority, issued a site license and then a few days later the country's cabinet approved the May intergovernmental agreement.[414] In April 2017, Tass, the Russian news agency, reported that permission to start construction had been granted and that work would commence in the second half of 2017.[415] In March 2017, officials from the two countries settled on the draft of an agreement that calls

403 - Sharier Khan, "Nuke power plant cost up three times", *The Daily Star*, Updated 2 June 2015, see http://www.thedailystar.net/frontpage/nuke-power-plant-cost-three-times-82738, accessed 26 April 2017.

404 - All dollar (equivalent) amounts are expressed in U.S. dollars unless indicated otherwise. However, the year's dollars are not always clear in the original references.

405 - *Associated Press*, "Russia to lend $1.5B to Bangladesh to build nuclear power station, buy arms", as published by The Star, 15 January 2013, see https://www.thestar.com/news/world/2013/01/15/russia_to_lend_15b_to_bangladesh_to_build_nuclear_power_station_buy_arms.html, accessed 7 June 2016.

406 - *BBC*, "Bangladesh nuclear power plant work begins", 2 October 2013, see http://www.bbc.co.uk/news/world-asia-24371991, accessed 23 May 2016.

407 - Bangladesh Awami League, "PM Sheikh Hasina inaugurates Rooppur Power Plant", see http://www.albd.org/index.php/en/updates/news/281-pm-sheikh-hasina-inaugurates-rooppur-power-plant, accessed 25 April 2017.

408 - *The Independent* (of Bangladesh), "Rooppur N-plant cost to double", 7 April 2014, see http://newsfrombangladesh.net/new/top-news/27087-rooppur-n-plant-cost-to-double, accessed 29 March 2016.

409 - *NIW*, "Bangladesh: Newbuild Financing Talks with Russia in Tricky Territory", 6 November 2015.

410 - Rahman A., "Ruppur Nuclear Power Plant: Bangladesh's Potential Blackhole", *The Daily Star*, Updated 31 December 2015, see http://www.thedailystar.net/op-ed/politics/ruppur-nuclear-power-plant-bangladeshs-potential-blackhole-194017, accessed 28 March 2016.

411 - *WNN*, "Bangladesh, Russia ink $12.65 billion Rooppur plant deal", 29 December 2015, see http://www.world-nuclear-news.org/NN-Bangladesh-Russia-ink-12.65-billion-Rooppur-plant-deal-29121501.html, accessed 31 March 2016.

412 - *NW*, "Bangladesh will begin construction of first nuclear unit in August 2017: official", 14 April 2016.

413 - *NEI*, "Russia initials credit agreement with Bangladesh for Rooppur NPP", 30 May 2016, see http://www.neimagazine.com/news/newsrussia-initials-credit-agreement-with-bangladesh-for-rooppur-npp-4907672/, accessed 2 June 2016.

414 - *WNN*, "Bangladesh moves forward with Rooppur", 28 June 2016, see http://www.world-nuclear-news.org/NN-Bangladesh-moves-forward-with-Rooppur-2806167.html, accessed 28 June 2016.

415 - *TASS*, "Rosatom plans to launch construction of Ruppur power plant in Bangladesh", 19 April 2017, see http://tass.com/economy/942156, accessed 25 April 2017.

for Russia to take back all the spent fuel from the project and reprocess it; the formal Inter Governmental Agreement will be signed after appropriate government bodies approve the draft.[416]

There is growing interest in the project and concern over the lack of information and over the impact on water use. Pressing concerns has also been raised over the lack of preparedness of emergency planning and possible terrorist acts against the facility.[417]

The project's economics have been widely questioned. Earlier in 2017, a retired nuclear engineer who had been involved in advising the Bangladesh Atomic Energy Commission (BAEC), argued in one of the leading English-language newspapers in Bangladesh that the country was "paying a heavy price" for BAEC not having "undertaken a large-scale programme of recruitment, and training of engineers"; he also charged that Bangladesh was buying reactors at the "unreasonable and unacceptable" price of US$5,500/kW because its "negotiators didn't have the expertise to properly scrutinise the quoted price".[418]

At the current price, "nuclear electricity from Rooppur will be about three times more expensive than wind or solar electricity" in Bangladesh, for a rate of return of a little over 15 percent as assumed by the Bangladesh Energy Regulatory Commission.[419] If solar energy prices continue to decline the same way they have been declining in the recent past, the cost differential would be greater by the time Rooppur comes online.

In addition to Rooppur, Bangladesh's government "has shortlisted eight sites" for a second nuclear power plant that it plans to import.[420] Bangladesh has been in talks with Japanese vendors for some years, but it is reported that South Korea and China are also interested in the project, which remains very vague for the time being.

Lithuania had two large RBMK (Chernobyl-type) reactors at Ignalina, which were shut down in 2004 and 2009, a requirement for joining the European Union. Since then there have been ongoing attempts to build a replacement, either unilaterally or with neighboring countries. (See earlier editions of the WNISR for an annual account). However, in October 2012 a consultative national referendum on the future of nuclear power was held and 63 percent voted against new nuclear construction, with sufficient turnout to validate the result.[421] Prior to his appointment as Prime Minister, Algirdas Butkevicius stated that legislation prohibiting the project would be submitted once the new parliament convenes and that "the people ex-

416 - Aminur Rahman Rasel, "Russia to take back radioactive waste of Rooppur power plant", *Dhaka Tribune*, 18 March 2017, see http://www.dhakatribune.com/bangladesh/power-energy/2017/03/18/dhaka-moscow-approve-spent-nuclear-fuel-draft-deal/, accessed 14 May 2017.

417 - Petr Topychkanov, "Why the Bangladeshi public has concerns over the Rooppur nuclear project", *Russia and India Report, Russia Beyond The Headlines*, 27 February 2017, see http://in.rbth.com/blogs/south_asian_outlook/2017/02/27/why-the-bangladeshi-public-has-concerns-over-the-rooppur-nuclear-project_709866, accessed 26 April 2017.

418 - Abdul Matin, "The economics of the Rooppur Nuclear Power Plant", *The Daily Star*, 2 March 2017, see http://www.thedailystar.net/op-ed/economics/the-economics-the-rooppur-nuclear-power-plant-1369345, accessed 17 May 2017.

419 - M. V. Ramana and Zia Mian, "False nuclear hope", *Himal Southasian*, 14 August 2016, see http://himalmag.com/false-nuclear-hope-bangladesh-russia/, accessed 17 May 2017.

420 - Aminur Rahman Rasel, "Govt shortlists eight sites for second nuclear power plant", *Dhaka Tribune*, 20 September 2016, see http://www.dhakatribune.com/bangladesh/2016/09/20/govt-shortlists-eight-sites-second-nuclear-power-plant/, accessed 17 May 2017.

421 - Christian Lowe and Andrius Sytas, "Lithuanians send nuclear plant back to drawing board", *Reuters*, 15 October 2012, see http://www.reuters.com/article/us-lithuania-nuclear-idUSBRE89E0BW20121015, accessed 26 April 2017.

pressed their wish in the referendum, and I will follow the people's will".[422] In early 2016, the Energy Minister of Lithuania, Rokas Masiulis, said that the project had been shelved indefinitely, due to unfavorable market conditions.[423] No significant changes have been reported since.

In **Turkey**, up to three projects are being developed, but rather than proceeding with a single builder and design, the Government has decided to undertake at least three different reactor designs and three different sets of financial sources. Analysts have pointed out that the "regulatory framework for nuclear energy in Turkey has severe shortcomings", which makes even more difficult to deal with the complexity of the strategy.[424]

Akkuyu

The first project, on the southern coast, is at Akkuyu, which is to be built under a Build-Own-Operate- (BOO) model by Rosatom of Russia. An agreement was signed in May 2010 for four VVER1200 reactors, with construction originally expected to start in 2015. However, this has been delayed and it is now expected that limited construction might start in 2017, but a full construction license will not be granted until 2018.[425] At the heart of the project is a 15-year Power Purchase Agreement (PPA), which includes 70 percent of the electricity produced from units 1 and 2 and 30 percent of units 3 and 4. Therefore 50 percent of the total power from the station is to be sold at a guaranteed price for the first 15 years, with the rest to be sold on the market.

The CEO of Akkuyu JSC (the project company set up by Russia's Rosatom) Alexander Superfin, said in October 2013 that the project was going to be operational by mid-2020.[426] However, further delays have occurred, as the Akkuyu JSC's Environmental Impact Assessment was rejected by the Ministry of Environment, when it was submitted in July 2013. When it was eventually approved in December 2014, it was said that the commissioning of the first unit was likely to be in 2021.[427] As a result of these domestic developments and financing problems, it was reported in November 2015 that the operation would now occur only in 2022[428] and at an estimated budget for the two units of US$22 billion.[429] Site preparation work started in April 2015[430]

422 - *NIW*, "Lithuania—Prospective PM Wants to Scrape Visaginas", 9 November 2012.

423 - *Baltic Course*, "Masiulis: Visaginas NPP project has been shelved for now", 20 January 2016, see http://www.baltic-course.com/eng/energy/?doc=115564, accessed 26 April 2017.

424 - İzak Atiyas, "A Review of Turkey's Nuclear Policies and Practices", EDAM, Centre for Economics and Foreign Policy Studies, *EDAM Discussion Paper Series* 2015/5, 12 August 2015, see http://www.edam.org.tr/en/File?id=3174, accessed 26 April 2017.

425 - *NEI*, "Turkey and Russia accelerate Akkuyu nuclear project", 14 March 2017, see http://www.neimagazine.com/news/newsturkey-and-russia-accelerate-akkuyu-nuclear-project-5761593, accessed 10 May 2017.

426 - Orhan Coskun and Humeyra Pamuk, "Turkey's first nuclear plant facing further delays-sources", *Reuters*, 7 February 2014, see http://uk.reuters.com/article/uk-turkey-nuclear-delay-idUKBREA160P220140207, accessed 26 April 2017.

427 - *WNN*, "Akkuyu project EIA gets ministry approval", 1 December 2014, see http://www.world-nuclear-news.org/NN-Akkuyu-project-EIA-gets-ministry-approval-01121401.html, accessed 26 April 2017.

428 - *Sputnik International*, "First reactor of Turkey's Akkuyu nuclear plant to start operating by 2022", 19 November 2015, see http://sputniknews.com/middleeast/20151119/1030420598/akkuyu-nuclear-plant-start-2022.html, accessed 26 April 2017.

429 - *Vatan*, "Russian pressed for money, Akkuyu delayed 2 years", 24 March 2015, (in Turkish), see http://www.gazetevatan.com/ruslar-paraya-sikisti-akkuyu-2-yil-gecikecek-752934-ekonomi/, 26 April 2017.

430 - *WNN*, "Ground broken for Turkey's first nuclear power plant", 15 April 2015, see http://www.world-nuclear-news.org/NN-Ground-broken-for-Turkeys-first-nuclear-power-plant-1541501.html, accessed 26 April 2017.

and it was estimated that US$3 billion had been spent as of autumn 2015.[431] On 3 March 2017, Akkuyu JSC applied for a construction license, and construction is now scheduled to begin in March 2018.[432] Rosatom stated: "According to the Intergovernmental Agreement, the commissioning of the first power unit must take place no later than 7 years after the issuance of all permits for construction by the Republic of Turkey."[433]

Sinop

Another proposed project is at Sinop, on the northern coast, where the latest project proposal is for 4.4 GW using the ATMEA reactor-design. If completed this would be the first reactor of this design, jointly developed by Mitsubishi and AREVA.[434] In April 2015, Turkish President Erdogan approved parliament's ratification of the intergovernmental agreement with Japan.[435]

The estimated cost of the project is US$22 billion and involves a consortium of Mitsubishi, AREVA, GDF-Suez (now known as Engie), and Itochu, who between them will own 51 percent of the project, with the remaining 49 percent owned by Turkish companies including the State-owned electricity generating company (EÜAS).[436] Although, the division between the international partners remains undecided. The ongoing problems with the financial viability of AREVA and its merger with EDF are affecting its ability to invest in the project as does the review by Engie of its involvement in nuclear projects across its portfolio.[437] With Engie exiting nuclear power projects in other countries, like the UK, it seems likely that their departure from this project is just a matter of time.[438] Furthermore, site concerns remain about its suitability given its seismic conditions, which have led to discussions about putting the station on pads to reduce possible ground movement.[439] Despite this, Mitsubishi are aiming finishing the technical and economic feasibility studies by March 2018.[440] According to AREVA, in September 2016, AREVA NP signed a "preliminary engineering contract with Mitsubishi Heavy Industries (MHI) to support the technical and cost feasibility study for the proposed construction and operation of four ATMEA1 reactors at the Sinop site".[441]

431 - *Hurriyet Daily News*, "$3 billion spent on Akkuyu power plant so far: CEO", 29 September 2015, see http://www.hurriyetdailynews.com/3-bln-spent-on-akkuyu-power-plant-so-far-ceo.aspx?pageID=238&nID=89154&NewsCatID=348, accessed 26 April 2017.

432 - *WNN*, "Akkuyu project receives production licence", 16 June 2017, see http://www.world-nuclear-news.org/NN-Akkuyu-project-receives-production-licence-16061701.html, accessed 21 July 2017.

433 - Press Service of Rusatom Energo International, "Turkish companies are part of the JSC AKKUYU NUCLEAR shareholders", Rosatom, 19 June 2017, see http://www.rosatom.ru/en/press-centre/highlights/turkish-companies-are-part-of-the-jsc-akkuyu-nuclear-shareholders/, accessed 21 July 2017.

434 - *WNN*, "Turkish utility eyes large stake in Sinop project", 12 May 2015, see http://www.world-nuclear-news.org/C-Turkish-utility-eyes-large-stake-in-Sinop-project-12051501.html, accessed 26 April 2017.

435 - *WNN*, "Ground broken for Turkey's first nuclear power plant", 15 April 2015, see http://www.world-nuclear-news.org/NN-Ground-broken-for-Turkeys-first-nuclear-power-plant-1541501.html, accessed 26 April 2017.

436 - *WNN*, "Turkish utility eyes large stake in Sinop project", 12 May 2015, see http://www.world-nuclear-news.org/C-Turkish-utility-eyes-large-stake-in-Sinop-project-12051501.html, accessed 26 April 2017.

437 - *NIW*, "Weekly roundup", 9 December 2016.

438 - Jean-Michel Bezat, "Pourquoi Engie renonce à la construction de nouvelles centrales nucléaires", *Le Monde*, 8 April 2017, (in French), see http://www.lemonde.fr/economie/article/2017/04/08/pourquoi-engie-renonce-a-la-construction-de-nouvelles-centrales-nucleaires_5108119_3234.html, accessed 27 April 2017.

439 - *NIW*, "Akkuyu's Prospects Pull Past Sinop", 22 July 2016.

440 - Huseyin Erdogan, "Sinop nuke project's site review to be ready by end '17", *Anadolu Agency*, 24 March 2017, see http://aa.com.tr/en/economy/sinop-nuke-projects-site-review-to-be-ready-by-end-17-/778770, accessed 26 April 2017.

441 - AREVA, "Reference Document 2016", April 2017.

The project is complicated by the region's lack of large-scale demand and the existing coal power stations, so 1,400 km of transmission lines will be needed to take the electricity to Istanbul and Ankara.

İğneada

In October 2015, the government suggested that it was aiming to build a third power plant, at the İğneada site. The most likely constructors would be Westinghouse with the Chinese State Nuclear Power Technology Corporation (SNPTC), with Chinese companies "aggressively" pursuing the contract, said to be worth US$22-25 billion.[442] However, the financial collapse of Westinghouse, makes their current involvement in the project impossible.

Vietnam's nuclear power ambitions got a cold shower in November 2016, when 92 percent of the members of the National Assembly approved a government motion to cancel the proposed nuclear projects

A decision by the Prime Minster of **Vietnam** of July 2011 stated that by 2020 the first nuclear power plant will be in operation, with a further 7 GW of capacity to be in operation by 2025 and total of 10.7 GW in operation by 2030. In October 2010, Vietnam had signed an intergovernmental agreement with Russia's Atomstroyexport to build the Ninh Thuan-1 nuclear power plant, using 1200 MW VVER reactors. Construction was slated to begin in 2014, with the turnkey project being owned and operated by the state utility Electricity of Vietnam (EVN). However, numerous delays have occurred and in May 2016 a presentation from the Vietnam Atomic Energy Institute suggested that construction would not start until 2028.[443] "The national electricity development plan, approved by the government in March 2016, envisioned the "first nuclear power plant put into operation in 2028".[444] At the same time, the revised National Power Master Plan—likely the same as the "national electricity development plan—suggested a diminishing role for nuclear power from 10.1 percent to 5.7 percent by 2030.[445]

Vietnam's nuclear power ambitions got a cold shower in November 2016, when 92 percent of the members of the National Assembly approved a government motion to cancel the proposed nuclear projects with both Russia and Japan, due to slowing electricity demand increases, concerns over safety and rising construction costs.[446]

"COMMITTED PLANS"

In **Egypt**, the government's Nuclear Power Plants Authority was established in the mid-1970s, and plans were developed for 10 reactors by the end of the century. Despite discussions

442 - *NEI*, "Turkey finalizes site for third NPP", 18 March 2016, see http://www.neimagazine.com/news/newsturkey-finalizes-site-for-third-npp-4843161/, accessed 26 April 2017.

443 - *NIW*, "Newbuild, Sobriety, Secrecy and Reluctance", 24 June 2016.

444 - *VietNamNet*, "Vietnam needs US$148 billion to develop national electricity until 2030", 20 March 2016, see http://english.vietnamnet.vn/fms/society/152739/vietnam-needs-us-148-billion-to-develop-national-electricity-until-2030.html, accessed 26 April 2017.

445 - Viet Phuong Nguyen, "The fate of nuclear power in Vietnam", *Bulletin of the Atomic Scientists*, 5 December 2016, see http://thebulletin.org/fate-nuclear-power-vietnam10245, accessed 17 April 2017.

446 - *NIW*, "Briefs—Vietnam", 28 November 2016.

with Chinese, French, German, and Russian suppliers, little development occurred for several decades. In October 2006, the Minister for Energy announced that a 1000 MW reactor would be built, and this was later expanded to four reactors by 2025, with the first one coming on line in 2019. In early 2010, a legal framework was adopted to regulate and establish nuclear facilities; however, an international bidding process for the construction was postponed in February 2011 due to the political situation in the country. Since then, there have been various attempts and reports that a tender process would be restarted, all of which have come to nothing.

In February 2015, Russia's Rosatom and Egypt's Nuclear Power Plant Authority eventually did sign an agreement that could lead to the construction and financing of two reactors and possibly two additional ones. In November 2015, an intergovernmental agreement was signed for the construction of four VVER-1200 reactors at Dabaa. The deal, was apparently worth €20-22 billion (US$22-24 billion), with Russia providing up to 90 percent of the finance,[447] to be paid back through the sale of electricity. Reports suggested that the first plant could be completed by 2022[448], which is technically impossible. In May 2016, it was announced that Egypt concluded a US$25 billion loan with Russia for nuclear construction.[449] According to the Egyptian official journal, the loan is to cover 85 percent of the project cost, with the total investment thus estimated at around US$29.4 billion. The 3-percent annual-interest loan is to be paid back over 22 years starting in 2029.[450] In March 2017, Ayman Hamza, the Egyptian Minister for Electricity, said that contracts for construction works and for training of personnel had been signed with Russia and that commercial contracts were expected to be signed later in 2017.[451] In April 2017, the Energy and Environment Committee of the Parliament began discussions about regulating nuclear construction in Egypt.[452] *TASS*, the Russian News Agency, reported, in February 2017, that it expected to sign contracts in 2017, with the project taking 12 years to implement.[453]

Influential policy makers in **Jordan** have long desired the acquisition of a nuclear power plant. In 2007, the government established the Jordan Atomic Energy Commission (JAEC) and the Jordan Nuclear Regulatory Commission. JAEC started conducting a feasibility study on nuclear power, including a comparative cost/benefit analysis.[454] In November 2009, JAEC awarded an US$11.3 million contract to Australian engineering company WorleyParsons for pre-construction consulting for Jordan's first nuclear power plant.[455] JAEC and WorleyParsons narrowed down the choices to the ATMEA-1 design from AREVA and Mitsubishi (as projec-

447 - *NIW*, "Cairo and Moscow Ink Deal for Four-Unit Dabaa Plant", 20 November 2015.

448 - Omar Fahmy, Asma Alsharif and Luke Baker, "Egypt, Russia sign deal to build a nuclear power plant", *Reuters*, 19 November 2015, see http://www.reuters.com/article/us-nuclear-russia-egypt-idUSKCN0T81YY20151119, accessed 26 April 2017.

449 - Asma Alsharif, "Russia to lend Egypt $25 billion to build nuclear power plant", *Reuters*, 1 May 2016, see http://www.reuters.com/article/us-egypt-russia-nuclear-idUSKCN0YA1G5, accessed 23 May 2016.

450 - *NIW*, "Egypt Approves $25 Billion Loan From Russia for Nuclear Project", 26 April 2017.

451 - *NEI*, "Egypt and Russia agree on two contracts for El Dabaa NPP", 20 March 2017, see http://www.neimagazine.com/news/newsegypt-and-russia-agree-on-two-contracts-for-el-dabaa-npp-5765715/, accessed 25 April 2017.

452 - Gamal Essam El-Din, "Egypt to issue new law on construction of nuclear power stations soon", *AhramOnline*, 22 April 2017, see http://english.ahram.org.eg/NewsContent/1/64/265411/Egypt/Politics-/Egypt-to-issue-new-law-on-construction-of-nuclear-.aspx, accessed 10 May 2017.

453 - *TASS*, "Russia and Egypt can sign contracts on nuclear power plant in 2017", 9 February 2017, see http://tass.com/economy/930010, accessed 10 May 2017.

454 - Mark Hibbs, "Jordan reactor siting study to be done in 2009, JAEC says", *NW*, Vol.48, 2007.

455 - Ann MacLachlan, "WorleyParsons to help Jordan run program for first nuclear power plant", *NW*, Vol.50, 2009.

ted in Turkey); the Enhanced Candu-6 (EC6) from Atomic Energy of Canada Limited; the APR-1400 from Korea Electric Power Corporation, and the AES-2006 and AES-92 variants of the VVER design from Rosatom.[456] Eventually, the ability of Rosatom to potentially finance, as well as its offer to take back spent fuel to Russia,[457] seems to have trumped all other considerations and Jordan decided on two VVER light water reactors. According to the initial announcement, Russia was to finance 49.9 percent of the nuclear power plant.[458] In September 2014, JAEC and Rosatom signed a two-year development framework for a project, which was projected to cost under US$10 billion and generate electricity costing US$0.10/kWh.[459] An international advisory panel established by JAEC noted that "JAEC, and JNPC are short of experienced staff required for projects". The IAG also noted "the extremely tight (and possibly even overly optimistic) timelines" to enable operation by the mid 2020s.[460] The current timetable envisages operation of the reactor by 2025.

Since then, JAEC has been unsuccessfully trying to raise the remaining 50.1 percent. In a July 2016 interview to *AP News*, JAEC Chairman Khaled Toukan admitted that the probability of the two reactors being built is "70 to 75 [percent] ... it is not 90 percent".[461]

The decline in the official probability might have to do with Russia's difficulties in funding all of Rosatom's agreements.[462] Partly due to this difficulty, JAEC is seeking partners from other countries. This was revealed by Toukan in August 2016, saying that "Jordan is currently in talks with German, Czech, Chinese and Japanese companies among others to supply turbines and electrical systems for the power plant and things are going well", with the implication that these companies would pay for these pieces of equipment.[463] In an October 2016 interview with *Nuclear Intelligence Weekly* (*NIW*) Toukan and JAEC identified four specific companies " the Czech Republic's Skoda Praha, GE-Alstom, Russia's Power Machines, and Germany's Siemens". Toukan also said: "We're requesting technology for the conventional island, export credit financing, and, if they are willing, to have some equity in the plant...We're open to this".[464]

The difficulty in obtaining funding might have been one reason for JAEC to start talking about importing small modular reactor (SMR) designs—which are yet to be designed, licensed and

456 - Ibidem.

457 - Communications Department of ROSATOM, "Russia and Jordan signed Intergovernmental Agreement on NPP construction in Jordan", Rosatom, 25 March 2015, see http://www.rosatom.ru/en/press-centre/highlights/russia-and-jordan-signed-intergovernmental-agreement-on-npp-construction-in-jordan-5/; and Ariel Ben Solomon, "Jordan and Russia to sign $10b nuclear deal this month", *Jerusalem Post*, 22 March 2015, see http://www.jpost.com/landedpages/printarticle.aspx?id=394732, both accessed 26 April 2017.

458 - *AFP*, "Jordan agrees deal for Russia to build nuclear plant", *Yahoo! News*, 25 March 2015, see https://www.yahoo.com/news/jordan-agrees-deal-russia-build-nuclear-plant-231404790.html, accessed 26 April 2017.

459 - *NIW*, "Briefs—Jordan", 18 April 2014.

460 - IAG, "Jordan nuclear energy program—International Advisory Group Report—Submitted to the Government of Jordan", July 2016, see http://www.jaec.gov.jo/CMS/UploadedFiles/491539b1-e01e-482d-9e30-e92a85c3557e.pdf, accessed 25 July 2017.

461 - Karin Laub, "AP Interview: Jordan eager to reach nuke deal with US", *AP*, 4 July 2016, see http://bigstory.ap.org/article/8ddf51fbf3004c1382f69a1795c2eef7/ap-interview-jordan-eager-reach-nuke-deal-us, accessed 18 April 2017.

462 - Geert De Clercq, Svetlana Burmistrova and Jack Stubbs, "Rosatom's global nuclear ambition cramped by Kremlin politics", *Reuters*, 26 June 2016, see http://www.reuters.com/article/us-russia-nuclear-rosatom-idUSKCN0ZC0QZ, accessed 1 June 2017.

463 - Mohammad Ghazal, "Jordan seeking funds for first nuclear power plant — official", *Jordan Times*, 20 August 2016, see http://www.jordantimes.com/news/local/jordan-seeking-funds-first-nuclear-power-plant-—-official, accessed 1 June 2017.

464 - Phil Chaffee, "Jordan: Looking for Better Offers", *NIW*, 21 October 2016.

constructed—from the United States.465 But that appears rather as "wishful thinking", and SMRs will not fit all the constraints that JAEC has to operate under.[466]

Meanwhile, in December 2016, the Korea Atomic Energy Research Institute and Daewoo Engineering & Construction together completed building Jordan's first research reactor, the Jordan Research and Training Reactor (JRTR).[467] Built at a cost of US$161 million, the JRTR has a power output of 5 MW. The agreement with South Korea to construct the reactor was signed in 2010.[468] It also provided a soft loan of US$70 million that is to be paid "over 29 years, with a 10-year grace period and a 0.2 percent interest rate".[469]

on a per unit of GDP basis, Jordan ranks third in the world when it comes to investment in renewable power and fuels

Local opposition comes in particular from members of the Beni Sakher tribe that lives around the Al Amra area.[470] One member of the tribe, Hind Fayez, is a prominent parliamentarian and a noted opponent.[471] She is quoted as saying: "I will not allow the construction of the nuclear reactor, not even over my dead body (...). The Bani Sakher tribe also rejects the construction of the nuclear reactor in Qusayr Amra".[472] A particular concern is water requirements for the reactor, which is to come from the Al-Samra Waste Water Treatment Plant in nearby Irbid.[473] If and when the reactor is commissioned, over 20 percent of the total capacity of the Treatment Plant would be used to supply water to the reactors. The output of the Treatment Plant is currently being used for irrigation;[474] diversion of water to the reactor is, naturally, of public concern. The treatment of wastewater would also add to the already high costs of generating nuclear power.[475] It has been suggested that "it may well be water, the Middle East's most precious resource, rather than fiscal issues that shoves the country's nuclear hopes farther into the future".[476] Non-proliferation and regional security concerns are also adding to the calls for Jordan to forgo nuclear power, with Chen Kane, director of the Middle East program at the

465 - Karin Laub, "AP Interview: Jordan eager to reach nuke deal with US", *AP*, 4 July 2016, see http://bigstory.ap.org/article/8ddf51fbf3004c1382f69a1795c2eef7/ap-interview-jordan-eager-reach-nuke-deal-us, accessed 18 April 2017.

466 - M. V. Ramana and Ali Ahmad, "Wishful Thinking and Real Problems: Small Modular Reactors, Planning Constraints, and Nuclear Power in Jordan", *Energy Policy*, 22 March 2016.

467 - Kim Tae-gyu, "Korea installs nuclear reactor in Jordan", *The Korea Times*, 7 December 2016, see http://www.koreatimes.co.kr/www/tech/2017/06/693_219701.html, accessed 31 May 2017.

468 - Ann MacLachlan, "South Koreans celebrate new role as nuclear technology exporters", *NW*, 22 April 2010.

469 - Dana Al Emam, "Korean soft loan to fund safety features of nuclear research reactor", *Jordan Times*, 28 October 2015, see http://www.jordantimes.com/news/local/korean-soft-loan-fund-safety-features-nuclear-research-reactor, accessed 31 May 2017.

470 - Alice Su, "Jordan faces no-nukes campaign", *Al-Monitor*, 12 November 2013, see http://www.al-monitor.com/pulse/originals/2013/11/jordan-nuclear-rosatom-environment-energy.html; and Areej Abuqudairi, "Jordan nuclear battle heats up", *Al Jazeera English*, 14 April 2014, see http://www.aljazeera.com/news/middleeast/2014/02/battle-heats-up-over-jordanian-nuclear-power-201422685957126736.html, both accessed 26 April 2017.

471 - David Schenker, "The Middle East's Next Nuclear Power?", *Politico*, 28 January 2015, see http://www.politico.com/magazine/story/2015/01/jordan-nuclear-power-114712.html, accessed 7 June 2016.

472 - *Jordan Times*, "Nuclear programme 'to lower electricity costs by 70%'", 30 October 2013.

473 - Elisa Oddone, "Russian Nuclear Energy Deal Signed", *Venture Magazine*, 19 May 2015, see http://www.venturemagazine.me/2015/05/russian-nuclear-energy-deal-signed, accessed 26 April 2017.

474 - *Water Technology*, "As-Samra Wastewater Treatment Plant (WWTP), Jordan", see http://www.water-technology.net/projects/as-samra-wastewater-treatment-plant-jordan/, accessed 26 April 2017.

475 - Thomas S., "Jordan's Nuclear Power Plans", Istanbul, 2013, 29.

476 - John C.K Daly "Water shortages may end Jordan's nuclear power hopes", *oilprice.com*, *Mining.com*, 18 June 2013, see http://www.mining.com/web/water-shortages-may-end-jordans-nuclear-power-hopes/, accessed 26 April 2017.

James Martin Center for Nonproliferation Studies stating "I think nuclear energy is a way too expensive, risky and unpredictable option" for Jordan.[477]

While Jordan has been grappling with financing and siting problems with regard to nuclear reactors, it has been moving fast on renewables. Its first large scale solar photovoltaic plant at Shams Ma'an was commissioned in October 2016. The project cost about US$170 million and has a generating capacity of 52.5 MW, over 1 percent of Jordan's installed electricity capacity.[478] Much more is on the way: in November 2016, the government of Jordan announced the opening of the third round of direct proposal submissions for 200 MW of solar PV and 100 MW of wind plants.[479] Jordan has also been successful in getting foreign investment, in particular from Saudi companies.[480] Overall, investment in 2016 on renewables was $1.2 billion, up 148 percent from 2015; on a per unit of GDP basis, Jordan ranks third in the world when it comes to investment in renewable power and fuels.[481]

Poland planned the development of a series of nuclear power stations in the 1980s and started construction of two VVER1000/320 reactors in Żarnowiec on the Baltic coast, but both construction and further plans were halted following the Chernobyl accident. In 2008, however, Poland announced that it was going to re-enter the nuclear arena and in November 2010, the Ministry of Economy put forward a Nuclear Energy Program. On 28 January 2014, the Polish Government adopted a document with the title "Polish Nuclear Power Programme" outlining the framework of the plan.[482] The plan includes proposals to build 6 GW of nuclear power capacity with the first reactor starting up by 2024. The reactor types under consideration include AREVA's EPR, Westinghouse's AP1000, and Hitachi/GE's ABWR.

In January 2013, the Polish utility PGE (Polska Grupa Energetyczna) had selected WorleyParsons to conduct a five-year, US$81.5 million study, on the siting and development of a nuclear power plant with a capacity of up to 3 GW.[483] At that time, the project was estimated at US$13–19 billion, site selection was to have been completed by 2016, and construction was to begin in 2019.[484] A number of vendors, including AREVA, Westinghouse, and GE-Hitachi, all lobbied Warsaw aggressively.[485] PGE formed a project company PGE EJ1, which also has a ten percent participation each of the other large Polish utilities, Tauron Polska Energia and Enea, as well as the state copper-mining firm KGHM. In January 2014, PGE EJ1 received four bids from companies looking to become the company's "Owner's Engineer" to help in the ten-

477 - Karin Laub, "AP Interview: Jordan eager to reach nuke deal with US", *AP*, 4 July 2016, see http://bigstory.ap.org/article/8ddf51fbf3004c1382f69a1795c2eef7/ap-interview-jordan-eager-reach-nuke-deal-us, accessed 18 April 2017.

478 - Shams Ma'an, "Shams Ma'an Launches Production Phase of the largest Electricity Generation Project Using Photovoltaic Cells in Jordan", 3 December 2016, see http://www.shamsmaan.com/page/shams-ma'-launches-production-phase-largest-electricity-generation-project-using-photovoltaic, accessed 31 May 2017.

479 - Danielle Ola, "Jordan announces tender submissions for 300MW of wind and solar", *PV Tech*, 15 November 2016, see https://www.pv-tech.org/news/jordan-announces-tender-submissions-for-300mw-of-wind-and-solar, accessed 31 May 2017.

480 - LeAnne Graves, "Saudi Arabian companies move ahead on Jordan solar projects", *The National*, 30 May 2017, see http://www.thenational.ae/business/energy/saudi-arabian-companies-move-ahead-on-jordan-solar-projects, accessed 31 May 2017.

481 - REN21, "Renewables 2017—Global Status Report", 2017, see http://www.ren21.net/gsr-2017/, accessed 8 June 2017.

482 - Ministerstwo Gospodarki, "Polish Nuclear Power Programme", January 2014. Apparently, an updated version of the Program was published in the Polish Monitor MP on 24 June 2014.

483 - *NIW*, "Briefs—Poland", 8 February 2013.

484 - *The Economist*, "Polish Energy, Going nuclear", 31 January 2014, see http://www.economist.com/blogs/easternapproaches/2014/01/polish-energy, accessed 26 April 2017.

485 -*NIW*, "Potential and Existing Global Nuclear Newbuild Projects", 25 April 2014.

dering and development of the project, which was eventually awarded to AMEC Nuclear UK in July 2014. The timetable demanded that PGE make a final investment decision on the two plants by early 2017.[486] Final design and permits for the first plant were expected to be ready in 2018, allowing construction start in 2020 and commercial operation in 2025. As of early 2016, that schedule has slipped to commercial operation beginning in 2030-31.[487]

The Polish General Directorate for the Environment (GDOS) started, in December 2015, the scoping phase for the Environmental Impact Assessment for the first Polish nuclear power station with a notification to states within 1,000 km from the proposed three sites. Directly after the start of this scoping phase, PGE EJ1 informed GDOS that it was withdrawing one of the three proposed sites, at Choczewo, because of the potential impacts on protected nature areas.[488] In March 2017, PGE EJ1 began, again, environmental assessment and site selection at two sites, both in the Northern province of Pomerania due to be completed in 2020.[489]

"WELL DEVELOPED PLANS"

There seems little to indicate that **Chile** is actively developing nuclear power. WNA stated that in 2010 the Energy Minister had said that the first nuclear plant of 1100 MWe should be operating in 2024, joined by three more by 2035 and that a public-private partnership is proposed to build the first plant, with a tender to be called in 2016.[490] However, plans have not developed significantly since then. Public opinion in Chile turned strongly against nuclear power after the Fukushima accident.[491]

According to the Chilean Nuclear Energy Commission, they continue to evaluate the feasibility of building a nuclear power plant although a "political decision has been postponed".[492] At the same time, in January 2016, President Michelle Bachelet signed a new energy strategy that sets a goal of renewable energy providing 70 percent of the country's power needs by 2050.[493] Chile's solar capacity has increased six fold since 2014 and energy officials want to turn the country into a 'solar Saudi Arabia'.[494]

486 - *NucNet*, "Amec Wins USD 430 Million Contract To Support Polish New-Build", 9 July 2014, see http://www.nucnet.org/all-the-news/2014/07/21/amec-wins-usd-430-million-contract-to-support-polish-new-build, accessed 26 April 2016.

487 - *NW*, "Polish nuclear program facing additional delays of at least one year: analyst", 21 April 2016.

488 - Emilia Derewienko, "PGE EJ1 rezygnuje z lokalizacji 'Choczewo'", *Rynek Infrastruktury*, 2 February 2016, (in Polish), see http://www.rynekinfrastruktury.pl/wiadomosci/elektrownia-jadrowa-nie-powstanie-w-choczewie-52648.html, accessed 26 April 2016.

489 - *NEI*, "Site Studies begin for Poland's first NPP", 12 April 2017, see http://www.neimagazine.com/news/newssite-studies-begin-for-polands-first-npp-5784946/, accessed 27 April 2017.

490 - WNA, "Emerging Nuclear Energy Countries", Updated March 2017, see http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx, accessed 26 April 2017.

491 - *HydroWorld.com*, "Public increasingly opposed to HidroAysén, nuclear power – Ipsos", 13 April 2011.

492 - Jerson R. Reyes, "Technology Assessment for Embarking Countries", Chilean Nuclear Energy Commission, 24 June 2013, Presentation at the Technical Meeting on Technology Assessment for Embarking Countries, IAEA, Vienna (Austria), see https://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-06-24-06-28-TM-NPTD/6-chile.pdf, accessed 26 April 2017.

493 - Conor Ryan, "Chile introduces new Energy 2050 renewable-energy goals", *PV-Tech*, 6 January 2016, see http://www.pv-tech.org/news/chile-introduces-new-energy-2050-renewable-energy-goals, accessed 26 April 2017.

494 - Nick Miroff, "A Solar Saudi Arabia", *Washington Post*, 31 March 2017, see http://www.washingtonpost.com/sf/world/2017/03/31/while-trump-promotes-coal-other-countries-are-turning-to-cheap-sun-power/?utm_term=.4b10457c32af, accessed 26 April 2017.

Since the mid-1970s, **Indonesia** has discussed and brought forward plans to develop nuclear power, releasing its first study on the introduction of nuclear power, supported by the Italian government, in 1976. The analysis was updated in the mid-1980s with help from the IAEA, the United States, France and Italy. Numerous discussions took place over the following decade, and by 1997 a Nuclear Energy Law was adopted that gave guidance on construction, operation, and decommissioning. A decade later, the 2007 Law on National Long-Term Development Planning for 2005–25 stipulated that between 2015 and 2019, four units should be completed with an installed capacity of 6 GW.[495] In July 2007, Korea Electric Power Corp. (KEPCO) and Korea Hydro & Nuclear Power Co. (KHNP) signed a Memorandum of Understanding with Indonesia's PT Medco Energi Internasional to undertake a feasibility study for building two 1000 MW units at a cost of US$3 billion. Then, in December 2015, the Indonesian government pulled the plug on all nuclear plans, even for the longer-term future. Trade journal *Nuclear Engineering International* commented: "This effectively cancels a previous [US]$8bn plan to operate four nuclear plants with a total capacity of 6 GWe by 2025."[496]

Indonesia plans to achieve an ambitious build-up of electricity generating capacity—from currently less than 50 GW to 137 GW by 2025 and 430 GW by 2050—without nuclear power. Beyond 2050, nuclear power could be a "last resort" option.

Kazakhstan is the world's largest producer of uranium, with about 40 percent of the global total. It had a small fast breeder reactor, BN 350, which operated at Aktau, between 1972-1999. A number of countries, including Russia, Japan, South Korea, and China have all signed co-operation agreements for the development of nuclear power. In 2014, President Nursultan Nazarbayev, used his State of the Nation address to highlight the need to develop nuclear power. Since then, negotiations have continued, particularly with Toshiba-Westinghouse of Japan and Rosatom of Russia.[497] However, others are less positive about the timetable and, in October 2015, the Vice Minister of Energy Bakhytzhan Dzhaksaliyev said that finding a suitable site and strategic partner may take two to three years.[498] In December 2015, a draft Atomic Energy Law was referred to the Senate, in order to address licensing, security, environmental protection rules and standards.[499] An April 2016 joint declaration by the energy ministers of Kazakhstan and the U.S. notes that the 2016 work plan "encourages the use of alternative energy sources in Kazakhstan, reduces emissions, and enhances nuclear safety".[500] In December 2016, the government announced that it was undertaking research into five dif-

495 - Hanan Nugroho, "Development of Nuclear Power in Indonesia: Stop or Go?", *Jakarta Post*, 5 May 2010, see http://www.thejakartapost.com/news/2010/05/05/development-nuclear-power-indonesia-stop-or-go.html, accessed 26 April 2017.

496 - *NEI*, "Indonesia rules out nuclear as major power source", 14 December 2015, see http://www.neimagazine.com/news/newsindonesia-rules-out-nuclear-as-major-power-source-4752814, accessed 26 April 2017.

497 - *WNN*, "Russia and Kazakhstan to ink nuclear power accord this year", 2 March 2016, see http://www.world-nuclear-news.org/NP-Russia-and-Kazakhstan-to-ink-nuclear-power-accord-this-year-02031601.html, accessed 26 April 2017.

498 - *Tengri News*, "Kazakhstan to define location and strategic partners for its first nuclear power plant in 2-3 years", 23 October 2015, see http://en.tengrinews.kz/industry_infrastructure/Kazakhstan-to-define-location-and-strategic-partners-for-its-262679/, accessed 26 April 2017.

499 - Government of the Republic of Kazakhstan, "Draft law on use of nuclear energy, as amended, referred to Senate", 21 December 2015, see http://www.government.kz/en/novosti/29961-draft-law-on-use-of-nuclear-energy-as-amended-referred-to-senate.html, accessed 26 April 2017.

500 - U.S.DOE, "Kazakhstan - United States Special Commission on Energy Partnership", 6 April 2016, see http://www.energy.gov/articles/kazakhstan-united-states-special-commission-energy-partnership, accessed 26 April 2017.

ferent locations for a new nuclear power plant and that a Gen III or Gen III+ was their favored design.[501]

In 2012, the IAEA suggested that in 2013 the Kingdom of **Saudi Arabia** might start building its first nuclear reactor.[502] The King Abdullah City for Atomic and Renewable Energy (KA-CARE) had earlier been set up in 2010 to advance this agenda, and in June 2011, the coordinator of scientific collaboration at KA-CARE announced plans to construct 16 nuclear power reactors over the next 20 years at a cost of more than 300 billion riyals (US$80 billion). The first two reactors were planned to be online in ten years and then two more per year until 2030.

During 2015, new co-operation agreements were signed with France, Russia, China and South Korea. The latter seemed to be the most advanced with proposals for the building of two "smart" reactors and ongoing research and collaboration.[503] A further MoU was signed in November 2016 to strengthen cooperation on nuclear safety and regulations. While in March 2017 a co-operation agreement was signed with CNEC on the development of high-temperature gas cooled reactors.[504]

Saudi Arabia continues to explore existing and future reactor designs with a wide variety of countries and companies. However, the decisions on which reactors and the introduction of hard deadlines remains elusive and operation targets for reactors continue to be 20 years from now.

The National Energy Policy Council of **Thailand** in 2007 proposed that up to 5 GW of capacity be operational between 2020 and 2028. However, this target will not be met for a number of reasons, but significant among them is local opposition on the proposed sites. The latest proposal from the Electricity Generating Authority of Thailand (EGAT) is for two 1 GW units to be operational by 2036, although no location has been named.[505] Thailand's largest private power company has announced that it will invest US$200 million for a 10 percent stake of the CGN and Guangxi Investment Group's Fangchenggang nuclear power plant in China.[506] CGN obviously eyes a role in the potential 2 GW nuclear project in Thailand.

"DEVELOPING PLANS"

The projects listed under the WNA's category of "developing plans", demonstrate current or past government intent and in most cases discussion with foreign vendors but little or no actual project development work.

501 - *NEI*, "Kazakhstan considers five possible NPP sites", 1 December 2016, see http://www.neimagazine.com/news/newskazakhstan-considers-five-possible-npp-sites-5685167/, accessed 26 April 2017.

502 - Lucas W. Hixson, "IAEA – Vietnam and 4 other countries to incorporate nuclear energy after Fukushima", *Enformable.com*, 24 February 2012, see http://enformable.com/2012/02/iaea-vietnam-and-4-other-countries-to-incorporate-nuclear-energy-after-fukushima/, accessed 26 April 2017.

503 -*NIW*, "Saudi Arabia, Will Water Scarcity Spur Nuclear Growth?", 31 July 2015.

504 -*NEI*, "Saudi Arabia looks to China and Korea for nuclear assistance", 20 March 2017, see http://www.neimagazine.com/news/newssaudi-arabia-looks-to-china-and-korea-for-nuclear-assistance-5767240/, accessed 25 April 2017.

505 -WNA, "Emerging Nuclear Energy Countries", Updated March 2017, see http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx, accessed 26 April 2017.

506 -*WNN*, "Thai power company buys into Fangchenggang II", 25 January 2016, see http://www.world-nuclear-news.org/NN-Thai-power-company-buys-into-Fangchenggang-II-2501164.html, accessed 26 April 2017.

Algeria: In October 2016, Rosatom said that it was in discussion with Algeria about the construction of 2 GW of nuclear capacity, at cost of US$10 billion, with plans for the plant to start operating in 2026.[507]

Israel: As a non-signatory of the Non-Proliferation Treaty, it is not possible for Israel to get international assistance for the construction of a commercial nuclear power plant and building it with domestic knowledge and equipment would be extremely problematic.

Kenya: The Kenyan Nuclear Electricity Board has said that it would like to start building a 1 GW plant by 2021 with a targeted operation in 2027, and is currently looking for a suitable site. It has signed nuclear co-operation agreements with South Korea[508] and China[509].

Table 6 | Summary of Nuclear Newcomer Countries (Actual and Potential)

Countries	Reactor Name	Proposed Vendor	Initial Startup Date	Proposed Construction Start	Official Startup date
Under Construction					
Belarus	Ostrovets	Rosatom	2016/18		2019/20
UAE	Barakah	KEPCO	2017/18/19/20		2018/18/19/20
Contract Signed or Advanced Development					
Bangladesh	Rooppur	Rosatom	2018	Decision expected 2017	
Lithuania	Visegrade	Hitachi	2020	Suspended	
Turkey	Akkuyu	Rosatom	2015	Final investment expected 2017	2023
	Sinop	Mitsubishi/Areva		?	
	Ingeada	SNPTC/Westinghouse		2019	
Vietnam	Ninh Thuan	Rosatom	2020	Suspended	
Committed Plans					
Egypt		Rosatom	2019	Decision expected 2017	
Jordan		Rosatom		2019	
Poland				?	
Well Developed Plans					
Chile			2024	Suspended	
Indonesia		Rosatom		Indefinitely Postponed	
Kazakhstan		Rosatom or Westinghouse		?	
Saudi Arabia			2020	?	2040
Thailand			2020-8	?	2036

Sources: Various, compiled by WNISR, 2017

507 -PEi, "Russian in talks over Algeria's first nuclear power plant", 3 August 2016, Power Engineering International, see http://www.powerengineeringint.com/articles/2016/03/russia-in-talks-over-algeria-s-first-nuclear-power-plant.html, accessed 27 April 2017.

508 -Christine Wanjala, "Kenya Plans First Nuclear Power Plant at $5 Billion Cost", *Bloomberg*, 30 November 2016, see https://www.bloomberg.com/news/articles/2016-11-30/kenya-plans-first-nuclear-power-plant-by-2027-at-5-billion-cost, accessed 27 April 2017.

509 -*China Daily*, "CGN signs Kenya nuclear training, technology support agreement", 24 March 2017, see http://www.chinadaily.com.cn/business/2017-03/24/content_28660259.htm, accessed 26 July 2017.

Laos: In April 2016, Laos signed a Memorandum of Understanding with Russia on the co-operation on the design, construction and operation of two nuclear power plants, on a build-operate-transfer basis.[510]

Malaysia: The latest Economic Transformation Program, assumes that two nuclear power plants will be operational by 2021. However, even the Government has said that these dates are unfeasible, as they recognize that it takes 11 years from any decision to operation. To date no decision has been taken on whether or not to proceed with nuclear at all.[511]

Morocco: The country is considering introducing nuclear power after 2030 and has involved the IAEA who undertook an Integrated Nuclear Infrastructure Review mission, in 2015.[512]

Nigeria: In December 2016, the Government of Nigeria said it had signed a project development agreement, to build 4.8 GW of nuclear capacity at a cost of US$20 billion.[513]

CONCLUSION ON POTENTIAL NEWCOMER COUNTRIES

Over the past two decades, just two countries, Romania and Iran started operating nuclear power plants for the first time. In the 20 or so countries that are said to be currently considering building nuclear power plants, the interest in the projects goes up and down the political agenda, depending on the energy agenda of the government of the time and its relationship with the vendor countries.

During 2017, it was expected that the first unit in the UAE would be completed, however, as of the middle of the year, it is clear that grid connection will take place in 2018 at the earliest. The timeline for the completion of the two reactors in Belarus—the only other country with reactors under-construction for the first time— also slipped by at least one year to the end of 2019.

Beyond these two countries, it is difficult seeing any, with the possible exception of Turkey and, to a lower degree Bangladesh, of the aspiring countries actually being able to or even seriously aspiring to build a nuclear power program, especially given the rapidly falling system costs of renewable energy technologies, the new main competitor.

510 -*WNN*, "Russia and Laos plan nuclear cooperation", 15 April 2016, see http://www.world-nuclear-news.org/NP-Russia-and-Laos-plan-nuclear-cooperation-1504164.html, accessed 27 April 2017.

511 -*Bernama*, "No decision yet on building nuclear power plants in Malaysia, says Nancy Shukri", *Malay Mail*, 3 November 2016, see http://www.themalaymailonline.com/malaysia/article/no-decision-yet-on-building-nuclear-power-plants-in-malaysia-says-nancy-shu - sthash.Jf3Gu25p.dpuf, accessed 27 April 2017.

512 - IAEA, "IAEA Delivers Report on Nuclear Power Development to Morocco", 1 March 2016, see https://www.iaea.org/NuclearPower/News/2016/2016-03-01-NIDS.html, accessed 27 April 2017.

513 - *Daily Trust*, "Nigeria, Russia sign nuclear power plants pact – Osaisai", 21 December 2016, see https://www.dailytrust.com.ng/news/business/nigeria-russia-sign-nuclear-power-plants-pact--osaisai/176939.html, accessed 10 May 2017.

NUCLEAR FINANCES A TOUGH MARKET ENVIRONMENT

INTRODUCTION

The Trend Towards a Decentralized Model

The power sector is in the middle of a profound structural change. The introduction of renewable energy at scale, due to fast declining costs driven by technological advances, have in many parts of the world increased renewable power output at the expense of conventional technologies such as coal and nuclear.

The move from a centralized model to a decentralized one is expected to accelerate, as renewable investment continues, increasing the demand for better performing electricity storage and efficient peak assets, as the model transforms from a basic base- and–peak load model, towards a forecast and balanced one (based on weather conditions and demand expectations).

The entire concept of baseload is being replaced by high-flexibility demand-response options.

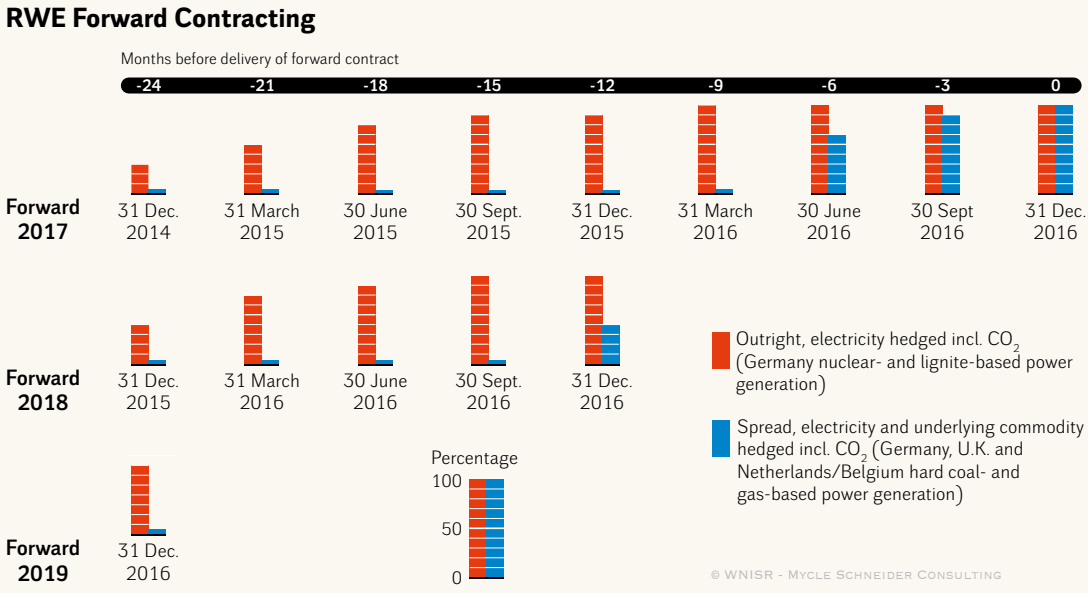
As the electricity market moves towards a decentralized model, the need of massive generation assets decreases as the electricity sector requires assets that should rapidly respond to demand gaps without major distortions on the power grid. In other words, conventional generation assets would be closer to where they are needed most. Following this idea, smaller generation capacity, spread geographically and closer to demand hubs, will be a better response to the increased volatility seen on the intra-day equilibrium, while providing a better source of baseload electricity with lower distortions on the networks. The entire concept of baseload is being replaced by high-flexibility demand-response options.

About Spot Power-Price Exposure

Some power utilities' stock-prices move in accordance with electricity spot-price movements besides specific information concerning the companies and interest-rate movements. Nonetheless, the exposure to spot-price movements is limited, especially for baseload producers as they are almost fully covered through financial derivatives (hedges) for the year ahead, given that their production is relatively stable, providing reliability in terms of earnings and cash flows. Forwards are the most popular asset class for hedging positions, whereby producers reduce their volatility risk as future price contracts have been agreed at a level at which the electricity production would be sold.

As illustrated in Figure 25 with the example of German utility RWE, the financial coverage for baseload production normally starts three years ahead, increasing over time. Companies

Figure 25 | RWE Forward Contracting



Source: RWE, Annual Report 2016, 2017

use forward contracts on electricity prices, which are less volatile than spot prices, as they do not depend on intra-day supply and demand, but rather on sector trends and commodity price expectations (oil, gas, coal, etc.). This process allows power-generation companies to reduce their volatility on earnings, while avoiding uncertainty, as spot prices can fluctuate ±50 percent within a day.

However, substantial increases in spot prices may happen over possible supply shortages, or radical movements in commodity prices. In this case, the hedging strategy may backfire and companies may end up losing on financial expenses what could have been won by producing at higher prices, as derivative contracts for forward hedging normally have margin calls, that need to be paid, if fluctuations are above a certain threshold: the investor would be required to either deposit more money into the account or sell some assets given that the derivatives used have decreased in value past a certain point.

Peak producers rely more on spot prices as they produce electricity, when needed, for a short period of time. Those assets benefit from increased volatility, as well as from spread variations (profitability of an asset at a given period). A higher price-volatility affects distribution networks too, mainly to balance supply and demand gaps, by efficiently attributing the required capacity to cover demand needs.

In the second half of 2016, an unexpected rebound in power prices driven by higher fuel prices and lower nuclear capacity in France caught some power utilities off-guard, generating negative effects in their trading performance from positions mainly related to forward contracts on commodity prices (coal and power), for a total loss of €139m[514] (US$149.9m) for RWE and €18m (US$19.4m) for ENEL[515]. However, a higher volatility, if properly managed, can allow compa-

514 - Considering the number of numbers in this chapter, here m=million and bn=billion.

515 - RWE, "Annual Report 2016", 14 March 2017, see http://www.rwe.com/web/cms/mediablob/en/3688522/data/105818/7/rwe/investor-relations/RWE-annual-report-2016.pdf, accessed 2 August 2017; and ENEL, "2016 Annual Results", March 2017.

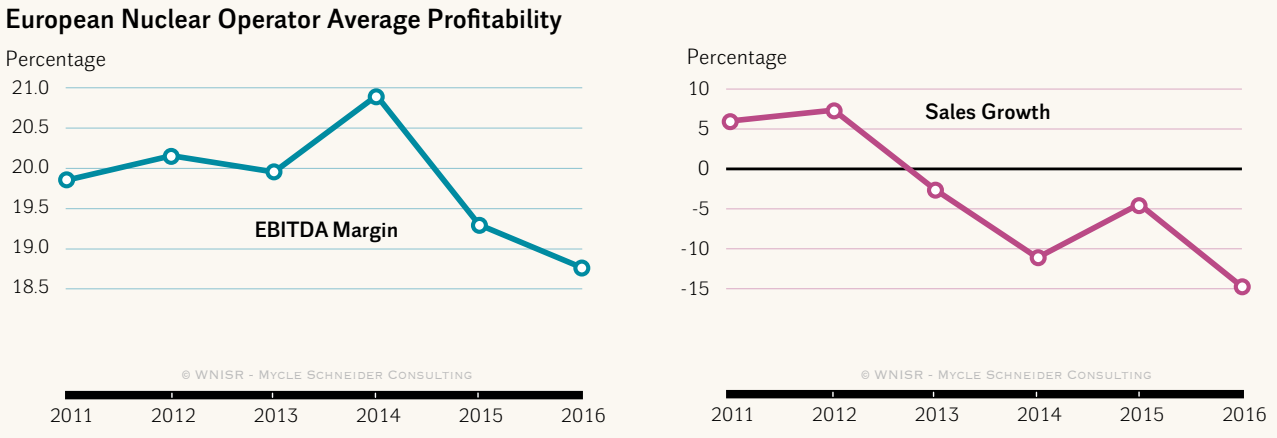
nies to profit from arbitrage opportunities (simultaneous purchase and sale of an asset/security to profit from price differences). For instance, it has led EDF to partially offset some of the downward effect faced on its nuclear generation, with an increase of 56.8 percent in trading's earnings, reaching €729m (US$786m) in 2016[516].

Spot-price movements rarely affect the profitability of baseload producers such as nuclear in the current year, but it may push forward prices within the same path (although, with a lower volatility): forward prices affect the hedging level of the company in the future, affecting the profitability of the assets in the coming years (at a stable production level).

Contracting Profits

The low-price environment over recent years has decreased the achieved price of baseload production and reduced margins. Moreover, a greater integration of renewables has decreased the utilization rate of conventional power plants, forcing operators to adjust the amortization of the assets to a shorter expected lifetime. Due to this, multiple large impairments have been booked over recent years. In 2016, E.ON, ENGIE, and RWE have once again reported profits into negative territory, with net income losses of €8.45bn, €0.4bn, and €5.7bn (US$9.45bn, US$0.45bn, and US$6.38bn) respectively[517]. These are mainly driven by one-offs from adjusted depreciation levels and impairment charges, with little impact on cash flows. However, on an adjusted basis the operating profit and margins of nuclear and conventional power plant operators continue to decrease.

Figure 26 | Average Profitability of Six European Nuclear Operators



Sources: Companies' Annual Reports

As can be seen in Figure 26, average EBITDA (Earnings Before Interest, Tax, Depreciation and Amortization) margins and sales of six large European nuclear utilities (E.ON, RWE, ENEL, Engie, EDF, Fortum) from four countries (Germany, Italy, France, Finland) have fallen as a result of lower commodity prices, increased competition, and lower capacity factors. With no

516 - EDF, "Consolidated Financial Statements at 31 December 2016", 13 February 2017.

517 - RWE, "Annual Report 2016", 14 March 2017; E.ON, "Annual Report 2016", 15 March 2017, see https://www.eon.com/en/investor-relations/financial-publications/annual-report.html; also ENGIE, "Management report and Annual consolidated financial statements", 2 March 2017, see http://www.engie.com/en/investors/results/2016-results/, all accessed 2 August 2017.

revenue support, companies have decided to optimize operating costs and reduce workforce to minimize the negative effect in profits.

Moreover, as many nuclear assets are getting closer to the end of their nominal operating life, substantial investments are needed in the coming years, either for an extension of the lifetime, or to cover expected expenses for decommissioning. In fact, the implementation of the energy transition legislation, as pledged by the new French government, will combine both constraints: lifetime extension for some reactors, with decommissioning for others. Under a depressed price environment and sluggish demand expectations, the expected return on those assets may be lower than the investment required for lifetime extension.

As a result, driven by decreasing profits and increasing investment needs, there were at least three major capital increases within the European nuclear sector: a €5bn (US$5.4bn) one for AREVA to ramp-up its balance sheet, a €4bn (US$4.3bn) for EDF to strengthen its balance sheet in front of the AREVA NP takeover, Hinkley Point C and the Grand Carénage (investment on the nuclear fleet to extend operational lifetime by 10 years), and a €1.34bn (US$1.53bn) increase for E.ON to cover the additional payment required by the German government to transfer the nuclear waste provisions towards a sovereign nuclear waste fund.

Moreover, the two main German operators, E.ON and RWE, driven by the closure of nuclear assets, a fast contraction of margins for conventional generation, and the weakening of their financial structure, decided to create separate entities. These are Uniper—E.ON's conventional generation, trading, and Exploration and Production (E&P) subsidiary—and Innogy—RWE's renewable, networks and retail branch, which started to be traded separately in 2016. This was performed in an attempt to create value for shareholders, while concentrating capital towards sources that may provide growth, with stable earnings and cash flows.

THE GERMAN NUCLEAR SINGULARITY

The Spin-off Idea

Following the country's commitment to the Energiewende—the German transition to a low-carbon, environmentally sound, reliable and affordable energy supply—and the overall transition faced by the international energy sector, E.ON has undertaken a quite revolutionary attempt to find value for its shareholders, while decreasing their exposure to power-price movements. It did this by proposing a "good bank–bad bank" approach, through the spin-off of its conventional generation, retail and E&P businesses, while keeping the assets with stable returns and growth expectations under E.ON's umbrella[518]. However, this strategy appeared too ambitious, too early, and it backfired as the company did not see the political impact that this choice was creating.

The possible transfer of the German nuclear assets in a newly created company opened the Pandora's box of nuclear provisions in the country and the ability of companies to cover them

518 - E.ON, "New Corporate Strategy", 30 November 2014, see https://www.eon.com/en/about-us/media/press-release/2014/new-corporate-strategy-eon-to-focus-on-renewables-distribution-networks-and-customer-solutions-and-to-spin-off-the-majority-of-a-new-publicly-listed-company-specializing-in-power-generation-global-energy-trading-and-exploration-and-production.html, accessed 24 June 2017.

in the future. As a consequence of E.ON's move, the German government decided to assess the situation to reduce the possible risks on taxpayers for pending liabilities and costs that may arise in the future.

Following the review, a liability law was passed, under which historical operators should be liable for future dismantling costs, blocking any attempt to transfer E.ON's German nuclear assets to newly created Uniper[519]. Prior to the new legislation following E.ON's spin-off attempt, companies were liable for units that become independent up to five years after a spin-off was performed. The German government extended the liability law to make historic operators liable for nuclear decommissioning costs for an unlimited period, even after a spin-off is performed. Hence, E.ON had to come back on its strategy and include the German nuclear assets under the "good-bank" entity, reducing the value creation possibilities of the new structure, as the profitable assets have the nuclear risks and decommissioning charges on their backs[520].

However, the valuation given by the market to Uniper was far below E.ON's expectations. Under E.ON's accounts, Uniper's value was close to €11bn (US$11.9bn) when the spin-off was achieved, compared to the €5bn (US$5.4bn) market capitalization given at the initial public offering (IPO), forcing the company to adjust its valuation on mark-to-market basis (valuing assets at quoted market prices) by –€6.1bn (–US$6.6bn)[521]. This adjustment has been made on top of the €3.8bn (US$4.1bn)[522] on impairments booked prior to the spin-off, mainly on Uniper's coal assets due to eroding profits and lower than expected growth. The combined factor "New E.ON" (with nuclear) plus low Uniper, instead of creating value for shareholders, has pushed the company towards a contractual phase.

Following the failed attempt taken by E.ON to transfer the risk, RWE took the same "good bank – bad bank" strategy, but transferred the "good assets" into a newly created group, Innogy, a company focusing on renewables, networks, and retail. RWE, the historic operator, acts as the "bad bank", keeping under its belt conventional generation (including nuclear), trading, and E&P[523]. By doing this, the company complies with new German regulation under the liability law, while at the same time creating value for its shareholders by providing a growth entity with a lower risk profile.

Creation of the KFK and Provision Analysis

The German government has become increasingly aware of the costs of decommissioning nuclear power stations. Following the utilities' spin-off proposals, the government started an investigation to see whether nuclear provisions set aside by the operators (i.e. E.ON, EnBW, RWE, and Vattenfall) for €38bn (US$41bn) were sufficient. Concerns arose over the ability of these companies to provide the necessary cash in the future if their profitability did not improve. With its investigation, the German government hoped to avoid a bailout (not replicating

519 - Gernot Heller and Markus Wacket "Germany approves law extending nuclear liability", *Reuters*, 14 October 2015, see http://uk.reuters.com/article/uk-germany-nuclear-liability-idUKKCN0S816Y20151014, accessed 24 June 2017.

520 - E.ON, "Ad hoc announcement §15 WpHG—Spin-off in schedule", 9 September 2015, see https://www.eon.com/en/about-us/media/press-release/2015/ad-hoc-announcement-15-wphg.html, accessed 24 June 2017.

521 - E.ON, "Nine month 2016 interim report", November 2016.

522 - E.ON, "Half-year 2016 report", August 2016.

523 - RWE, "One group, two companies with a clear strategic focus to unlock value", 1 December 2015.

what happened for banks in the past decade) and therefore protect its interest and those of taxpayers.

Being required to keep the German nuclear assets under the historical operators' umbrella, in addition to a limited operating lifetime (since the country is expected to fully exit nuclear generation by the end of 2022), the German government put the nuclear provisioning issue under close scrutiny. Driven by the weak financial situation of German utilities and the substantial costs expected in the future, the government studied multiple options to secure the future coverage of nuclear liabilities.

For this purpose, at the end of 2015, the government created a 19-member independent nuclear commission (Kommission zur Überprüfung des Kerneenergieausstiegs or KFK), which included politicians, lawyers, academics, and businessmen to avoid conflict of interest. The KFK met multiple times to develop recommendations to secure the financing of nuclear reactors' decommissioning and the funding of future costs for the storage and disposal of nuclear waste. As a first step, KFK analyzed the nuclear provisions booked by nuclear operators to assess, whether these are sufficient to cover possible future costs.

Proposal of a Sovereign Fund for Nuclear Waste

After KFK's deliberation on the adequacy of provision levels, a second step was taken to ensure satisfaction of the long-term financial obligations for the disposal and storage of nuclear waste. Since the German government had concerns over the ability of nuclear operators to finance these expenses in the long term (as the time horizon for nuclear waste storage prior to final disposal can go beyond 100 years), it created a sovereign fund to support these expenditures.

To set up this fund, with the idea of becoming responsible for future liabilities, the government asked a 35-percent premium on current provision levels. This premium takes into account the risk of potential future cost increases and the application of a high discount rate (above 4 percent). The total risk premium requested from operators under this draft law amounted to €6.1bn (US$6.5bn), adding to the €17.4bn (US$18.6bn)[524] already provisioned by the companies (E.ON, RWE, EnBW, and Vattenfall) for the same purpose. The nuclear operators first refused the proposition, considering that a 35-percent premium was excessive,[525] but at the end, they all agreed on the proposed terms.

KFK, considering the financial situation of the companies, also demanded that the financing of this premium come from equity and not from debt, as the government does not want the debt levels of the country's major utilities to increase. The sovereign fund was created/set-up in January 2017 and utilities should pay a 4.58 percent per year interest on any delayed payment. To comply with the law and to avoid additional interest payments, utilities have agreed to transfer the required amounts to the fund by July 2017.[526]

524 - Bundesrat, "Gesetzentwurf der Bundesregierung—Entwurf eines Gesetzes zur Neuordnung der Verantwortung in der kerntechnischen Entsorgung", October 2016.

525 - RWE, "Energy companies are ready for a joint solution to finance the phase out of nuclear power generation in Germany", 27 April 2016, see http://news.rwe.com/en/energy-companies-are-ready-for-a-joint-solution-to-finance-the-phase-out-of-nuclear-power-generation-in-germany/, accessed 24 June 2017.

526 - RWE, "Annual Report 2016", 14 March 2017; E.ON, "2016 Annual Results Presentation", March 2017.

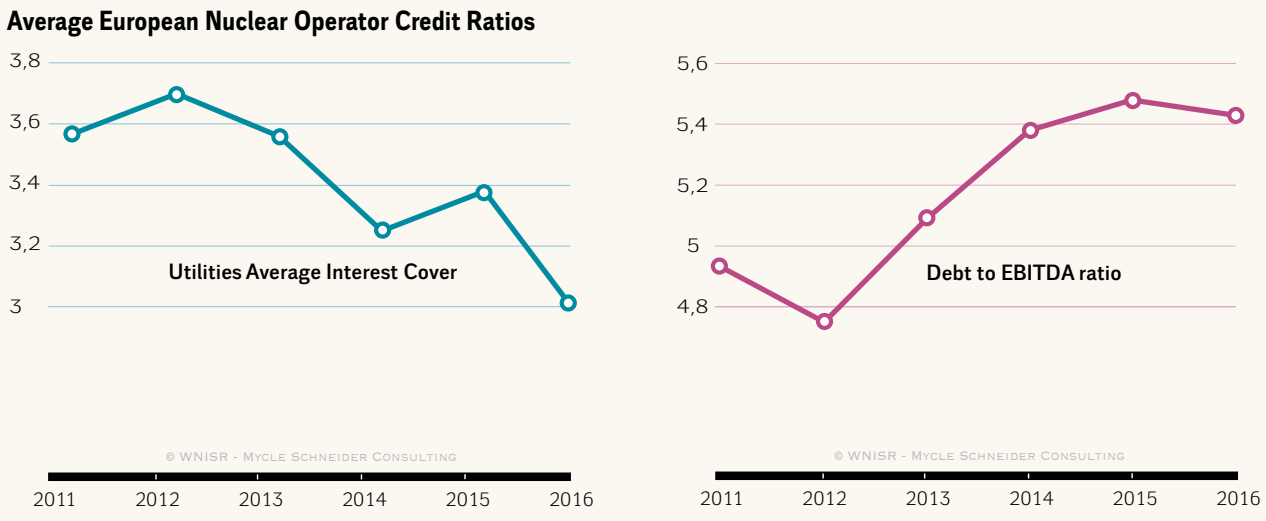
EFFECTS OF THE LOW-RATE ENVIRONMENT

Lower Interest Cost and Higher Debt Levels

Following the 2007–2008 financial crisis, central banks across the globe have opted to apply an accommodating policy to provide a breath of fresh air to a dampened macro-economic environment by reducing the inter-bank interest rate, and with it, decrease the cost of debt. In addition, following an [unconventional] monetary policy known as quantitative easing, central banks have started to purchase debt obligations, a type of financial instrument with a particular characteristic: the higher its price, the lower its interest rate. By increasing the purchased amounts of debt obligations (bonds), central banks increase the demand for the assets, pushing up prices and lowering interest rates. As a result of lower inter-bank interest rates and quantitative easing, the cost of debt for both governments and corporates has been reduced to historically low levels.

A lower cost of debt allows companies to invest at a time when earnings are not strong enough to support growth. This possibility generates multiple changes in the financial situation of companies: their debt levels increase and with earnings falling, ratios deteriorate. However, higher debt levels have a lower impact on companies' profits compared to the past, as a lower cost of debt implies lower interest expenses for a same borrowed amount.

Figure 27 | Average European Nuclear Operator Credit Ratios



Sources: Companies' Annual Reports

As can be seen in Figure 27, despite a decreasing interest cost, higher net debt and a decrease in profitability has reduced the interest-coverage ratio of the previously mentioned six companies from four countries. The interest-coverage ratio is a measure of the ability of a company to meet its interest payment obligations, comparing its operating profit with its interest expenses. The lower this ratio is, the higher the burden for a company to meet its interest expenses, as debt costs represent a higher share of the profits. Conversely, the debt to EBITDA ratio—which indicates the amount of time a company would need to pay off its debt—is increasing, representing greater debt difficulties for companies.

With a deterioration in the debt ratios used by agencies to determine their credit rating, it is inevitable that companies with higher debt levels and lower earnings will see lower ratings. The effect over time can be seen in Table 7.

Undeniably, a lower rate environment has supported the investment power of companies and governments by providing capital when earnings and cash flows were not supportive. Nonetheless, a low interest-rate environment has created additional side effects, as it implies that there would be lower allowed returns on regulated assets, added to a negative effect on the balance sheet for pensions and nuclear provisions.

Table 7 | Credit Rating History of Major European Utilities

	Rating Agency Changes 2016				
	Rating	Perspective		Rating	Perspective
Iberdrola	BBB	Positive	↑	BBB+	Positive
Enel	BBB	Positive	=	BBB	Positive
Fortum	BBB+	Stable	=	BBB+	Stable
Engie	A	Stable	↓	A-	Stable
EDF	A+	Negative	↓	A-	Stable
RWE	BBB	Negative	↓	BBB-	Negative
E.ON	BBB+	Stable	↓	BBB	Stable
Centrica	BBB+	Stable	↓	BBB+	Negative
AREVA	B+	Develop	↓	B	Develop

Sources: S&P; Companies' Annual Reports

Lower Allowed Returns on Regulated Assets

Transmission and distribution networks, as they operate under a natural monopoly, are regulated assets. The regulator determines the earnings operators would be allowed in a given year to avoid excessive profits from market control. To determine this, the regulator uses the Regulated Asset Value (RAV) or the Regulated Asset Base (RAB) to determine the Return on Capital Employed (ROCE) within a regulatory period (normally three to five years).

For this, regulators normally use the 10-year interest rate on government bonds (from the country where the assets are operated), added to a risk premium. Additional parameters such as inflation levels, growth investment, and control in operating expenses are used to calculate the return operators would have in a given period. The low interest environment has generated a lower cost of debt and decreased the Weighted Average Cost of Capital (WACC), thus forcing regulators to revise downwards the allowed return on regulated assets so as to reduce the ROCE. The objective is to minimize ROCE and WACC differences to avoid excess value creation.

Following this idea, in October 2016 the German Federal Network Agency (Bundesnetzagentur), which is responsible for regulatory functions, has revised the regulatory parameters taking into account lower interest rates. The given measures would be applied for the next regulatory period of five years. The parameters will be enforced for gas and electricity networks in 2018 and 2019 respectively.

Driven by the low-rate environment, the regulator has applied a 200-basis-point (2 percent) decrease to the Return on Equity (ROE), which determines the tariffs linked to distribution and transmission networks. The regulated tariffs have been reduced to 6.91 percent ROE for new investments and 5.12 percent for existing grids reduced from 9.05 percent and 7.14 percent respectively)[527]. The level of the ROE determined by the Federal Network Agency is based on the 10-year average risk-free rate plus a risk premium: the base interest rate has been cut to 2.49 percent (from 3.8 previously) and the risk premium set at 3.15 percent (down from 3.59 previously). Similar downward revisions were performed in Italy and the U.K. in 2015, being enforced from 2016 onwards.

As many nuclear operators have network assets, a lower interest rate environment reduces grid revenues, as a lower return is expected on regulated assets, adding pressure to contracting earnings on the generation side.

Higher Provision Requirements

The current value of a future amount of money given a specified rate of return is called its present value. As a result, future cash flows are discounted at a specified rate: the higher the discount rate, the lower the present value of future cash flows. Conversely, the lower the discount rate, the higher the provisions should be. The discount-rate method is required to calculate future obligations, used to determine such long-term commitments as pensions and nuclear decommissioning or waste-management provisions.

ENGIE's nuclear subsidiaries in Belgium (Electrabel and Synatom) received on 12 December 2016 the revaluation for Belgian nuclear provisions from the Commission for Nuclear Provisions (CNP). As a result, the discount rate has been revised downwards from 4.8 percent to 3.5 percent, with an unchanged inflation rate at 2 percent[528]. This implies that the company's €8.4bn (US$9.1bn) nuclear provisions rose by 21.4 percent or €1.8bn (US$1.95bn).

Similarly, EDF had to apply higher provisions on the nuclear side from a 0.3 percentage point reduction in the discount rate to 4.2 percent, increasing provisions by €1,342m (US$1,447m) and €680m (US$733m) in financial expenses[529]. Due to the prolonged lower-interest-rate environment, the group has estimated that the discount rate for nuclear provisions will be reduced to 4.1 percent in 2017 (+€735m or +US$793m in provisions) and to 3.9 percent in 2018 (+€1,470m or +US$1,585m in provisions).[530]

RWE has agreed to transfer to the nuclear energy fund the €6.8bn (US$7.33bn) it is liable for, taking its €5bn (US$5.4bn) base amount and a €1.8bn (US$1.94bn) risk premium.[531] The transfer was performed in July 2017 for the full amount. Following this, and taking into account that

527 - Bundesnetzagentur, "Bundesnetzagentur sets return on equity for electricity and gas networks", Press Release, 12 October 2016, see https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2016/161012_EK_Zins.html, accessed 24 June 2017.

528 - ENGIE, "Financial information—Triennial revisions of provisions for Belgian nuclear power plants", 13 December 2016, see https://www.engie.com/wp-content/uploads/2016/12/financial-information_nuclear-provisions_fv.pdf, accessed 24 June 2017.

529 - EDF, "Consolidated Financial Statements at 31 December 2016", 13 February 2017.

530 - EDF, "Annual Results 2016", Presentation, 14 February 2016.

531 - RWE, "RWE Annual Report 2016", 14 March 2017.

there is a lower maturity for the residual provisions (below 10 years), the calculation of the discount rate changed to follow market rates and inflation levels. Hence, the residual provisions (after the transfer to the nuclear fund) increased by €0.9bn (US$0.97bn) or +18.7 percent to €5.7bn (US$6.15bn).

E.ON has accepted the payment of €10.2bn (US$11bn) to the nuclear fund. This includes €7.8bn (US$8.4bn) in provisions, a €2bn (US$2.2bn) premium, €200m (US$216m) in interest costs and €200m (US$216m) in minority interests held in a nuclear power plant with RWE.[532] The base amount will be paid through liquidity on its balance sheet and will also use debt with up to €3bn (US$3.2bn) in bonds and commercial paper. In line with RWE, the group had to change the method for the discount rate on the remaining provisions. The method is based on risk-free rates and has a real discount rate of -0.9 percent, which generated an increase on E.ON's remaining provisions of €1.5bn (US$1.6bn). The nuclear provisions will have quarterly fluctuations, as pension ones do. Moreover, the group has increased the annual depreciation over the remaining life of the nuclear assets.

Table 8 | Nuclear Operators' Provisions

Nuclear Operators' Provisions							
Company	**Method Used**	**Nb of Reactors** (majority owned)	**Total Nuclear attr. Capacity** (MW)	**Total Nuclear Provisions** ($m)	**Provisions per Reactor** ($m)	**Provisions per installed MW** ($m)	**Equity 2016 - net of hybrids** ($m)
EDF	Private Funding	73	74 883,0	50 235,1	688,2	0,67	26 290,4
RWE	Private Funding	5	3 926,0	13 714,9	2 743,0	3,49	2 974,3
E.ON (+ Uniper)	Private Funding	6	8 555,2	23 088,2	3 848,0	2,70	- 1 139,4
Fortum	Gover. Fund	2	1 020,0	1 181,5	590,8	1,16	14 535,7
Engie (ex GDF)	Private Funding	7	5 937,9	13 083,1	1 869,0	2,20	42 744,2
Kepco	Private Funding	25	23 116,0	11 446,00	457,8	0,50	61 807,0
Exelon	Private Funding	23	22 000,0	21 196,0	921,6	0,96	25 837,0

Sources: Companies' Annual Reports for 2016

The effect from a lower-rate environment has been less dramatic in France than in other countries, because in March 2015, the French government decided to review the discount method—calculation of the ceiling allowed for the discount rate applied—increasing it from the 4-year to 10-year average of the French 30-year rate (TEC 30yr), plus 100 basis points[533]. This change reduced the short-term impact for movements in the discount rate, but the variations will remain for a longer-term horizon.[534]

Higher provision requirements negatively impact the balance sheet and the profit & loss statement, but not the cash flows. The balance sheet is affected, as higher provisions imply that a company would have to reserve additional funds for future expected costs. The increase in provisions would hurt equity levels as the additional funding would have to come from the reserved capital. However, over time, the provisions should be covered by assets (financial assets that can provide a rate of return close to the discount level used).

532 - E.ON, "Annual Report 2016", 15 March 2017.

533 - EDF group, "Reference Document—2015 Annual financial report", 29 April 2016.

534 - EDF, "Consolidated Financial Statements at 31 December 2016", 13 February 2016.

On the profit & loss statement, a negative one-off would be reported as a financial cost due to an increase in nuclear provisions, decreasing the earnings of the company in the given year. The movement is booked under net financial expenses, reducing the firm's profit before taxes. Nonetheless, given that this is not a recurring issue, it is not linked to operational performance, and the variations are not included under the adjusted results.

On the cash-flow side, no movements are recorded, as the cash does not leave the company until the costs have been incurred or a transfer is needed. As a result, higher nuclear provisions from lower discount rates reduce the reported net profit and the equity levels, but have no effect on the adjusted profit or the cash flows. Moreover, the higher the nuclear provisions already booked, the greater the effects of discount rate movements both on the balance sheet and reported net profit. Hence in 2016, the increase of nuclear provisions hurt both the equity level and reported net profit of nuclear operators.

Higher Pension Deficits

Following the same discount rate method, pension provisions are calculated as the difference between future pension obligations and the amount of assets to cover them (funded pension scheme). The greater the difference is, the greater the deficit and the higher the provisions should be, which implies that the pension plan is underfunded (the money to cover current and future retirements is not yet available).

EDF, E.ON, and RWE have more exposure to a lower interest rate environment due to their high pension deficits. As a result, in 2016, RWE had an increase in pension provisions of €1.9bn (US$2.05bn) due to low interest rates, raising the group's net debt.[535]

E.ON's similar effect in 2016 on pension provisions, under Germany's rate cut to 1.4 percent and the U.K.'s to 2.9 percent, generated a €2.3bn (US$2.5bn) increase in provisions.[536] EDF similarly revised downwards the discount rate applied both in France (1.9 percent) and in the U.K. (2.76 percent), raising pension obligations by €2.04bn (US$2.2bn).[537]

The increase in pension provisions generates a similar effect as nuclear ones, whereby higher provision levels from a decrease in the discount rate weaken the balance sheet through lower equity levels and a lower reported net profit. The greater pension deficit a company has, the higher its sensitivity to discount rate movements, and the greater the impact on both the balance sheet and reported net income. However, in line with nuclear provision movements, higher pension provisions would have no impact on adjusted net profit or cash flows. As a result, the increased pension provisions seen in 2016 have negatively impacted the equity levels and reported net profits of the companies.

535 - RWE, "RWE Annual Report 2016", 14 March 2017.

536 - E.ON, "Annual Report 2016", 15 March 2017.

537 - EDF, "Consolidated Financial Statements at 31 December 2016", 13 February 2016.

COMPANY STRATEGY, SHARE PRICE BEHAVIOR, AND RESULTS

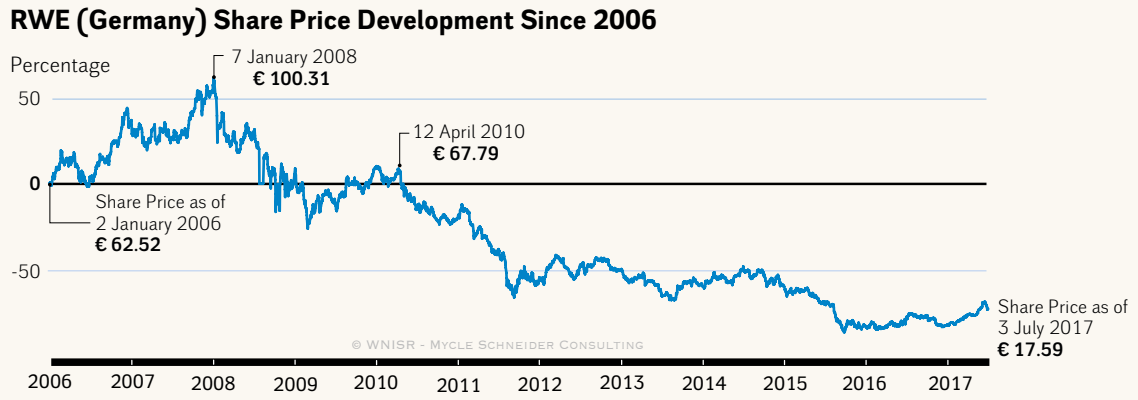
RWE (Germany)

For 2016, Rheinisch-Westfälisches Elektrizitätswerk or RWE group published financial results with revenues falling 5.7 percent, while adjusted EBITDA fell by 23 percent. Net income finished in the red once again at –€5.7bn (–US$6.15bn) as the group booked €4.3bn (US$4.6bn) of impairments in its power portfolio, in addition to €1.8bn (US$1.94bn) for the nuclear energy fund 35 percent risk premium, and €0.8bn (US$0.86m) from mark-to-market of derivatives (valuing assets at quoted prices). Adjusted for this, net income fell by 30 percent to €777m (US$838m).[538]

In line with 2015, the company has decided to pay no dividend for its common shares and €0.13 (US$0.14)/share on preferred shares. Net debt decreased by 10.8 percent, helped by the positive cash generated from the placement of Innogy shares through the spin-off.

RWE's share price peaked in January 2008 at €100 and stood at €18 per share by early July 2017, an 82-percent decline. However, RWE is clearly on its way to recovery as share value hit the bottom in December 2016 at €11.40 (see Figure 28).

Figure 28 | RWE Share Price Development Since 2006



Source: Yahoo Finance, August 2017

The group showed a strong operational performance in 2016 on its conventional generation business as it has achieved an increase in power generation of 1.4 percent.[539] Despite the higher load factor, the low-price environment continues to hurt the group from lower generation margins, decreasing the division earnings by 36.3 percent. Innogy's earnings (renewable and networks subsidiary) decreased by 7 percent. The trading division's earnings finished in negative territory, despite the settlement achieved with Russia's Gazprom for gas deliveries.

RWE's objective on nuclear provisions is to keep enough financial assets to cover its medium- and long-term obligations (nuclear, mining/lignite, and pensions) 100 percent for the next five

538 - RWE, "RWE Annual Report 2016", 14 March 2017.

539 - RWE, "Annual Report 2016", 14 March 2017.

years and 75 percent for the next ten years. Nuclear provisions will be recalculated like pension ones on a quarterly basis, where the movements will be registered on the Profit & Loss (P&L) statement.

Following the Innogy spin-off and the current financial structure of the company, with all the senior debt being transferred to Innogy, but still being liable for its long-term provisions, RWE can be seen as a financial portfolio with no debt, which has "volatile" cash flows from trading and generation, but where its financial investments and received dividends should allow both its provision levels and cash payments to be covered.

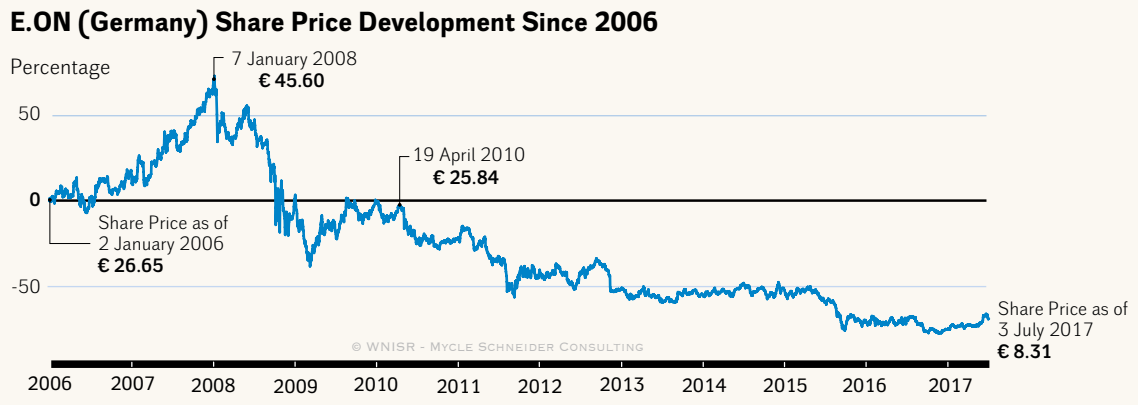
The important news came from 2017 guidance with topline earnings expecting to have a flat to 5 percent increase, implying that the downward trend may be over and the strategy is finally paying off. Moreover, there is a strong net income improvement expected, implying a 25 to 62 percent increase in net profit.[540] The group will reinstate a dividend payment of €0.50 (US$0.54) per common share in 2017. It seems as if the worst days are over and the separation strategy with the creation of Innogy as a growth driver is paying off.

E.ON (Germany)

In 2016, revenues fell by 11 percent, with adjusted operating profit and net income decreasing by 13 percent and 16 percent respectively. On a reported basis, the group booked a combined net income loss of €16bn (US$17.3bn), of which €8.4bn (US$9.1bn) is attributable to E.ON's shareholder, driven by close to €11bn (US$11.9bn) in impairment charges. The dividend proposed for 2016 is €0.21 (US$0.23)/share.[541]

The equity attributable to E.ON shareholders finished in negative territory at -€1.05bn (-US$1.13bn), while the net debt of the group reached €26.3bn (US$28.4bn), confirming the firm's weak balance sheet.[542] E.ON shares hit the bottom in November 2016 at just over €6 per share, down from an all-time high in January 2008 at €45.60 (–87 percent). At €8.31 per share as of early July 2017, the title has made up some lost territory. (See Figure 29)

Figure 29 | E.ON Share Price Development Since 2006



Source: Yahoo Finance, August 2017

540 - RWE, "RWE 2016 Results Presentation", 14 March 2017.

541 - E.ON, "Annual Report 2016", 15 March 2017.

542 - E.ON, "E.ON 2016 Results Presentation", 15 March 2017.

Following its spin-off strategy, E.ON has achieved an improvement in exposure to market-driven earnings, as 63.3 percent of its operating profit now comes from regulated and semi-regulated assets. Energy networks, had an 8 percent reduction in adjusted operating profit. The retail business (Customer Solutions) had relatively stable operating profit (+1 percent). The renewable division's operating profit improved by 10 percent.

German nuclear (Preussen Elektra)'s operating profit has been more resilient than expected as its operating profit decreased by 2 percent. However, profits should continue to deteriorate as production for the coming years is hedged at a lower price: 100 percent hedged for 2017 at €32/MW (US$34.5/MW), 94 percent in 2018 at €27/MW (US$29.1/MW), and 19 percent in 2019 at €25/MW (US$27/MW).[543] At constant production levels, the coverage would imply a decrease in revenues of 13.5 percent for 2017, an additional 21.7 percent contraction in 2018, and a further 7.4 percent decrease in 2019.

But not all is so bleak on this front, as the transfer of the storage-related provisions to the nuclear waste fund would allow the company to stop interest payments on €7.8bn (US$8.4bn) of provisions from 1 January 2017, having a positive net income effect of €200–250m (US$216m–270m) per year. Moreover, the change in the discounting method for the remaining provisions would also reduce the accretion charges by €350m (US$377m). Hence, the combined financial effect from 2017 onwards is expected to be improved by roughly €400m (US$431m), partially offset by higher depreciation expenses.

Over the medium term, the company is targeting to reduce net debt, reduce its investment budget by 20 percent, could sell all of its remaining Uniper shares, divest additional assets, and perhaps pay a scrip dividend with newly issued shares. As for the objective expectations, Earnings per Share (EPS) have been lowered as they are now expected to be relatively flat.[544] This downward revision is driven by the negative EPS-diluting effects on capital measures to pay the nuclear premium for the sovereign fund. A flat EPS is expected until 2019, meaning E.ON has turned into a no-growth story for the coming years.

AREVA's shares peaked in June 2008 at just under €80 per share and stood at below €4.50 in early July 2017 (–94 percent)

AREVA (France)

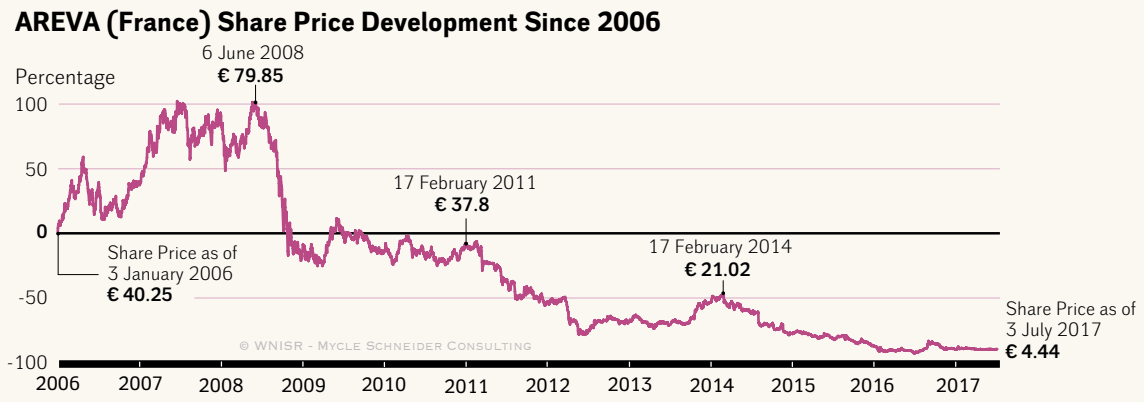
For 2016, the company reported a net loss of €665m (US$717m), reduced from €2.04bn (US$2.2bn) in 2015, and €4.83bn (US$5.2bn) in 2014[545]. Cash flows continue to be in negative territory, with a net cash flow from operations at –€621m (-US$661m). In recent years, the group had to revise downwards its expectations for the construction of third-generation EPR reactors, driving massive depreciations, added to constant delays on the EPRs at Olkiluoto in Finland, Flamanville in France, and Taishan in China. In addition, AREVA had to cope with a

543 - E.ON, "Annual Report 2016", 15 March 2017.

544 - E.ON, "E.ON 2016 Results Presentation", 15 March 2017.

545 - AREVA, "2016 Annual Results", 1 March 2017.

Figure 30 | AREVA Share Price Development Since 2006



Source: Investing.com, August 2017

vast quality-control problem at its Creusot Forge site, where inspectors identified irregularities that have apparently lasted for decades (see Focus France).

AREVA's shares peaked in June 2008 at just under €80 per share and stood at below €4.50 in early July 2017 (–94 percent ; see Figure 30). The French government bailout announcements did not fundamentally change investors' opinions.

The group has been obliged to split in two to get the much-needed financing, with the nuclear reactor division (AREVA NP) being sold to EDF (51–75 percent) for a €2.5bn (US$2.7bn) price, with a possible earn-out of €350m (US$377m), if results meet expectations. AREVA SA will keep the fuel fabrication and spent fuel reprocessing operations. On top of this, a €5bn (US$5.4bn) capital increase will be performed, whereby the French government will inject €4.5bn (US$4.9bn), potentially letting some international investors such as Japan Nuclear Fuel Limited (JNFL) and Mitsubishi Heavy Industries (MHI) get in with the remaining €500m (US$534m)[546].

EDF (France)

Électricité de France (EDF) had a volatile year. In addition to multiple strategic decisions taken in 2016, the company suffered from the decreasing profitability on its nuclear assets due to a low-price environment. This added to increased competition in its two main markets (France and U.K.) created not only erosion of its market share but also dwindling earnings and profitability.

EDF issued two different profit warnings in 2016. The negative impact from lower power prices had been accentuated by a reduced nuclear production, as the nuclear regulator (ASN) demanded additional tests on nuclear reactors affected by the AREVA manufacturing anomalies. Moreover, in 2016, EDF issued its final investment decision on the construction on the £19.6bn (US$25.4bn)[547] EPR project in the U.K., which has been validated by the U.K. government,

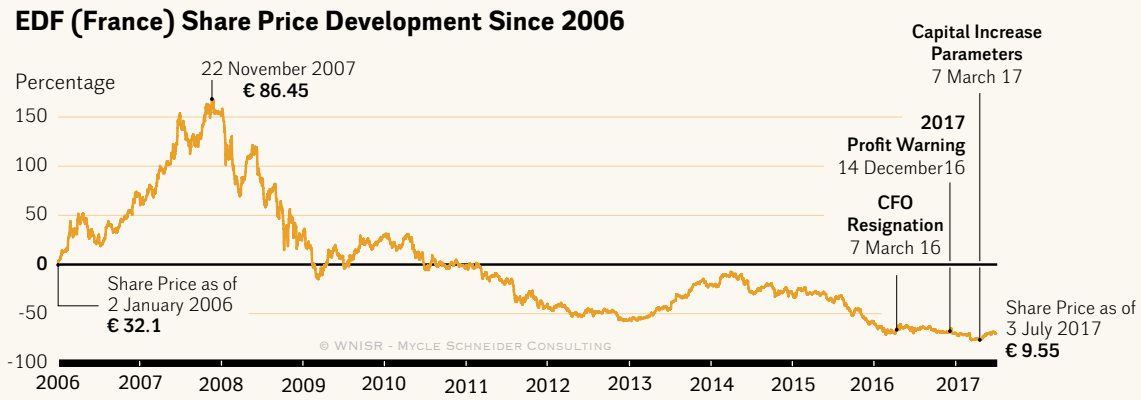
546 - Geert de Clercq, "UPDATE 2-Japanese firms takes 10 percent stake in new AREVA, capital hike approved", *Reuters*, 3 February 2017, see http://www.reuters.com/article/areva-restructuring-idUSL5N1FO1G1, accessed 24 June 2017.

547 - Latest cost assessment according to EDF, "Clarifications on Hinkley Point C project", Press Release, 3 July 2017.

including Chinese investors (CGN and CNNC) in its capital structure.[548] The group has also found an agreement on the purchase of AREVA NP for an agreed price of €2.5bn (US$2.7bn).

Driven by its financial difficulties, weak balance sheet, and multiple capital-intensive projects and ambitions, EDF has issued a €4bn (US$4.3bn) capital increase at €6.35 (US$6.85)/share, with 634.71m new shares created for this purpose. The subscription price has been set with a 34 percent discount to the closing level on 2 March 2017 and 29 percent on the theoretical value of the share ex-right, i.e. €8.92 (US$9.62)/share.[549] The discount provided was required as the company needs to get €1bn (US$1.08bn) of fresh capital from private investors (representing 25 percent of the total objective, but targeting 15 percent of the shareholders). The French government participated with a €3bn (US$3.23bn) envelope (75 percent), but has an 85 percent stake in the company. As a result, the public stakeholder disposed 10 percent of its share rights at €0.40 (US$0.43)/right, implying a 40 percent discount on the ex-right values and creating a technical 8 percent decrease on the stock price. EDF's share price dropped 22 percent in the week following the launch of the capital increase on 7 March 2017. EDF shares plunged by 89 percent since they peaked in November 2007 (value as of 3 July 2017; see Figure 31).

Figure 31 | EDF Share Price Development Since 2006



Source: Yahoo Finance, August 2017

Moreover, the company substantially revised downwards its 2017 earnings objectives. As the company normally starts the year with its production fully hedged, it implies a lower hedging price, in addition to a lower nuclear production and increased competition in its main markets. The group expects a rebound in 2018 earnings, as forward prices increased across Europe at the end of 2016 and production is expected to return to normal levels.

The group's 2016 financial performance was heavily affected by the French generation and supply business as it had a 11.2 percent contraction and represents 37.5 percent of the group's earnings.[550] The division suffered from lower nuclear generation, market share losses, and the

548 - EDF, "Hinkley Point C: EDF is delighted by the British Government's decision", Press Release, 15 September 2016, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/hinkley-point-c-edf-is-delighted-by-the-british-government-s-decision, accessed 24 June 2017.

549 - EDF, "EDF announces the launch and the terms of a share capital increase with preferential subscription rights for an amount of approximately 4 billion euros", Press Release, 7 March 2017, see https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-announces-the-launch-and-the-terms-of-a-share-capital-increase-with-preferential-subscription-rights-for-an-amount-of-approximately-4-billion-euros, accessed 24 June 2017.

550 - EDF, "2016 Annual Results", 14 February 2017.

negative effects on market purchases: the company had to buy electricity at higher prices in the fourth quarter of 2016 to cover its electricity needs as production did not cover retail demand.

The U.K. division showed a 23.6 percent contraction in earnings, despite the 7.4 percent increase in nuclear production, mainly driven by lower wholesale and retail prices, added to the erosion in market share and negative foreign exchange effects. The best-performing division was trading, with a 56.8 percent increase in profit, mainly due to the high volatility in power and gas markets. The renewable energy business had a positive year due to commissioned capacity and a strong Development and Sale of Structured Assets (DSSA), which generated a combined earnings growth of 6.1 percent. However, the renewables and trading performances achieved in 2016 are not expected to be replicated in 2017.[551]

EDF decided in 2016 to apply an extension of the accounting depreciation of its 900 MW nuclear fleet from 40 to 50 years reducing the depreciation charges of the company by €1bn (US$1.08bn) or 11.6 percent, generating a positive effect on net income of €700m (US$754m).[552] This has also created a €2bn (US$2.2bn) decrease in nuclear provisions and a €1.7bn (US$1.83bn) contraction in the scope of dedicated assets, used to cover the expected costs for nuclear decommissioning. This decision has been taken just before the ramp-up of its life-extension program (Grand Carénage) with an investment envelope of €50bn+. Nonetheless, the life extension of nuclear assets in France has to be validated by the nuclear regulator, with no decision expected before 2018.

2017 will be a decisive year for the company

The group's operating income shrank by 3.4 percent, driven by earnings contraction plus higher provisions on the nuclear side, offsetting the positive effect from an increase in the accounting depreciation.[553] Reported net debt remained stable at €37.4bn (US$40.3bn), which is a positive, although operating cash flows decreased by 12.6 percent year-on-year. Free cash flow continues to be on the negative side, but has eased with the help of the share dividend payment. The company expects to be cash flow positive by 2018.

Looking forward, 2017 will be a decisive year for the company with the purchase of AREVA NP, expected results from the regulator on the Flamanville-3 EPR reactor vessel, added to multiple asset disposals and the end of the capital measures to ramp-up its balance sheet. The capital increase should allow the company to partially finance its multiple investment projects, but in a low-price environment and earnings-contracting trend, EDF still has a bumpy road ahead. The high reliance on nuclear does not support earnings in the short term. Asset disposals and scrip dividends are needed to cover cash flow deficits and high investment requirements. If everything happens according to the company's expectations, 2017 may be the bottom on the earnings side; however, there are too many unknowns to see a clear path.

551 - EDF, "2016 Group Annual Results", Presentation, 14 February 2017.

552 - EDF, "2016 Half-year Results", Presentation, 29 July 2016.

553 - EDF, "2016 Annual Results", 14 February 2017.

ENGIE (France)

The restart of the Belgium nuclear assets at the end of 2015, following the approval on the life extension and tax agreements, helped the group's 2016 results by making a full-year earnings contribution. Nonetheless, their exposure to market prices across Oil & Gas, Liquefied Natural Gas (LNG), and power prices negatively impacted earnings, despite the fact that now close to 75 percent of the group's profits come from regulated or semi-regulated assets.

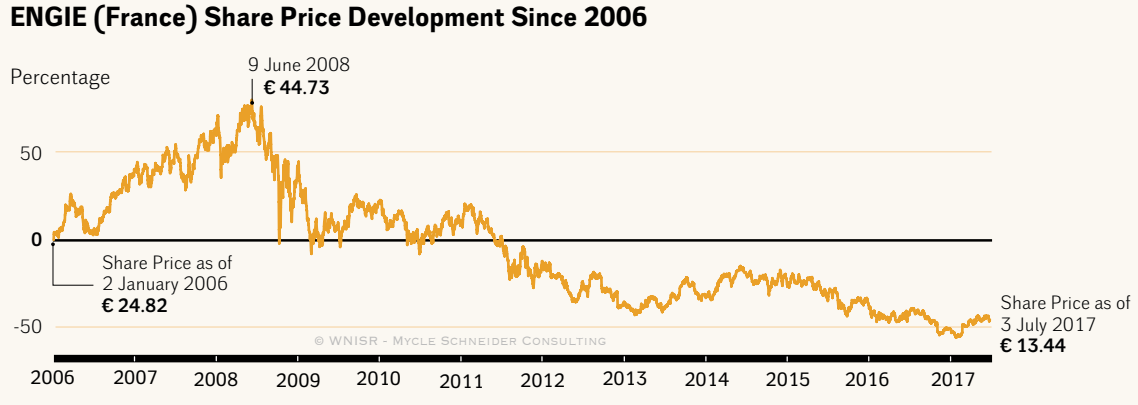
For 2016, ENGIE presented financial results with revenues falling 4.6 percent, earnings down 5.2 percent, and adjusted net income down 4.3 percent. On a reported basis, the group finished once again in negative territory with reported net income at –€0.4bn (–US$0.43bn) driven by €3.8bn (US$4.1bn) of impairments in power plants, nuclear assets and merchant activities.[554]

The infrastructure segment continues to be the main profit driver as it reached a 2.3 percent increase and represents 32.4 percent of the overall profits. Latin America had an 8.5 percent increase in earnings, with a similar increase in Europe (+9.5 percent). Belgium's profits rose sharply (+69.5 percent) mainly due to the restart of three nuclear reactors in the country. In France, the group benefited from the positive weather effects on gas and electricity volumes to reach a 3.2 percent increase in profits, offsetting lower prices to both consumers and its power generation assets.

On the other hand, the LNG business has been harmed by the reduction in supply conditions, and lower geographical spreads on LNG prices, pushing profits down by 98.3 percent. Following this, the E&P business showed a 20.9 percent earnings decrease due to lower prices in both oil and gas and a 4.7 percent decrease in production.

Share prices hit the bottom in February 2017 at just over €11 per share, 75 percent down from its historic peak in June 2008 , but has been slowly recovering since (see Figure 32).

Figure 32 | ENGIE Share Price Development Since 2006



Source: Investing.com, August 2017

It seems that a better horizon is in sight, as the continued efforts of the company in its cost-cutting program and a lower exposure to commodity prices should start to pay off. A more dynamic profile seems to be gaining momentum as it should show organic growth across all

554 - ENGIE, "2016 Annual Results", 2 March 2017.

business segments except North America (due to disposals).[555] Thus 2016 may be seen as the bottom in terms of earnings as the company expects 2017 growth despite the drag of asset disposals. The recovery is a positive and one year earlier than expected. It seems that the strategy to go towards a more network oriented model would start to bear fruit.

In line with this, on 4 April 2017, ENGIE decided to step away from the NuGen nuclear project in the U.K. by transferring its 40-percent stake to Toshiba for ¥15.3bn (US$138.5m).[556] The company decided to exercise its contractual rights on the project, which plans to build three Westinghouse AP1000 reactors. ENGIE estimates that NuGen has significant challenges, whereby the filing of Chapter 11 bankruptcy protection by Westinghouse was an event of default and allows the company the option to sell its stake to Toshiba, making Toshiba the sole stake owner of the uncertain project.

ENEL (Italy)

At the end of 2015, ENEL agreed with EPH ("Energeticky a Prumyslovy Holding", a privately-held Czech-Slovak holding company) to sell its 66 percent stake in its Slovakian assets for €750m (US$799m). The sale will be executed through the creation and transfer of ENEL's stake in Slovenské Elektrarne to a newly-established company ("HoldCo"), with the later transfer of the HoldCo to EPH.[557] The disposal agreement would be divided into two stages: 1) A €375m with the transfer of half of the HoldCo's share capital (50 percent) at signing, and 2) the transfer of the remaining shares of the holding company and the remaining €375m (US$399.5m) payment subject to the completion and operation of two nuclear reactors under construction at Mochovce in Slovakia since 1985 (now expected to be completed in late 2018 and 2019 respectively), added to an adjustment mechanism.

The adjustment mechanism would be calculated at the time of the reactors' completion and would include the net financial position, developments in energy prices in the Slovak market, operating efficiency levels, and the enterprise value of the company with the completion of the two reactors. In addition to this, ENEL has signed a Memorandum of Understanding with the Slovak Ministry of the Economy, validating the agreement.[558] This has allowed the company to deconsolidate the assets from its accounts in 2016, reducing their nuclear capacity and the provisions for those.

On the financial side, the Italian group has presented its 2016 results with revenues decreasing 6.7 percent, EBITDA in line with last year's level, but net income increasing 17 percent driven by lower income taxes and minority interests, offsetting the 13 percent increase in interest expenses.[559] On recurrent earnings adjusted for one-offs, EBITDA increased by 1 percent

555 - Ibidem.

556 - ENGIE, "FY2016 Results Presentation", 4 April 2017.

557 - ENEL, "Enel signs agreement with EPH for sale of stake in Slovenské Elektrárne", Press Release, 18 December 2015, see https://www.enel.com/content/dam/enel-com/sustainability/ENEL SIGNS AGREEMENT WITH EPH FOR SALE OF STAKE IN SE.pdf, accessed 25 June 2017.

558 - ENEL, "Enel signs agreement on Enel Produzion's stake in Slovenské Elektrárne with Slovak Economy Ministry", 21 December 2015, see https://www.enel.com/en/media/press/d201512-enel-signs-agreement-on-enel-produziones-stake-in-slovensk-elektrrne-with-slovak-economy-ministry-.html, accessed 25 June 2017.

559 - ENEL, "Enel's net income up 17% in 2016", 17 March 2017, see https://www.enel.com/content/dam/enel-common/press/en/1666941-1_PDF-1.pdf, accessed 25 June 2017.

and net income by 12.3 percent. A dividend of €0.18/share will be paid. The strong results at the net income level has allowed the company to further strengthen its balance sheet as it has increased by 7.5 percent its equity levels. The relatively flat net debt has been mainly due to the 21.7 percent decrease in the cash reserve, as the company has obtained a 3 percent decrease in gross debt. Hence, the financial structure has strengthened as the company has reduced its gearing (net debt/equity).

The company expects for 2017 a further growth in profits with EBITDA reaching +2 percent, net income +10 percent, and a minimum dividend payment of €0.21/share representing a 16 percent increase with a 65 percent payout ratio (US$0.22/share).[560] The group proposed the buy-back of 500 million shares, or a total of €2bn (US$2.12bn) in addition to a similar amount for a minority buy-out. ENEL's objectives for 2017 onwards are reassuring with higher profits both at the top and bottom line levels, added to a greater return expected for shareholders. The group has a well-diversified generation portfolio, a strong presence in developing economies with demand growth, and a resilient positioning within the network business. Investment towards growth has been revised upwards, towards projects with a low risk profile with a commissioning expected in less than three years.

TEPCO (Japan)

The Japanese Ministry of Economy, Trade, and Industry (METI) on the updated estimates provided on 9 December 2016, raised the expected budget for the decommissioning and decontamination of Fukushima, which will cost twice as much as originally expected. The total costs are expected now at ¥22 trillion (US$220bn).[561] According to the ministry, the cost of decommissioning the damaged reactors will increase to ¥8 trillion (US$72bn), while the compensation will rise to ¥8 trillion (US$72bn), which makes TEPCO responsible for ¥16 trillion (US$144bn) for the clean-up process. The company's shares fell close to 3 percent after the new estimates were provided. TEPCO's share value had been wiped out after the 3/11 events. While much of the decline from the February 2007 peak value had already happened prior to 3/11, in early July 2017, barely more than one tenth of that share price was left (see Figure 33).

Moreover, in March 2017 the district court in Maebashi (North of Tokyo), ruled in favor of evacuees from the Fukushima Daiichi plant seeking damages for being removed of their home due to radiation dangers.[562] It is the first time a court has recognized that the Japanese government has liability over the accident, stating that both TEPCO and the government are liable for negligence, making it necessary to award compensation damages to the victims.

For the company to be able to cover the increased costs, the Japanese government increased the credit line from ¥9 to ¥13.5 trillion (from US$82 to US$123bn).[563] Driven by higher expec-

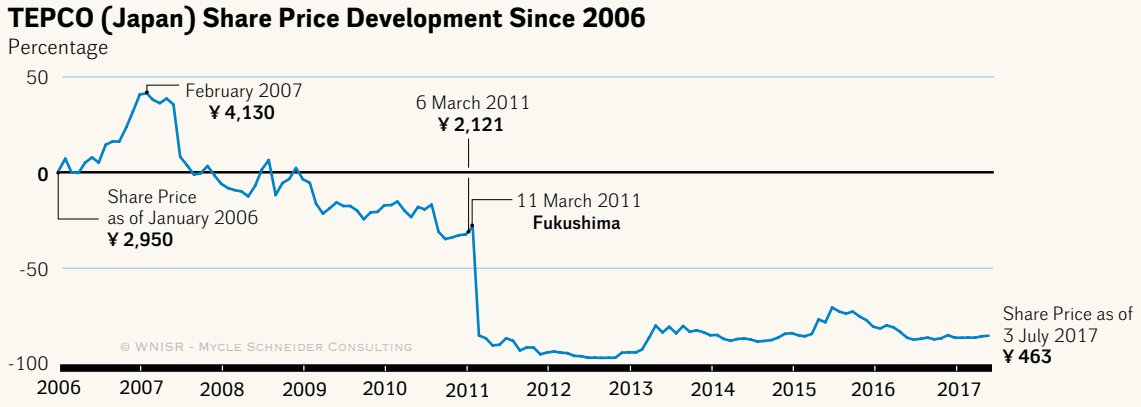
560 - ENEL, "FY2016 Consolidated Results", Presentation, 17 March 2017, see https://www.enel.com/content/dam/enel-com/investors/Enel_FY2016-results.pdf, accessed 25 June 2017.

561 - Yuka Obayashi, "Japan urges bold reform for Tepco as Fukushima costs soar", *Reuters*, 20 December 2016, see http://www.reuters.com/article/us-tepco-fukushima-reform-idUSKBN14911V, accessed 25 June 2017.

562 - Osamu Tsukimori, "Japan court rules government liable over Fukushima", *Reuters*, 17 March 2017, see http://in.reuters.com/article/tepco-fukushima-liability-idINKBN16O0S8, accessed 25 June 2017.

563 - Stephen Stapczynski, "Fukushima's $70 Billion Cleanup Leaves Foreign Firms in Cold", *Bloomberg*, Updated 28 December 2016, see https://www.bloomberg.com/news/articles/2016-12-20/fukushima-s-70-billion-cleanup-leaves-foreign-firms-in-the-cold, accessed 25 June 2017.

Figure 33 | TEPCO Share Price Development Since 2006



Source: Investing.com, August 2017

ted costs and compensation damages, the company, which was once Asia's largest utility and was essentially nationalized after the 3/11 accidents, has decided to tap debt markets for the first time since then, as the company mandated six investment banks to sell bonds worth ¥100bn (US$890m).[564] The objective is to re-enter the bond market in 2017 and restart regular bond issuance in order to help to pay the compensation costs in addition to the credit line provided by the government.

On its financial results, in 2016 (third quarter) TEPCO had a 13.8 percent contraction in operating revenues to ¥3.88 trillion (US$35.3bn), decreasing for a second consecutive year due to a decrease in the price of electricity from fuel cost adjustments.[565] Despite this, cost decreases from lower fuel expenses and cost optimization measures have allowed the company to post profits in the positive side for a second year with net income reaching ¥306bn (US$2.8bn), but representing a 29.8 percent decrease from a year earlier. Up to date, the cumulative financial impact of the 3/11 disaster for the company has been revised upwards from ¥6.35 to 6.66 trillion (from US$57.9bn to 60.7bn).[566]

Toshiba (Japan)

Toshiba had major hiccups with its subsidiary Westinghouse after the group took over CB&I Stone and Webster in 2015 to resolve disputes related to cost increases from changes in NRC's regulation. Following this, the company became fully liable for any delays and cost overruns on two different nuclear projects under construction in the U.S., making the group to book close to US$6.8bn of impairments in the first half of 2016.

On 29 March 2017, the company decided that Westinghouse would file for bankruptcy protection (chapter 11) in the U.S. This allows Toshiba to deconsolidate Westinghouse from its accounts, but would force the company to book losses close to US$9bn. After the decision and the multiple scandals concerning the company's management policies, shareholders have

564 - Taiga Uranaka, "Tepco hires banks for first bond sale since Fukushima", *Reuters*, 9 February 2017, see http://www.reuters.com/article/tepco-bonds-sale-idUSL4N1FU2PK, accessed 25 June 2017.

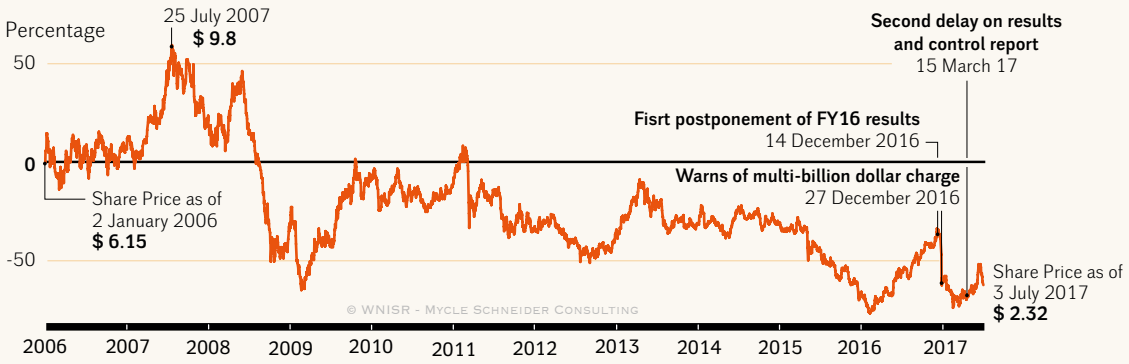
565 - Tepco, "FY16 Third Quarter Financial Results", Press Release, 31 January 2017, see https://www4.tepco.co.jp/en/press/corp-com/release/2017/1368651_10469.html, accessed 25 June 2017.

566 - Ibidem.

openly declared that they have doubts over any revival plan after the Westinghouse bankruptcy filing.[567]

On 11 April 2017, the company decided to publish its 9-month results without the signature of the auditors, as the auditors (PricewaterhouseCooper) have concerns that the previous accounting figures provided by Westinghouse are not proper.[568] Toshiba published without a signature after two previous postponements to avoid a further delay. With the publication, Toshiba raised a flag over its ability to continue as a going concern, driven their increasing losses and negative equity levels. Revenues decreased 4 percent to ¥3,847bn (US$33.2bn) and operating loss by 149 percent to ¥576.3bn (US$5bn), while net loss widened to ¥532.5bn (US$4.6bn) [569].

Figure 34 | Toshiba Share Price Development Since 2006



Source: Yahoo Finance, August 2017

Following Westinghouse-bankruptcy news, SCANA, which is developing two AP1000 reactors in South Carolina, decided to continue with the project through a transition and validation period. In March 2017, SCANA announced it would evaluate all options before giving a response to the regulator on the "most prudent path to follow".[570] On 31 July 2017, SCANA Corporation[571] and Santee Cooper (formally, the South Carolina Public Service Authority)[572] announced that they were halting construction. Southern Co. is facing a similar decision on two AP1000 reactors under construction at the Vogtle plant in Georgia (see United States Focus).

In order to cover some of the expected losses from the nuclear side, the Japanese group is divesting part or all the shares of its most profitable business: the memory chip unit. Moreover,

567 - Kana Inagaki, "Toshiba shareholders accuse group of 'chronic culture of lying'", *Financial Times*, 30 March 2017, see https://www.ft.com/content/1c3b9c9e-1529-11e7-b0c1-37e417ee6c76?mhq5j=e3, accessed 25 June 2017.

568 - Pavel Apeyev and Takako Taniguchi, "Toshiba warns of its ability to continue as going concern", *Bloomberg*, 11 April 2017, see https://www.bloomberg.com/news/articles/2017-04-11/toshiba-reports-earnings-without-auditor-s-approval-after-delays, accessed 25 June 2017.

569 - Toshiba, "Toshiba announces consolidated results for the first nine months, ending March 2017", 11 April 2017.

570 - Kevin Marsh, Jimmy Addison and Steve Byrne, "New Nuclear Construction Analyst", SCANA, presented at the Nuclear Project Discussion, 29 March 2017, see https://www.scana.com/docs/librariesprovider15/pdfs/presentations-and-transcripts/03292017-nnd-call-presentation-v14.pdf?sfvrsn=2, accessed 25 June 2017.

571 - SCANA, "South Carolina Electric & Gas Company to Cease Construction and Will File Plan of Abandonment of the New Nuclear Project", 31 July 2017, see https://www.scana.com/docs/librariesprovider15/pdfs/press-releases/07312017-sce-amp-g-to-cease-construction-and-will-pursue-abandonment-of-the-new-nuclear-project---scana-reaffirms-earnings-guidance.pdf, accessed 9 August 2017.

572 - Santee Cooper, "Santee Cooper suspends construction of V.C. Summer Units 2 and 3", 31 July 2017, see https://www.santeecooper.com/about-santee-cooper/news-releases/news-items/santee-cooper-suspends-construction-of-v.c.-summer-units-2-and-3.aspx, accessed 9 August 2017.

in a meeting with its creditors over a third extension waiver for breach of covenants on syndicated loans, the group has proposed some shares of its chip business as collateral to secure debt refinancing (rights to the assets to secure borrower's loan).

Going forward, the group is thinking about withdrawing from all new nuclear projects

Going forward, the group is thinking about withdrawing from all new nuclear projects , as it is no longer a major interest for the company, and it would like to sell all or a majority stake in the NuGen project where the company was expected to build three AP1000 reactors with a US$15-20bn investment envelope. On 30 March 2017, the Office of Nuclear Regulation (ONR) in the U.K. granted the AP1000 technology a generic license.[573] But then, on 4 April 2017, Toshiba was forced to buy ENGIE's 40 percent stake in the project as the Westinghouse bankruptcy can be considered as a default event, allowing the French group to exit the consortium and recover the ¥15.3bn (US$138.5m) investment already made.

KEPCO (South Korea)

The group currently has an installed nuclear capacity in South Korea of 23.1GW with 24 units operational. KEPCO expects to increase the number of operational nuclear units by an average of one per year for the 2018-2020 period, through the delivery of the UAE nuclear project with four APR1400 reactors. Moreover, the company expected to have six additional units operational by 2029. For this, the group has an average yearly investment envelope of KRW3500–5000 (US$3.11–4.44bn). However, the incoming government under President Moon has vowed to stop nuclear expansion and lifetime extension beyond 40 years (see South Korea Section).

On the financial side, in 2016, the company achieved an increase in revenues of 2.1 percent, driven by an increase of 2.0 percent in power sales and volumes, which is the main revenue generation of the company (represents 90.2 percent). With costs increasing only 1.2 percent (below revenue growth), the group achieved an increase in earnings of 5.8 percent. On a comparative basis, net income was lower in 2016 due to the positive one-off achieved in 2015 from land disposal profit of KRW6400bn (US$5.68bn); however, adjusted for this, the net profit of the group increased by 2.8 percent.[574]

KEPCO has continued to profit from its monopoly position in the regulated South Korean market environment. Unlike the other major international nuclear utilities that peaked prior to the 2008-09 economic crisis, achieved a record share price in August 2016. However, "higher fuel costs, effective tariff cuts in December, increased operating expenses, including environmental costs, and the temporary shutdown of the four reactors" seriously impacted the period starting with the last quarter of 2016.[575] By early July 2017, the share value had dropped by 37 percent (see Figure 35).

573 - ONR, "Design acceptance for the AP1000 reactor", U.K. Office of Nuclear Regulation, 30 March 2017, see http://news.onr.org.uk/2017/03/design-acceptance-for-the-ap1000-reactor/, accessed 25 June 2017.

574 - KEPCO, "Investor Presentation—March 2017", 2 February 2017.

575 - Moody's, "Moody's: KEPCO's 2016 results support credit quality", 7 February 2017, see https://www.moodys.com/research/Moodys-KEPCOs-2016-results-support-credit-quality--PR_361806, accessed 9 August 2017.

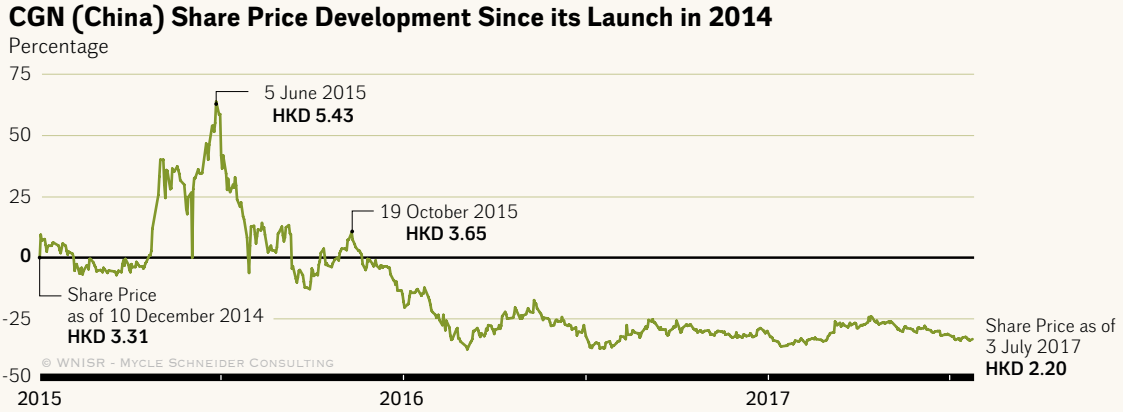
Figure 35 | Kepco Share Price Development Since 2006

Source: Yahoo Finance, August 2017

CGN (China)

In 2016, China General Nuclear Power Corporation (CGN) published an increase in revenues of 22.7 percent to reach RMB 32.89bn (US$4.94bn), mainly due to the improvement of sales of electricity from nuclear plants (+30.5 percent), offsetting the drop in revenue from construction contracts and design projects (–12.5 percent), technical and training services (–3 percent), and sales of equipment and other goods (–4.5 percent).[576] However, despite the increase in revenues, the direct profit before taxes dropped by 4.9 percent due to higher expenses, negative foreign exchange movements, and financial costs. The negative effect was partially offset by an increase share of results from associates and joint ventures, pushing earnings to drop 0.6 percent. Nonetheless, a 40.5 percent decrease on tax expenses from an increase in deferred taxes have pushed the net income of the company to increase 4.5 percent, reaching RMB 8.92bn ($1.34bn).[577]

Figure 36 | CGN Share Price Development Since its Launch in 2014



Source: Yahoo Finance, August 2017

CGN in 2016 benefited from the introduction into commercial operation of three nuclear reactors, which are majority owned (Yangjiang Unit 3, Fangchenggang Unit 1, and Fangchenggang

576 - CGN, "Annual Results Announcement for the year ended December 31, 2016", 15 March 2017.

577 - Ibidem.

Unit 2), added to one from associates (Hongyanhe Unit 4), and one from joint ventures (Ningde Unit 4), supporting revenues from higher electricity sales and a higher share of results from associates and joint ventures in 2016.

The share price of CGN has been under pressure over recent years as overcapacity, a higher share of renewable production, and increasing competition have been negatively impacting generators, despite the increase in electricity demand, which has slowed down significantly though. Moreover, the potential coming reform on tariffs for nuclear plants by the industry regulator to either decrease tariffs or free up some sales volumes and prices to competition, negatively weights in on CGN´s stock performance as investors prefer to avoid uncertainty. CGN´s stock has lost 33.5 percent of its value since its listing in December 2014 and almost 60 percent since it peaked in June 2015. (See Figure 36)

the potential coming reform on tariffs for nuclear plants by the industry regulator to either decrease tariffs or free up some sales volumes and prices to competition, negatively weights in on CGN´s stock performance

In 2017, the group expects to start commercial operation of two additional reactors (Yangjiang Unit 4 and Taishan Unit 1; both majority owned) out of the nine the group currently has under construction, which should support 2017 revenues from higher electricity sales; although, the nuclear environment is expected to continue to be challenging.

Exelon (U.S.)

In 2016 Exelon reported revenues increasing by 6.5 percent. However, lower margins, higher depreciation charges, and an increase in operating expenses shrank the group's earnings by 29.4 percent. In addition, higher interest expenses (+50.7 percent) reduced the group's reported net income by 50 percent. On an adjusted basis, EPS reached US$2.68bn, a 7.6 percent increase.[578]

On the nuclear side, in 2016 the company achieved a nuclear capacity factor of 94.6 percent—the best in the company's history. Nonetheless, nuclear investment has been substantially revised downwards (–29.7 percent) , as almost all the envelope would be for maintenance (84.6 percent).

Exelon expects a flat performance for 2017 as it targets adjusted net income to fluctuate between –6.7 percent and +4.5 percent. The group expects to decrease its investment in the coming years, while simultaneously targeting an increase on its regulated asset base (RAB) of 6.5 percent. The nuclear business is expected to be affected by lower energy prices, which would hit margins and drop profits by –17.3 to –9.5 percent. It is clear that the company currently follows the sectoral trend of lower reliance of nuclear earnings and higher exposure to networks and regulated assets to support profits and growth.

Driven by the low power price environment, Exelon and other nuclear operators in the U.S. are demanding new nuclear subsidies to continue operations as profitability erodes. In August 2016, the New York regulator approved a $500m/year subsidy for the company to avert imminent

578 - Exelon, "Earnings Conference Call—4th Quarter 2016", 8 February 2017.

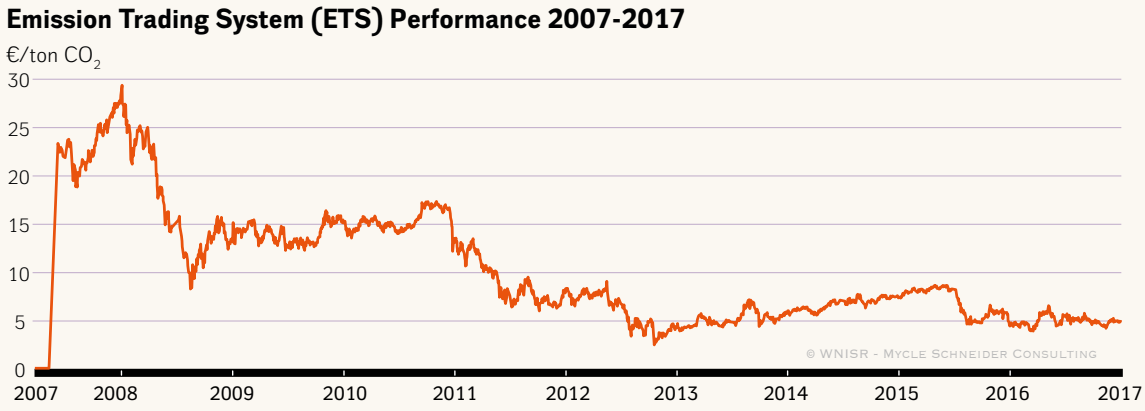
closures of its Ginna and Nine Mile Point reactors.[579] Moreover, Illinois approved the payment of $235m/year for 10 years to keep the Quad Cities and Clinton reactors open.[580] Nuclear operators are seeking direct subsidies in Ohio, Connecticut, Pennsylvania and New Jersey. In many states operators have stated that if no subsidies are given, they would be forced to close operations as profitability is rapidly decreasing. The subsidies, if approved, would be financed through higher tariffs charged to end-consumers. Those already awarded are being challenged in court, and those proposed are reportedly meeting with less enthusiasm.

OUTLOOK ON ENERGY SECTOR DEVELOPMENTS

Emission Trading System (ETS)

The United Kingdom introduced in April 2015 a carbon floor, which represents an emission tax that covers the difference between Emission Trading System (ETS) prices and £18/CO_2ton (US$23/$CO_2$ton), the objective set by the government. The introduction of this carbon floor/tax substantially decreased coal power generation as its higher emissions raised its marginal costs. Similar measures were tried by the European Union on a continental level, but Germany and Poland rapidly replied, as such measurs would make their fossil fuel industries unprofitable. The overall EU objective is to have an ETS price in the range of €20-30/CO_2ton (US$21.7/$CO_2$ton), the price level at which the system was created. However, the ETS market is oversupplied and prices have been falling constantly over the years (see Figure 37).

Figure 37 | European Emission Trading System Performance



Source: *Bloomberg*, 2017

Following the measures taken in the U.K., France tried to set-up a draft law to include a carbon tax floor at €30/CO_2ton (US$33.5/$CO_2$ton), but then narrowed the scope of the planned domestic carbon tax to be specifically applied to coal assets. However, the government had to back down, as the draft law only targeted a specific technology within a given industry, which could be taken by the European Commission as state aid. If a carbon tax were implemented, it would

579 - Jonathan Crawford, "U.S. Consumers May By $3.9 Billion "Losers" from Nuclear Aid", *Bloomberg*, Updated 22 March 2017, see https://www.bloomberg.com/news/articles/2017-03-21/consumers-would-be-3-9-billion-losers-from-nuclear-subsidies, accessed 25 June 2017.

580 - Ibidem.

have to be applied across the whole industry including all generation types and technologies, not just one. The country nonetheless currently has a carbon tax that represents €9.99/MWh (US$11.17/MWh) for coal and €5.88/MWh (US$6.57/MWh) for gas.

The EU currently is the main operational ETS market in auction revenues with US$18.3bn, far above California (USA) with US$4.1bn, and Québec (Canada) with US$1bn.[581] Moreover, following the Paris agreement on climate change agreed on December 2015 under the United Nations climate change conference (COP21), 195 nations did set the path to keep temperature rise below the 2C° mark. Under this target, the United States and China reflected their interest to create ETS models, similar to the one already created in Europe. Following this idea, China is expected to launch its new ETS system in 2017, after several pilot tests have been run in China's biggest cities[582]: China's carbon-trading zone is already larger than Europe's. If established, the Chinese ETS model may become the highest-volume market, surpassing Europe's. On the other hand, the expectations for the United States to create an ETS model have been diminished recently as the current federal government does not fully support climate action programs, though many states already operate them.

Power prices

Low wholesale electricity prices started to be taken into consideration once a substantial decrease in oil prices began by end 2014, making investors to assess that all commodity prices are towards a downwards trend. However, the downward trend on electricity prices started long before that, it began once overcapacity and falling demand created a negative impact on the market. This effect has been accentuated by a higher usage of renewable assets added to lower coal prices, as a decrease in global coal demand supported by cheaper gas in the U.S. (following the shale gas revolution) is decreasing coal consumption as an arbitrage is being made between coal and gas for power generation.

However, power prices rebounded on 2016 from historical low levels. This was not the impact of higher electricity demand or lower overcapacity in the market, but mainly driven by measures taken by the Chinese government to cut coal supply through a reduction in the production time, in an attempt to stabilize the global supply and demand gap.[583] As coal is the first conventional asset in the merit order for peak capacity (a way of ranking available sources of energy based on an ascending order of price taken from the short-time marginal costs), electricity prices are highly correlated to coal price movements.

Nonetheless, the rebound of global coal prices seems short-lived as the Chinese government in early 2017 took further measures to control the country's high pollution levels, including the aim to abandon 103 coal plants (operational and future projects).[584] This would put additional pressure on global coal prices as the main world coal consumer, China, should decrease its de-

581 - ICAP, "Emissions Trading Worldwide: ICAP Status Report 2017", International Carbon Action Partnership, 15 February 2017.

582 - Ibidem.

583 - Aibing Guo, "China's Coal Prices to Rise 20% Amid Production Cuts", *Bloomberg*, 25 May 2016.

584 - James Pennington, "China has abandoned 103 coal power plants. Here's what else is changing", Circular Economy, World Economic Forum, 16 February 2017, see https://www.weforum.org/agenda/2017/02/how-circular-and-sharing-economy-models-can-create-a-more-resource-efficient-society-in-china/, accessed 27 June 2017.

mand for the coming years, in addition to the one already seen in recent years in the U.S., the second largest consumer. Over 300 GW of projects under various stages of development have been put on hold in China at least until 2020, including 55 GW of coal plants already under construction.[585] On top of this, if the U.S. revamps production on its coal mines, as proposed by the newly elected government, oversupply will accentuate as there is not sufficient demand to absorb it. And similar bearish trends for coal power are rapidly emerging in India, where renewables now beat coal.

CONCLUSION ON NUCLEAR FINANCES

In 2017, an increase in electricity-generation overcapacity in developed economies is expected, with demand not fully recovering, electricity prices should continue in a backwardation curve, as future prices are below current levels until 2019. Renewable investment is expected to continue, focusing on offshore wind for Europe, while onshore wind and solar for the U.S., and developing economies seem dominating. Demand on mature markets is not expected to increase fast enough—if growing at all—to cover the additional capacity to be installed, increasing the market oversupply.

Hence, lower prices would put further pressure on nuclear operators in 2017 as their margins should continue to decrease given that their production is normally hedged for the year at a lower price level, reducing the profitability of the assets. Due to this, on the nuclear side, all operators expect lower profits in 2017 from a reduction in the hedging prices (at constant production levels).

Going forward, 2017 would be an interesting year nonetheless for the sector, as multiple decisions (both financial and regulatory) are expected on nuclear reactor developments with Flamanville EPR (France), NuGen (U.K.), KEPCO's APR1400 (UAE), CGN's EPR (China), SCANA's and Southern Co's AP1000s (USA), Hinkley Point C EPRs (U.K.), and Olkiluoto-3 EPR (Finland). The path 2017 may bring to nuclear operators could reveal what can be expected for the sector in the coming years: whether a brighter light shines at the end of the tunnel or whether that's the headlight of an oncoming train.

585 - Christine Shearer, Nicole Ghio, et al.,"Boom and Bust 2017—Tracking the Global Coal Plant Pipeline", Sierra Club, Coalswarm and Greenpeace, March 2017, see http://endcoal.org/wp-content/uploads/2017/03/BoomBust2017-English-Final.pdf, accessed 27 June 2017.

SMALL MODULAR REACTORS

Small Modular Reactors (SMRs) and other kinds of so-called "advanced reactors" continue to be positioned as a solution to one or more of the problems confronting nuclear power.[586] There are multiple reactor designs at various stages of development, starting from designs at just an early stage of conceptualization to ones that are at a relatively advanced state of construction. Rather than discussing the hypothetical advantages or disadvantage of the various designs, below we describe some of the recent developments and the current status of reactor projects by country.

United States

Over the years, the U.S. Department of Energy (DOE) has persisted in promoting the design, licensing, and construction of SMRs. An important form of promotion started in 2012, when DOE put out a Funding Opportunity Announcement (FOA) to provide support "first-of-a-kind engineering, design certification and licensing through a cost-shared partnership". Later, the DOE selected two SMR designs for awards of up to US$226 million each, mPower in 2012 and NuScale at the end of 2013.

The mPower design was proposed by Babcock & Wilcox (B&W) and, for a while, seemed poised to be the first SMR to be built in the United States. When DOE selected mPower, James Ferland, president of B&W, pronounced that the award represented "another key milestone in the work to establish *the world's first commercially viable SMR nuclear plant*" (our emphasis).[587]

There was even a client lined up for the reactor. Back in 2011, the Tennessee Valley Authority (TVA) sent a letter of intent to B&W announcing plans to construct the mPower SMR at the Clinch River site. In 2013, B&W and TVA "signed a contract to prepare and support Nuclear Regulatory Commission (NRC) review of a Construction Permit Application" for this project.[588]

The impact of mPower was expected not just to be confined to that reactor design but to facilitate the establishment of a wider market for SMRs. As John Kelly, the Deputy Assistant Secretary for Nuclear Reactor Technologies at the DOE's Office of Nuclear Energy told the Annual Platts SMR Conference in May 2013: "Success of this project will be an enabling factor for the follow-on programs and policies supporting broader SMR deployment".[589]

586 - The acronym SMR is also used to mean "small and medium-sized reactor" by the IAEA. For the IAEA, a "small" reactor is one having electrical output less than 300 MWe and a "medium" reactor is one having a power output between 300 MWe and 700 MWe.

587 - *Power Engineering International*, "Growing backing for small reactors", 22 May 2013, see http://www.powerengineeringint.com/articles/print/volume-21/issue-5/features/growing-backing-for-small-reactors.html, accessed 27 April 2017.

588 - BWXT, "B&W, TVA Sign Contract for Clinch River mPower Construction Permit", BWX Technologies, 20 February 2013, see http://www.bwxt.com/news/2013/02/20/BW-TVA-Sign-Contract-for-Clinch-River-mPower-Construction-Permit, accessed 27 April 2017.

589 - John Kelly, "DOE Strategic Vision for Small Modular Reactors", Nuclear Reactor Technologies, Office of Nuclear Energy, US.DOE, Presentation at the 4th Annual Platts SMR Conference, 29 May 2013, see http://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2013/pc330/presentations/John_Kelly.pdf, accessed 27 April 2017.

Then, in 2014, things started moving in a different direction. First, B&W slashed its spending on the SMR project from about US$80 million/year to less than US$15 million/year.[590] The main reason offered by B&W was that it had not found any companies willing to invest in mPower or customers willing to enter into a contract for an mPower reactor.[591] B&W also terminated the contract with Christopher Mowry, the head of the mPower project (giving him close to one million dollars as severance payment).[592]

The mPower team then started one more attempt at resuscitation. In 2016, Bechtel Corporation, the company that was earlier responsible only for the construction of the reactors, took on the job of project lead and explored "options of outside investors and future potential customers" but gave itself a one-year deadline, after which the program was to be terminated, if "no adequate investors or customers were found".[593] In March 2017, "Bechtel notified BWXT that it was unable to secure sufficient funding to continue the Generation mPower program and that it was invoking the settlement scenario provisions of the framework agreement to terminate the program".[594] For now, mPower officials have promised to "keep a complete archive of our work to date" in case future conditions warrant reconsideration.[595]

The other beneficiary of DOE funding, NuScale, has continued with the development of its reactor design. In January 2017, it announced having "asked the U.S. Nuclear Regulatory Commission (NRC) on December 31st, 2016 to approve the company's small modular reactor (SMR) commercial power plant design".[596] On 15 March 2017, NRC accepted NuScale's application for full review and has commenced the design certification process that, according to officials, is "expected to take 40 months".[597]

The equivalent of TVA, which expressed an interest in mPower, for NuScale is Utah Associated Municipal Power Systems (UAMPS), which is "a political subdivision of the State of Utah that provides comprehensive wholesale electric-energy, transmission, and other energy services, on a nonprofit basis, to community-owned power systems… [in] Utah, California, Idaho, Nevada, New Mexico and Wyoming".[598] UAMPS has 45 municipal public power utilities of whom 33 had signed on to the idea of building a NuScale power plant.

590 - *WNN*, "Funding for mPower Reduced," *World Nuclear News*, 14 April 2014, see http://www.world-nuclear-news.org/C-Funding-for-mPower-reduced-1404141.html, accessed 24 May 2015.

591 - Jason Ruiter, "Babcock & Wilcox Cuts Investment in mPower", *NewsAdvance.com*, 14 April 2014, see http://www.newsadvance.com/news/local/babcock-wilcox-cuts-investment-in-mpower/article_d7998d52-c3d3-11e3-8fbb-0017a43b2370.html, accessed 25 May 2015.

592 - John Downey, "Generation mPower ex-CEO to get $910,000 severance payment", *Charlotte Business Journal*, 15 April 2014, see http://www.bizjournals.com/charlotte/blog/energy/2014/04/generation-mpower-exceo-seeing-910-000-severance.html, accessed 29 April 2017.

593 - Will Davis, "mPower Consortium Halts Project", *ANS Nuclear Cafe*, American Nuclear Society, 16 March 2017, see http://ansnuclearcafe.org/2017/03/16/mpower-consortium-halts-project/, accessed 27 April 2017.

594 - Ibidem.

595 - Rod Adams, "Bechtel And BWXT Quietly Terminate mPower Reactor Project", *Forbes*, 13 March 2017, see http://www.forbes.com/sites/rodadams/2017/03/13/bechtel-and-bwxt-quietly-terminate-mpower-reactor-project/, accessed 30 April 2017.

596 - NuScale Power, "NuScale Submits First Ever Small Modular Reactor Design Certification Application (DCA)", 12 January 2017, see http://newsroom.nuscalepower.com/press-release/company/nuscale-submits-first-ever-small-modular-reactor-design-certification-applicat, accessed 29 April 2017.

597 - NEI, "NuScale SMR Design Ready for Full Review, NRC Says", Nuclear Energy Institute, 16 March 2017, see https://www.nei.org/News-Media/News/News-Archives/NuScale-SMR-Design-Ready-for-Full-Review,-NRC-Says, accessed 29 April 2017.

598 - UAMPS, "About UAMPS", Utah Associated Municipal Power Systems, see http://www.uamps.com/About-Us, accessed 29 April 2017.

The DOE's support for NuScale has also extended to siting, and, in February 2016, it entered into an agreement with UAMPS allowing the latter to evaluate various sites within DOE's Idaho National Laboratory to potentially construct a NuScale SMR.[599] In October 2016, UAMPS chose a location consisting of about 35 acres within an approximately 1,000acre plot within the Idaho National Laboratory.[600] NuScale, now described as "a frontrunner", is targeting an "initial operational date of 2024".[601]

NuScale has made extravagant claims in support of its project. In January 2017, NuScale officials projected that "once approved, global demand for its plants will create thousands of jobs during manufacturing, construction and operation" and "reestablish US global leadership in nuclear technology" and pave "the way for NRC approval and subsequent deployment of other advanced nuclear technologies".[602] They also predicted that "about 5575 GWe of global electricity will come from SMRs by 2035, equivalent to over 1,000 NuScale Power Modules".[603]

"The problem I have with SMRs is not the technology, it's not the deployment—it's that there's no customers...

NuScale's expectations for the future are reminiscent of the hype that surrounded Westinghouse's AP1000 reactor a little over a decade ago, both in terms of the size of market,[604] and how fast the reactor would be constructed.[605] Since then, of course, Westinghouse has filed for bankruptcy because of the formidable challenges it faced in translating these rosy projections into the real world. Prior to filing for bankruptcy, Westinghouse too had a SMR design under development, but, like B&W, it also abandoned that whole effort.[606] At that time, Danny Roderick, then president and CEO of Westinghouse, had offered an explanation: "The problem I have with SMRs is not the technology, it's not the deployment—it's that there's no customers... The worst thing to do is get ahead of the market".[607] It remains to be seen if NuScale will find different market conditions, when (and if) it emerges out of the NRC's review

599 - Office of Nuclear Energy, "Department of Energy Continues Commitment to the Development of Innovative Small Modular Reactors", Department of Energy, 18 February 2016, see https://www.energy.gov/ne/articles/department-energy-continues-commitment-development-innovative-small-modular-reactors, accessed 29 April 2017.

600 - *Modern Power Systems*, "Preferred site identified for first NuScale SMR plant", 31 October 2016, see http://www.modernpowersystems.com/features/featurepreferred-site-identified-for-first-nuscale-smr-plant-5653358/, accessed 29 April 2017.

601 - Ibidem.

602 - *WNN*, "NuScale makes history with SMR design application", 13 January 2017, see http://www.world-nuclear-news.org/NN-NuScale-makes-history-with-SMR-design-application-13011701.html, accessed 29 April 2017.

603 - Ibidem.

604 - The press release announcing Toshiba's acquisition of Westinghouse in February 2006 projected: "By 2020, the global market for nuclear power generation is expected to grow by 50 percent compared with today". See *Business Wire*, "Toshiba Acquires Westinghouse From BNFL", 6 February 2006, see http://www.businesswire.com/news/home/20060206005466/en/Toshiba-Acquires-Westinghouse-BNFL, accessed 15 August 2017.

605 - Westinghouse, too, projected a construction time of "approximately 36 months, from the pouring of first concrete to the loading of fuel" for the AP1000 reactor. Nick Shulyak, "Westinghouse AP1000® PWR: Meeting Customer Commitments and Market Needs", Westinghouse Electric Company, presented at the 10th International Conference on Nuclear Option in Countries with Small and Medium Electricity Grids, 1-4 June 2014, see http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/46/136/46136339.pdf, accessed 31 March 2017.

606 - Heba Hashem, "Westinghouse: Taking care of business", *Nuclear Energy Insider*, 12 February 2014.

607 - Anya Litvak, "Westinghouse Backs off Small Nuclear Plants", *Pittsburgh Post-Gazette*, 2 February 2014, see http://www.post-gazette.com/business/2014/02/02/Westinghouse-backs-off-small-nuclear-plants/stories/201402020074, accessed 3 February 2014.

with a design certification, especially given the steady increase in operational reactors in the U.S. declaring that they are no longer profitable in highly competitive power markets.

The poor state of the nuclear reactor market is cause for one of DOE's efforts to explore possibilities for federal government agencies to enter into Power Purchase Agreements (PPAs) with entities producing electricity from SMRs.[608] The nuclear industry and its spokespeople have also tried to come up with ways of obtaining government subsidies for SMR construction. The SMR Start program established by the Nuclear Energy Institute has recommended the establishment of an SMR commercial deployment program that uses a combination of Production Tax Credits (PTCs), PPAs and loan guarantees.[609]

Russia

Russia has a number of SMR designs under development. Among these, the first expected to be deployed is the KLT-40S, which is based on the design of reactors used in the small fleet of nuclear-powered icebreakers that Russia has operated for decades. The first two reactors of the KLT-40S design will be placed on a ship called the Akademik Lomonosov.

Construction of the ship first began in April 2007 and the initial cost was estimated at around six billion rubles (US$232 million at then exchange rates); six more such floating plants were to be built between 2008 and 2016.[610] The schedule at that time envisioned completion of the first plant by 2010.[611] Construction has been significantly delayed since then, and various subsequently announced deadlines have been missed. In October 2014, for example, delivery was promised for September 2016.[612] But that, of course, did not happen. By 2015, the cost estimate had gone up to 37 billion rubles (US$740 million at then exchange rates).[613]

The current estimate is that the power plant will start operating in 2019; construction of the dock that will host the ship started in October 2016.[614] In July 2016, the Akademik Lomonosov began "harbor tests" and these tests are scheduled to be completed in October 2017.[615] In

608 - Seth Kirshenberg, et al., "Purchasing Power Produced by Small Modular Reactors: Federal Agency Options", Kutak Rock LLP, Scully Capital, January 2017, report commissioned by Allegheny Science & Technology Corporation, report funded by the Office of Nuclear Energy from the US.DOE, see https://energy.gov/ne/downloads/purchasing-power-produced-small-modular-reactors-federal-agency-options, accessed 30 April 2017.

609 - SMR Start, "Policy Statement on U.S. Public-Private—Partnerships for Small Modular Reactors", NEI, 26 October 2016, see https://www.nei.org/Issues-Policy/New-Nuclear-Energy-Facilities/Small-Reactor-Designs, accessed 30 April 2017.

610 - *WNN*, "Russian floating reactor construction starts", 17 April 2007, see http://www.world-nuclear-news.org/newsarticle.aspx?id=13250, accessed 30 April 2017.

611 - *BBC*, "Russia making floating atom plant", 17 April 2007, see http://news.bbc.co.uk/2/hi/europe/6562925.stm, accessed 30 April 2017.

612 - Charles Digges, "Russia announces yet newer delivery date for first floating nuclear power plant", *Bellona*, 28 October 2014, see http://bellona.org/news/nuclear-issues/nuclear-russia/2014-10-russia-announces-yet-newer-delivery-date-first-floating-nuclear-power-plant, accessed 19 May 2015.

613 - Charles Digges, "New documents show cost of Russian floating nuclear power plant skyrockets", *Bellona*, 25 May 2015, see http://bellona.org/news/nuclear-issues/2015-05-new-documents-show-cost-russian-nuclear-power-plant-skyrockets, accessed 28 December 2015.

614 - *RT*, "Russia starts work on Arctic dock for 1st-ever floating nuclear power plant", 7 October 2016, see https://www.rt.com/news/361908-lomonosov-fnpp-russia-platform/, accessed 30 April 2017.

615 - *PortNews*, "Baltiysky Zavod shipyard starts harbor tests of world's first floating nuclear power plant Akademik Lomonosov", 1 July 2016, see http://en.portnews.ru/news/222051/, accessed 29 July 2016.

April 2017, it was reported that fueling of the reactor was set to start in St. Petersburg and this had become cause for safety concerns.[616]

No other Russian SMR is under construction nor are there definitive plans to start construction of any in the near future.

No other Russian SMR is under construction nor are there definitive plans to start construction of any in the near future.

A lead-cooled fast reactor design, SVBR-100, that has long been promoted by a section of Russia's nuclear establishment has ended costing much more than initial estimates—36 billion rubles (US$632 million) as compared to the initial 15 billion rubles (US$250 million). As a result, Rosatom is now looking for foreign partners in the endeavor.[617]

South Korea

South Korea's System-Integrated Modular Advanced Reactor (SMART) is the first land based SMR of LWR design (not including the designs from the 1950s and 1960s) to receive regulatory approval anywhere in the world. In July 2012, SMART received Standard Design Approval from Korea's Nuclear Safety and Security Commission.[618] But since then, the developers of SMART have learnt the same lesson that many US SMR vendors have been discovering: there is no market for SMRs. In South Korea's case, the reason seems to be the realization that the SMART is too expensive on a per-unit generating-capacity basis. The World Nuclear Association pointed this out when it stated: "KAERI planned to build a 90 MWe demonstration plant to operate from 2017, but *this is not practical or economic in South Korea*" (our emphasis).[619] There don't seem to be any concrete plans to construct a SMART in South Korea.

Korea Atomic Energy Research Institute (KAERI) has therefore been pursuing export orders. So far, its only potential client is Saudi Arabia's King Abdullah City for Atomic and Renewable Energy (KA-CARE), with whom KAERI signed a Memorandum of Understanding in 2015 to "conduct a three-year preliminary study to review the feasibility of constructing SMART reactors in Saudi Arabia".[620] No outputs from this study have been published, but last August KAERI announced that the study was progressing on schedule.[621] Meanwhile, Saudi Arabia's policy makers continue to be hesitant about nuclear power; in May 2016, Saudi Arabia's deputy

616 - Tatyana Voltskaya, "Russia's Secretive Floating Nuclear Power Plant Making Waves In St. Petersburg", *RadioFreeEurope/RadioLiberty*, 20 April 2017, see http://www.rferl.org/a/russia-petersburg-floating-nuclear-plant-safety-fears/28440654.html, accessed 21 April 2017.

617 - *NEI*, "Russia seeks partners for its SVBR project", Nuclear Engineering International, 15 November 2016, see http://www.neimagazine.com/news/newsrussia-seeks-partners-for-its-svbr-project-5669556, accessed 30 April 2017.

618 - Kwon Dong-joon, "Korean All-in-one SMR Won World's First Standard Design Approval", *ETnews*, 5 July 2012, see http://english.etnews.com/20120705200008, accessed 1 May 2017.

619 - WNA, "Nuclear Power in South Korea", Updated February 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx, accessed 1 May 2017.

620 - *WNN*, "Saudi Arabia teams up with Korea on SMART", 4 March 2015, see http://world-nuclear-news.org/NN-Saudi-Arabia-teams-up-with-Korea-on-SMART-0403154.html, accessed 8 August 2017.

621 - Daye Kim, "Marking Progress With Smart in Saudi Arabia", *NIW*, 22 January 2016.

economic minister told a conference in Dubai: "I don't think we need nuclear power plants in Saudi Arabia".[622]

South Korea has also explored the possibility of selling a SMART reactor to Indonesia. In October 2001, under the framework of the Interregional Technical Cooperation Project of the IAEA, KAERI and Indonesia's Badan Tenaga Nuklir Nasional (National Nuclear Energy Agency) undertook a joint study entitled "A preliminary economic feasibility assessment of nuclear desalination in Madura Island".[623] At that time, plant operations were expected to commence in 2015.[624] That has, of course, not happened. But then the prospects of nuclear power in general and the possibility of constructing an SMR in Indonesia have also dimmed considerably.[625]

"We will scrap the nuclear-centered policies and move toward a nuclear-free era. We will eliminate all plans to build new nuclear plants."

Prospects for the construction of SMART have essentially vanished for the present, ever since incoming President Moon stated in June 2017: "We will scrap the nuclear-centered policies and move toward a nuclear-free era. We will eliminate all plans to build new nuclear plants."[626]

China

China has pursued multiple SMR designs but the most advanced of these, and the one currently under construction, is the High Temperature Reactor (HTR) that it has developed since the 1970s. Called the HTR-PM, the power plant consists of two reactors with a gross (net) capacity of 211 (200) MW.

The HTR-PM received final approval from China's cabinet and its national energy bureau around two weeks before the Fukushima accidents began.[627] But due to the changes in Chinese policy following 3/11,[628] it was only on 9 December 2012 that construction of HTR-PM commenced (i.e. first pour of concrete) at Shidaowan in China's eastern Shandong province.[629] According to the official schedule, construction was to take 59 months,[630] and as of

622 - LeAnne Graves, "Saudi minister prefers solar potential over nuclear energy", *The National*, 25 May 2016, see http://www.thenational.ae/business/energy/saudi-minister-prefers-solar-potential-over-nuclear-energy, accessed 31 May 2016.

623 - Si-hwan Kim et al., "A preliminary economic feasibility assessment of nuclear desalination in Madura Island", *International Journal of Nuclear Desalination*, Vol.1, No.5, 2005, pp.466-476.

624 - International Nuclear Desalination Advisory Group, "Indonesia and Korea, Rep. of", INDAG Newsletter, 2003.

625 - Bernadette K. Cogswell et al., "Nuclear Power and Small Modular Reactors in Indonesia: Potential and Challenges", Indonesian Institute for Energy Economics, and Nautilus Institute for Security and Sustainability, April 2017, see http://liu.arts.ubc.ca/wp-content/uploads/2015/12/IIEE-Nautilus-SMR-Report-Final-For-Publication-April2017.pdf, accessed 30 April 2017.

626 - Hojun Hwang, "Korea's first nuclear power reactor turned off for good", *Arirang News*, 20 June 2017, see http://www.arirang.co.kr/News/News_View.asp?nseq=205377, accessed 22 June 2017.

627 - Keith Bradsher, "A Radical Kind of Reactor", *The New York Times*, 24 March 2011, see http://www.nytimes.com/2011/03/25/business/energy-environment/25chinanuke.html, accessed 24 April 2012.

628 - Amy King and M.V. Ramana, "The China Syndrome? Nuclear Power Growth and Safety After Fukushima", *Asian Perspective*, October-December 2015, Vol. 39, No. 4.

629 - Zuoyi Zhang et al., "The Shandong Shidao Bay 200 MWe High-Temperature Gas-Cooled Reactor Pebble-Bed Module (HTR-PM) Demonstration Power Plant: An Engineering and Technological Innovation", 2006, *Engineering*, pp.112–18.

630 - Ibidem., p.112.

31 December 2016, commercial operation was "scheduled to start in late 2017".[631] However, in mid-February 2017, grid connection had been delayed to 2018.[632]

The HTR program is pursued by groups that are somewhat outside the mainstream Chinese nuclear establishment. When construction of the HTR-PM power plant began, there were plans for eventually constructing a further 18 units of the same type at the same site.[633] That no longer seems to be the case.[634] Part of the reason might be the cost of generating electricity at the power plant, which is reported to be 60 fen (¢ 0.9) per kilowatt hour, significantly higher than the average 43 fen/kWh for Generation III reactors, and this has been listed as one of the "key challenges" confronting HTGRs in China.[635]

In recent years, mainstream Chinese nuclear institutions have been promoting other SMR designs: the ACPR50 and ACPR100 from China General Nuclear (CGN) and the ACP100 from China National Nuclear Corporation (CNNC). All these designs have been in the news recently, as a result of an announcement that China was going to build maritime nuclear power platforms in the South China Sea.[636] CNNC and CGN have been working on these designs since around 2010, but development and plans for deployment have clearly accelerated in the last couple of years, perhaps as a result of conflicts over islands in the South China Sea.

As in other areas of nuclear power, CNNC and CGN seem to be locked in competition, when it comes to SMR development. Both organizations have been putting out press releases rapidly. CNNC set the ball rolling in April 2016 when it announced that its ACP100 had passed an "IAEA safety review" and it was the "first reactor of its kind in the world" to have cleared this process.[637] According to the IAEA, this review is "performed on the safety documentation submitted to the IAEA, [and] provides an early evaluation of a vendor's new nuclear power plant design's safety documentation, against the IAEA Safety Standards at the fundamentals and requirements level".[638]

Then in November 2016, CGN held a press conference that was reported as the start of construction of an ACPR50.[639] Upon closer examination, it turns out that the company "had signed the pressure vessel purchase agreement with Dongfang Electric", but a company official argued that, "unlike the pouring of first safety concrete for a conventional land-based reactor, the

631 - *NEI*, "China construction update", Nuclear Engineering International, 9 January 2017, see http://www.neimagazine.com/news/newschina-construction-update-5711775, accessed 1 May 2017.

632 - *CCTV*, "China's 4th generation nuclear power plant to go online in 2018", 14 February 2017, see http://english.cctv.com/2017/02/14/VIDEOS4JarzcwUsx01sg28jZ170214.shtml, accessed 30 July 2017.

633 - *NucNet*, "China Begins Construction Of First Generation IV HTR-PM Unit", 7 January 2013, see http://www.nucnet.org/all-the-news/2013/01/07/china-begins-construction-of-first-generation-iv-htr-pm-unit, accessed 10 January 2013.

634 - *WNN*, "First vessel installed in China's HTR-PM unit", 21 March 2016, see http://www.world-nuclear-news.org/nn-first-vessel-installed-in-chinas-htr-pm-unit-2103164.html, accessed 25 February 2017.

635 - C. F. Yu, "CNEC-CFHI Deal—Boosting the HTGR Or Chinese Manufacturing?", *NIW*, 2 September 2016.

636 - *NEI*, "China gets onboard", 16 August 2016, see http://www.neimagazine.com/features/featurechina-gets-on-board-4980507/, accessed 5 March 2017.

637 - CNNC, "CNNC small multi-purpose modular reactor ACP100 reactor passes IAEA safety review", 28 April 2016, see http://en.cnnc.com.cn/2016-04/28/c_51725.htm, accessed 1 May 2017.

638 - Cornelia Spitzer, "IAEA Safety Review Services: Improving Application of IAEA Safety Standards for New Designs", Division of Nuclear Safety, IAEA, 19 May 2016, see https://www.iaea.org/newscenter/news/iaea-safety-review-services-improving-application-of-iaea-safety-standards-for-new-designs, accessed 1 May 2017.

639 - *WNN*, "CGN starts construction of offshore reactor", 7 November 2016, see http://www.world-nuclear-news.org/NN-CGN-starts-construction-of-offshore-reactor-0711164.html, accessed 1 May 2017.

signing of the vessel purchase agreement marks the official start of construction of the offshore unit" because the "vessel takes the longest to manufacture".[640]

Both companies claim that there is much interest in these reactors. CNNC has listed "Pakistan, Iran, the United Kingdom, Saudi Arabia, Indonesia, Mongolia, Brazil, Egypt and Canada" as countries it has engaged in discussions with over the ACP1000.[641] CGN has signed a contract with China National Offshore Oil to support oil and gas exploration at sea, and announced plans for 20 more vessels.[642]

India

India has been developing the Advanced Heavy Water Reactor (AHWR) since the 1990s.[643] There are two versions of this design, one utilizing plutonium as fuel and the other using LEU (low enriched uranium) instead of plutonium, which is advertised as possessing "intrinsic proliferation resistant features.[644]

The AHWR continues to be delayed. In the early 2000s, the construction of the first of this design was projected to start in 2005.[645] Building is yet to begin. In response to a question in the Indian Parliament in March 2017, the government said of the AHWR: "The design of all nuclear systems of the reactor has been completed. Several innovative features of the design are being validated through large scale engineering experiments. In order to facilitate an early scrutiny of the innovative features of the design from the safety considerations, a Pre-Licensing Design Safety appraisal of the reactor has been completed by the Atomic Energy Regulatory Board. Construction of this reactor can begin after associated statutory and regulatory clearances are obtained and financial sanction for the project is obtained".[646] This suggests that construction might still take a while.

In December 2016, an environmental activist used the country's Right to Information Act to ask the Department of Atomic Energy about what stage the AHWR is at. The DAE's reply stated that the reactor had received "in principle" approval for construction at the Tarapur site in Western India.

640 - Ibidem.

641 - Xin Zheng, "Countries interested in ACP100 reactor", *China Daily*, 28 April 2017, see http://www.chinadaily.com.cn/bizchina/2017-04/28/content_29122633.htm, accessed 1 May 2017.

642 - *AP*, "China's floating nuclear reactors plan spur attack concerns", *The National*, 1 August 2016, see http://www.thenational.ae/business/energy/chinas-floating-nuclear-reactors-plan-spur-attack-concerns, accessed 2 May 2017.

643 - R. K. Sinha and Anil Kakodkar, "Advanced Heavy Water Reactor", *Nu-Power*, 1999, pp.22–27.

644 - K. L. Ramkumar, "Th-LEU Fuel in AHWR to enhance proliferation resistance characteristics", presented at the IAEA 3rd Technical Meeting on Options to incorporate intrinsic proliferation resistance features to Nuclear Power Plants with innovative Small Modular Reactors, 15 August 2011.

645 - B. Bhattacharjee, "An Overview of R&D in Fuel Cycle Activities of AHWR", presented at 14th Annual Conference of Indian Nuclear Society on Nuclear Fuel Cycle Technologies, and 1st BRNS Conference on Nuclear Fuel Cycle, Indian Nuclear Society, 2003.

646 - Jitendra Singh, "Unstarred Question No. 3318—Thorium Based Nuclear Energy", Minister of State for the Personnel, Public Grievances & Pensions and Prime Minister's Office, Government of India, Released by the Department of Energy, Government of India, 22 March 2017, see http://dae.nic.in/writereaddata/parl/budget2017/lsus3318.pdf, accessed 3 May 2017.

Argentina

The CAREM-25 reactor has been under construction in Argentina since February 2014.[647] Although there is no official announcement of delay, construction of the reactor appears to have slowed down. In 2014, when construction started, Argentina's Comision Nacional de Energia Atómica (CNEA) announced that CAREM-25 would begin cold testing in 2016 and receive its first fuel load in the second half of 2017. But it was only in August 2016 that a contract was signed between CNEA and Tecna,[648] a subsidiary of Isolux Corsan, for "the design, engineering, manufacture, supply, transportation, construction, installation, commissioning and testing up to commercial licensing of all facilities, equipment and systems of the Balance of Plant of the CAREM 25 Project".[649] According to this announcement, "work under the contract is scheduled to be completed by the end of 2018, followed by a trial operation period ending in July 2019. Commercial operation of the prototype reactor will then follow".[650] This schedule seems very optimistic.

Many developing countries claim to be interested in SMRs but few seem to be willing to invest in the construction of one.

Conclusion on Small Modular Reactors

Since 2015, when WNISR included a section on small modular reactors, there have been two kinds of developments. First, as we have documented above, a few SMR designs have progressed towards construction as well as completion; one SMR project (in China) is reportedly to start up in 2018. But the implication of this progress is questionable because of the second development, namely the decline in even the stated interest, let alone the actual market for SMRs that can be backed up with financial commitment. A good example of the decline in interest can be seen in the case of the HTR-PM being built in China. When construction of that reactor started, there was talk about building 18 more such reactors. That has vanished, presumably because of the realization of the high costs of electricity from these power plants. Unfavorable economics is also the reason for there being no market for the SMART reactor in South Korea.

The decline in interest in SMRs is, of course, related to the decline in the interest in large nuclear reactors as well. The problems associated with mPower and the Westinghouse SMR are, in the final analysis, related to the absence of a market for SMRs in the United States. Likewise,

647 - *WNN*, "Construction of CAREM underway", 10 February 2014, see http://www.world-nuclear-news.org/NN-Construction-of-CAREM-underway-1002144.html, accessed 24 May 2015.

648 - In turn, TECNA is subcontracting supply of the "turbogenerator, condenser and control system" to Siemens.

649 - Isolux Corsán, "TECNA, a subsidiary of Isolux Corsan signs the contract for the Balance of Plant of the Reactor Carem 25 in Argentina", 17 August 2016, see http://www.isoluxcorsan.com/en/tecna-a-subsidiary-of-isolux-corsan-signs-the-contract-for-the-balance-of-plant-of-the-reactor-carem-25-in-argentina.html?texto=&idCategoria=0&fechaDesde=&fechaHasta=, accessed 3 May 2017.

650 - *WNN*, "Contract for prototype CAREM balance of plant", 6 September 2016, see http://www.world-nuclear-news.org/NN-Contract-for-Contract-for-prototype-CAREM-balance-of-plant-0609164.html, accessed 3 May 2017.

many developing countries claim to be interested in SMRs but few seem to be willing to invest in the construction of one.[651]

This latter factor has made it more difficult, perhaps impossible, for any SMR design to become a commercial success. This is clearly illustrated by the saga of mPower. Despite the expenditure of hundreds of millions of dollars, some of the biggest companies in the nuclear business could not succeed in commercializing a reactor design that had been described by *The New York Times* as being in the lead in the race to develop SMRs, in part because it had "the Energy Department and the T.V.A. in its camp".[652]

Of course, with powerful entities like the U.S. Department of Energy continuing to financially support the construction of SMRs, it is possible that one or two SMR projects might even start getting built over the next decade or beyond. But it appears that such projects would have to be supported by government funding in a major way if they are to be completed. There is no sign at this point that SMRs could play any major role in tomorrow's electricity generating business.

651 - Good examples are the cases of Jordan, Ghana and Indonesia, all of which have been touted as promising markets for SMRs, but none of which are buying one. See 1) M. V. Ramana and Ali Ahmad, "Wishful Thinking and Real Problems: Small Modular Reactors, Planning Constraints, and Nuclear Power in Jordan", *Energy Policy*, 2016, xciii : 236–245; see also 2) M. V. Ramana and Priscilla Agyapong, "Thinking big? Ghana, small reactors, and nuclear power", *Energy Research & Social Science*, 2016, xxi: 101–13; and 3) Bernadette K. Cogswell et al., "Nuclear Power and Small Modular Reactors in Indonesia: Potential and Challenges", Indonesian Institute for Energy Economics and Nautilus Institute for Security and Sustainability, April 2017, see http://liu.arts.ubc.ca/wp-content/uploads/2015/12/IIEE-Nautilus-SMR-Report-Final-For-Publication-April2017.pdf, accessed 30 April 2017.

652 - Matthew L. Wald, "Deal Advances Development of a Smaller Nuclear Reactor", *The New York Times*, 20 February 2013.

FUKUSHIMA STATUS REPORT

INTRODUCTION

Six years have passed since the Fukushima accident was triggered in March 2011 and in many areas serious problems remain. For example, since February 2017, an internal survey of a containment vessel has been carried out for the removal of fuel debris, but the project has not been proceeding as planned. As for actions taken outside the site, although the order was lifted

independent experts estimate that the actual costs might reach ¥50–70 trillion (US$453–635 billion)

for the largest evacuation area at the end of March 2017 so far, few people have actually gone back to their homes due to concerns about radioactivity. Furthermore, in December 2016, the government officially announced that estimation of the total cost of the Fukushima accident is ¥22 trillion (US$200 billion)[653]. However, independent experts estimate that the actual costs might reach ¥50–70 trillion (US$453–635 billion). These costs are to be paid for by citizens through electricity charges and taxes.

ON-SITE CHALLENGES

Current Status of the Reactors [654,655]

Water injection for cooling of the three molten reactor cores is still continuing. The rate of water injection into the reactor pressure vessel is 3 m^3/h per reactor, a total of over 200 m^3 per day. This enables the temperature at the bottom of the pressure vessel and the interior of the containment vessel to be maintained at about 15 to 25°C. The temperature of the cooling water of the fuel pool is maintained at about 24–27°C[656].

Since 5 April 2017, Tokyo Electric Power Company (TEPCO) has been experimentally circulating water in the pool of Unit 1 for three weeks without passing the water through a cooling device. According to TEPCO, because the decay heat of spent fuel is declining, the water temperature rose only to about 31°C.[657]

653 - Calculated as 1US$=110JPY using the exchange rate as of 29 July 2017. The same hereinafter.

654 - Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, "Summary of Decommissioning and Contaminated Water Management", Ministry of Economy, Trade and Industry (METI), 23 February 2017, see http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/d170223_01-e.pdf, accessed 15 April 2017.

655 - TEPCO, "Observation Data—Fukushima Daiichi NPS", see http://www.tepco.co.jp/en/decommision/news/data-e.html, accessed 1 May 2017.

656 - Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, "Summary of Decommissioning and Contamined Water Management", METI, 27 July 2017.

657 - TEPCO, "Status of Fukushima Daiichi Nuclear Power Station", 5 April 2017, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2017/images1/handouts_170405_06-j.pdf, accessed 1 May 2017.

The spent fuel of Units -1, -2 and -3 is still in the respective unit's spent fuel pool. According to the government's mid-and-long-term roadmap[658], which was revised in June 2016, fuel removal is now scheduled to begin by FY 2020 for Unit-1 and -2 and by FY 2017 for Unit-3.

TEPCO finished removing the covers of Unit 1 by November 2016 in preparation for for the installation of a sturdy fuel removal device. Currently, TEPCO is carrying out rubble removal and decontamination work in the upper part of the building. However, the method of spent fuel removal for Unit-2 is not decided yet and TEPCO plans to define the approach during FY 2017. As for Unit-3, rubble removal from the spent fuel pool was completed in August 2015 and work for installing the fuel removal device has been going on since January 2017. The start of spent fuel removal has been delayed because it took more time than expected to remove rubble, and it is now scheduled to start by mid-2018.

According to the roadmap, the policy for fuel debris removal would have been decided during 2017. Currently, with regard to the first unit, it is planned to decide on the fuel debris removal method only in the first half of FY2018, and to start removal during 2021. However, sufficient information to determine the policy has not been obtained yet.

In February 2017, TEPCO and the International Research Institute for Nuclear Decommissioning (IRID) introduced a robot into the containment vessel of Unit-2. This was to attempt to measure the inside of the pedestal—a cylindrical unit that supports the pressure vessel—which is located under the pressure vessel and which is assumed to contain fallen fuel debris. However, the robot's movement was blocked by debris and the investigation failed midway through its implementation.[659]

Although they could not put the robot inside the pedestal, photographs taken outside of it revealed some large holes in the platform, which is a metal scaffold in the pedestal.[660] About 210 Sv/h have been measured at a point about 3 m outside the inner wall of the pedestal[661]. In March 2017, a robot equipped with a dosimeter and a camera was put into the containment vessel of Unit-1.[662] As a result, about 10 Sv/h was observed at several points around the pedestal.[663]

658 - Inter-Ministerial Council for Contaminated Water and Decommissioning Issues, "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station", Government of Japan, 12 June 2015, (Provisional Translation), see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20150725_01b.pdf, accessed 1 May 2017.

659 - TEPCO, "Announcements: Investigation inside the pedestal for Unit 2 Primary Containment Vessel at Fukushima Daiichi Nuclear Power Station", Press Release, 8 February 2017, (in Japanese), see http://www.tepco.co.jp/en/announcements/2017/1374451_10494.html, accessed 1 May 2017.

660 - TEPCO and IRID, "Internal Survey for the Primary Containment Vessel of Unit 2—Investigation by self-propelled survey device", 15 February 2017, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2017/images1/handouts_170215_08-j.pdf, accessed 1 May 2017.

661 - TEPCO and IRID, "Internal investigation in reactor containment vessel of Unit 2—Results of the survey by self-propelled survey device", 16 February 2017, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2017/images1/handouts_170216_11-j.pdf, accessed 1 May 2017.

662 - TEPCO, "Fukushima Daiichi NPS Prompt Report 2017—Recent Topics: TEPCO Announces Results of Five-Day Robot Investigation in Unit 1", 27 March 2017, see http://www.tepco.co.jp/en/press/corp-com/release/2017/1398202_10469.html, accessed 1 May 2017.

663 - TEPCO, "Unit 1 Primary Containment Vessel Internal Investigation", 27 March 2017, see http://www.tepco.co.jp/en/nu/fukushima-np/handouts/2017/images/handouts_170327_01-e.pdf, accessed 1 May 2017.

Contaminated Water Management

Contaminated water countermeasures are still ongoing. To prevent a further increase in contaminated water, groundwater is pumped up from various wells, before it flows into the basements of the reactor buildings, and is discharged into the sea following a nuclide analysis.

Also, the freezing of artificial walls (land-side water-barrier walls)[664] to prevent the flow of groundwater into the buildings was started in March 2016, both on the buildings' sea-side and mountain-side. The sea-side walls were completely frozen in October but the mountain-side walls have not yet completely frozen, although the freezing operation has been ongoing there since March 2017.[665] As of 1 July 2017, TEPCO estimates that approximately 580 tons of water pass through the ice wall on the reactor buildings' landward side each day, down from 760 tons before freezing of soil began in March 2016. About 130 tons daily enter the reactor buildings themselves, and TEPCO hopes completing the wall will bring that figure below 100 tons, one reason why the NRA maintains that the barrier is "ultimately only a supporting measure" to other systems preventing contamination.[666]

The amount of treated, but still contaminated water stored in tanks was about 650,000 m³ in May 2016, but increased to about 750,000 m³ in May 2017

Water that is already contaminated has been stored in storage tanks after removal of radioactivity by the poly-nuclide removal-equipment or other apparatus. The amount of treated, but still contaminated water stored in tanks was about 650,000 m³ in May 2016, but increased to about 750,000 m³ in May 2017.[667] According to TEPCO, the construction capacity for treated-water tanks is equivalent to about 500 m³/day. Based on this figure, they insist that they have secured tank capacity for about 400 m³/day of groundwater and other inflows at the maximum.[668]

Because the number of contaminated water storage tanks is still increasing, the government wants to release stored water to the ocean. However, since tritium has not been removed from the contaminated water, the local fishery cooperatives are opposed to its release, as they are concerned this might further harm the reputation of fish caught off the Fukushima coast line.

The Ministry of Economy, Trade and Industry (METI) had summarized the tritium-water task-force report in June 2016 and presented disposal plans for contaminated water by relea-

664 - TEPCO, "Land-side Impermeable Wall (Frozen Soil Wall)", Undated, see http://www.tepco.co.jp/en/decommision/planaction/landwardwall/index-e.html, accessed 1 May 2017.

665 - TEPCO, "Status of Fukushima Daiichi Nuclear Power Station", 14 April 2017, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2017/images1/handouts_170414_08-j.pdf, accessed 1 May 2017.

666 - *Nikkei Asian Review*, "Fukushima ice wall facing doubts as project nears completion", 23 August 2017, see https://asia.nikkei.com/Tech-Science/Tech/Fukushima-ice-wall-facing-doubts-as-project-nears-completion, accessed 24 August 2017.

667 - Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, "Summary of Decommissioning and Contaminated Water Management", METI, Government of Japan, 25 May 2017, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20170525_e.pdf, accessed 4 August 2017.

668 - TEPCO, "Tank construction progress status", 25 May 2017, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2017/05/3-01-03.pdf, accessed 28 June 2017.

sing it into the ocean and evaporating it.[669] An agreement with local fishery cooperatives must be reached to implement these plans. But, at present, there are no prospects for an agreement.

Worker Exposure[670]

As of the end of March 2017, approximately 8,000 people per month are working at the site. About 90 percent are employees of subcontractors, not TEPCO staff. For these workers, the external exposure for the three-month period from December 2016 to February 2017 is 0.38–0.46 mSv on average, and the average cumulative dose from April 2016 to February 2017 was 2.58 mSv (max. 38.83 mSv).

From March 2011 to September 2015, 1,203 people have worked as specified high-dose workers—TEPCO employees only—to whom the emergency exposure limit (100 mSv) was applied. Their exposure level was on average 36.5 mSv (maximum 102.7 mSv).

For comparison, workers' emergency exposure limits were provisionally raised from the conventional level of 100 mSv/year to 250 mSv/year during the first phase of the Fukushima accident. Also, although the general public's dose limit is 1 mSv/year, after the Fukushima accident, the government set the dose limit for residents to 20 mSv/year as evacuation threshold. This decision by the government to multiply the admissible dose by a factor of 20, following the beginning of the Fukushima accident, caused serious social confusion, controversy and opposition.

In 2015, in addition to the conventional limit of 100 mSv/year, the Nuclear Regulation Authority (NRA) officially decided to set the exposure limit to 250 mSv/year for any case, when radioactive material is released outside a nuclear power plant site.

among the 1,020 companies that are performing the decontamination work, 586 companies have violated the law

In December 2016, the Ministry of Health, Labor and Welfare (MHLW) recognized the thyroid cancer developed by a TEPCO employee in his forties as occupational disease, related to decommissioning work at Fukushima. This is the third case of an occupational disease being recognized as related to the Fukushima accident and the first case of thyroid cancer. The first person is a man in his 30s, who developed leukemia. His exposure level at Fukushima Daiichi was 15.7 mSv (cumulative dose was 19.8 mSv, when work at other places is included), and the MHLW recognized his leukemia as an occupational disease in October 2015. The second person is a man in his 50s, who developed leukemia as well. His dose due to work at the Fukushima site was 54.4 mSv, and MHLW recognized his leukemia as occupational disease in August 2016.

669 - Tritiated Water Task Force, "Tritiated Water Task Force Report", METI, June 2016, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20160915_01a.pdf, accessed 1 May 2017.

670 - TEPCO, "Evaluation of the exposure dose of workers at the Fukushima Daiichi Nuclear Power Station", Press Release, 31 March 2017, see http://www.tepco.co.jp/en/press/corp-com/release/2017/1403551_10469.html, accessed 1 May 2017.

At the same time as this recognition, the MHLW's expert advisory committee, for the first time, presented criteria for recognizing thyroid cancer as occupational disease; for example, a cumulative dose of 100 mSv or more is one of the conditions for recognition.[671]

The Fukushima Labor Bureau of the MHLW released the results of supervision guidance from January to December 2016. According to the report, among the 348 companies that are performing the decommissioning work, 160 companies have violated the Labor Standards Law (46 percent, 273 violations). Also, among the 1,020 companies that are performing the decontamination work, 586 companies have violated the said law (57.5 percent, 982 violations). The violations in both cases included unpaid extra work, work hours exceeding the standards set by the law, and others. [672]

OFF-SITE CHALLENGES

Current Status of Evacuation

The Fukushima Prefecture insists that progress has been made in disaster recovery.[673] For instance, the number of evacuees continues to decrease. Their official number peaked at 164,865 evacuees in May 2012, and, as of 27 March 2017, there are officially a total of 79,233 evacuees: 37,616 evacuees living in the prefecture, 37,528 evacuees living outside the prefecture and 19 missing people.[674] For reference, there were 92,600 evacuees as of May 2016 (see WNISR 2016, page 93). In other words, as of May 2017, there are officially less than half of the evacuees there were in 2012.

From 31 March to 1 April 2017, as scheduled by the government, the evacuation order of a part of the original evacuation area in Fukushima Prefecture was lifted. While evacuation orders have been lifted gradually until now, this evacuation order concerned the largest area so far and involved about 32,000 previous inhabitants.

The government raises three conditions for lifting an evacuation order: [675]

- The annual accumulated dose by air dose-rate calculation drops to 20 mSv or below;
- Infrastructure (electricity, gas, water supply, sewerage, etc.) and basic services (medical, nursing care, postal, etc.) are restored and children's living environment is decontaminated;
- Adequate consultation with prefecture, municipalities and residents.

671 - MHLW, "Medical findings on the relationship between thyroid cancer and radiation exposure", Government of Japan, (in Japanese), see http://www.mhlw.go.jp/stf/houdou/0000146085.html, accessed 1 May 2017.

672 - Fukushima Labour Bureau, "Results of supervisory guidance for businesses that conduct decommissioning work at Fukushima Daiichi Nuclear Power Plant and the businesses that perform decontamination work in Fukushima Prefecture (2016)", MHLW, 6 March 2017, (in Japanese), see http://fukushima-roudoukyoku.jsite.mhlw.go.jp/var/revo/0143/9153/2017412174340.pdf, accessed 29 July 2017.

673 - Fukushima Prefecture, "Steps for Revitalization in Fukushima", 27 March 2017, see http://www.pref.fukushima.lg.jp/uploaded/attachment/213096.pdf, accessed 1 May 2017.

674 - Disaster Response Headquarters of Fukushima Prefecture, "Immediate report of damage due to the Great East Japan Earthquake of 2011 (Report number 1687)", 27 March 2017, (in Japanese), see http://www.pref.fukushima.lg.jp/uploaded/life/269699_638768_misc.pdf, accessed 1 May 2017.

675 - Nuclear Emergency Response Headquarters of the Cabinet Office, "The conditions for lifting evacuation orders", 12 June 2015, (in Japanese), see http://www.kantei.go.jp/saigai/pdf/hinan_youken.pdf, accessed 1 May 2017.

However, few people return after an evacuation order is lifted. For example, although the evacuation order of Naraha was lifted in September 2015, only 10 percent of the town's population and 16 percent of the households have returned as of the end of January 2017.[676]

According to a survey of residents' intentions conducted by the Reconstruction Agency in 2016, at the maximum only 18 percent of the households desired to return in each of the three municipalities among the five municipalities located in the evacuation zones.[677]

In August 2016, the government decided to implement measures for restoring and revitalizing difficult-to-return zones[678]. However, the specific content of the measures has not been decided at all.

The government has a keen interest in reducing these expenses and seems to be cutting off evacuees from support under the name of restoration and self-reliance assistance.

Evacuees from evacuation zones are receiving ¥100,000 (US$909) every month as compensation for damage such as emotional damage, medical treatment, and so on. However, the government has decided to terminate the compensation in March 2018 for all evacuees, regardless of the date of the lifting of the evacuation order for each area, except for the evacuees from the difficult-to-return areas for which there is no plan to lift the evacuation order.

After the Fukushima disaster started in March 2011, the government established the Dispute Reconciliation Committee for Nuclear Damage Compensation and repeatedly provided guidelines for assessment of nuclear damages through the committee. However, the government and the committee are yet to provide a clear explanation regarding the question of termination of the compensation for evacuees.

The government is actively implementing restoration projects and self-reliance support programs. For example, in the recovery budget for FY2017, METI is implementing a program for self-reliance support, in which it provides subsidies for companies that have suffered nuclear damages: ¥5.4 billion (US$49 million) is allotted for business restart and ¥18.5 billion (US$168 million) is contributed to new factory construction. Moreover, METI is providing ¥97.6 billion (US$887 million) for businesses involved in the robotics industry in Fukushima Prefecture.[679]

If the modest evacuee support of ¥100,000 (US$909) per month was spent for all of the 165,000 evacuees, it would still amount to almost ¥200 billion (US$1.8 billion) per year. The

676 - Nuclear Emergency Response Headquarters of the Cabinet Office, "The situation of the evacuation orders cancellation", 28 January 2017, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat1/sub-cat1-4/20170128_kyougikai_4shiryo3-2.pdf, accessed 1 May 2017.

677 - Reconstruction Agency, "Results of the investigation on the intentions of residents of municipalities affected by the nuclear accident", Government of Japan, 7 March 2017, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat1/sub-cat1-4/ikoucyousa/28ikouchousakekka_zentai.pdf, accessed 1 May 2017.

678 - Nuclear Emergency Response Headquarters of the Cabinet Office, "Concept on the management of the difficult-to-return zone", 31 August 2016, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/kinkyu/pdf/2016/0831_01.pdf, accessed 1 May 2017.

679 - Reconstruction Agency, "Budget approximate decision overview FY2017 (Reference material)", Government of Japan, December 2016, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat8/sub-cat8-3/20161222_3shiropansankou.pdf, accessed 26 July 2017.

government has a keen interest in reducing these expenses and seems to be cutting off evacuees from support under the name of restoration and self-reliance assistance. Norma Field, Professor Emeritus at the University of Chicago, is expressing concern that forced return is permitted by the word of "restoration".[680]

Greenpeace Japan has pointed out that evacuees may have to return to contaminated areas for economic reasons and has urged the Japanese government to secure compensation that fully covers all expenses.[681]

In its 2014 recommendation to the government, the Science Council of Japan—an institution that is independent from the government and composed of Japanese scientists—suggested extreme long-term evacuation for future return as the third option against the existing two options to either return to their hometown or relocate without any financial support. For the realization of this third option, with the assumption that evacuation may last for more than 30 years, the council proposed dual resident registration and issuance of an evacuees' record book, which would serve as a certificate. [682] However, the government has not yet responded to this recommendation.

The Fukushima Prefecture's citizens who evacuated voluntarily from locations outside the evacuation areas had been provided free housing, but this compensation was terminated on 31 March 2017. According to the survey conducted by Fukushima Prefecture as of June 2016,[683] there were over 12,400 households of voluntary evacuation; among the approximately 7,000 households that responded, about 4,700 households had no definite plans for the next residence to live in after April 2017.

The government and TEPCO insist that they are paying compensation money under an agreement, i.e., settlement payment, to the disaster-affected individuals and corporations. As of July 2017, the total amount had reached about ¥7.5 trillion (US$67.4 billion).[684]

On 17 March 2017, a judgment in a lawsuit against the government and TEPCO filed by nuclear accident evacuees was rendered for the first time. Although the judgment ruled that government and TEPCO were responsible for the accident and ordered the payment of compensation of about 38.5 million yen (US$350 thousand), the plaintiffs appealed the decision on grounds that they are dissatisfied with the outcome.

The problem of evacuated children being bullied has also become increasingly evident. On 11 April 2017, the Ministry of Education, Culture, Sports, Science and Technology (MEXT)

680 - Peggy McInerny, "Grappling With Nuclear Catastrophe In Japan", Terasaki Center For Japanese Studies, UCLA, 7 July 2016, see http://www.international.ucla.edu/japan/article/165856, accessed 29 July 2017.

681 - Kendra Ulrich, "Unequal Impact—Women's & Children's Human Rights Violations and the Fukushima Daiichi Nuclear Disaster", Greenpeace Japan, March 2017, see http://www.greenpeace.org/japan/Global/japan/pdf/Uequal-impact-en.pdf, accessed 28 June 2017.

682 - The Science Council of Japan, "Recommendations on Improvement of the Policy for Restoration from the Great East Japan Earthquake", 25 September 2014, (in Japanese), see http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-22-t200-1.pdf, accessed 26 July 2017.

683 - Fukushima Prefecture, "Investigation on intentions for housing", 20 June 2017, (in Japanese), see https://www.pref.fukushima.lg.jp/uploaded/attachment/170906.pdf, accessed 1 May 2017.

684 - TEPCO, "Records of Applications and Payouts for Indemnification of Nuclear Damage", 28 July 2017, see http://www.tepco.co.jp/en/comp/images/jisseki-e.pdf, accessed 5 August 2017.

conducted a nationwide survey of school bullying. As a result, it turned out that there have been at least 129 documented cases of bullying of evacuated children up to FY2016.[685]

Radiation Exposure and Health Effects

Thyroid examination for children, who were under 18 years old at the time of the accident, by Fukushima prefecture is still being conducted. The first round (preliminary survey) and the second round (1st full survey) have been completed. The third round (2nd full survey) started in April 2016 and is still underway. As of February 2017, no cancer diagnosis has been made in the third round yet.[686],[687]

In total, until now, 185 children have been diagnosed with cancer or suspected of having contracted cancer. Among them, 102 children underwent operation. Excluding one person who had a benign tumor, 101 out of those 102 children were confirmed of having cancer.[688] In the second round, 44 children underwent operation and all were confirmed of having cancer[689] (see Table 9).

Table 9 | Results of Thyroid Cancer Examinations 2011-2016

Survey (Period)		Subjects	Examined (Ratio to the subjects)	Cancer, suspected cancer	Operation performed	Operation results
1st round	Preliminary survey (October 2011 to March 2014)	367,672	300,476 (81.7%)	116	102	100: Papillary cancer 1: Other cancer (1: Benign)
2nd round	Full survey (1st) (April 2014 to March 2016)	381,282	270,489 (70.9%)	69	44	43 Papillary cancer 1 Other cancer
3rd round	Full survey (2nd) (From April 2016)	336,623	87,217 (25.9%) as of the end of 2016	-	-	-
Total				**185**	**146**	**145 (1: Benign)**

Sources: Compiled by the author based on the following materials:
Fukushima Prefecture, "The 23rd & 26th Prefectural Oversight Committee Meeting forFukushima Health Management Survey", 2017

In addition, the effective dose of radiation exposure of people who were suspected of having cancer or were diagnosed of cancer are as follows: In the 1st round, among the 65 children (56 percent of subjects), who submitted the questionnaire, the effective dose was <1 mSv for 46 children, <2 mSv for 18 children and <5 mSv for 1 child. The maximum value was 2.2 mSv.

685 - MEXT, "Results of the follow-up on bullying of students who evacuated from Fukushima Prefecture due to the nuclear power accident", Government of Japan, 11 April 2017, (in Japanese), see http://www.mext.go.jp/b_menu/houdou/29/04/__icsFiles/afieldfile/2017/04/11/1384371_2_2.pdf, accessed 1 May 2017.

686 - Fukushima Prefecture, "The 26th Prefectural Oversight Committee Meeting for Fukushima Health Management Survey", 20 February 2017, see http://fmu-global.jp/survey/the-26th-prefectural-oversight-committee-meeting-for-fukushima-health-management-survey-2/, accessed 1 May 2017.

687 - Fukushima Prefecture, "Report of Third-Round Thyroid Ultrasound Examinations (Second Full-Scale Thyroid Screening Program)", 20 February 2017, see http://fmu-global.jp/?wpdmdl=2200, accessed 1 May 2017.

688 - See Appendix 7: Fukushima Prefecture, "Thyroid Ultrasound Examination (Preliminary Baseline Screening) Supplemental Report of the FY 2015 Survey", 6 June 2016, see http://fmu-global.jp/?wpdmdl=1632, accessed 1 May 2017.

689 - See Appendix 6: Fukushima Prefecture, "Report of Second-Round Thyroid Ultrasound Examinations (First Full-Scale Thyroid Screening Program)", 20 February 2017, see http://fmu-global.jp/?wpdmdl=2199, accessed 1 May 2017.

In the 2nd round, among the 36 people (52.2 percent of subjects), who submitted the questionnaire, the effective dose was <1 mSv for 15 people, <2 mSv for 16 people and <5 mSv for five people. The maximum was 2.1 mSv.

The evaluation group conducting the survey consistently stated that "it cannot be concluded whether or not the incidences of thyroid cancer found in the examination are due to exposure from the Fukushima accident." Discussions on the cause of thyroid cancer (see WNISR 2016) have not yet been concluded. At present, the number of cancer cases found in these children is about 30 times that of the national average. There are two hypotheses: one is that it is the result of overdiagnosis and the other is that the result is due to the effect of radiation exposure.[690, 691]

Government and TEPCO do not pursue their own investigations into the problem. Fukushima Prefecture is the only entity that has carried out examinations and has continuously provided patients with payments to cover thyroid cancer treatment costs after establishing a dedicated fund.

Food Contamination

The inspection of radioactive substances in food is continuing. For example, ten items distributed or non-distributed agricultural, livestock or fishery items in the prefectures subject to the inspection exceeded the legal limit—100 Bq/kg of radioactive total cesium (cesium-134 + cesium-137)—according to inspections conducted by the Ministry of Health, Labor and Welfare (MHLW) in the week of 15–21 May 2017.[692]

However, shipment restrictions—restrictions on shipment and consumption of foods containing radioactive materials at levels exceeding the legal limit—have not yet been lifted for some food stuffs in some prefectures; e.g., shiitake mushrooms grown outdoors, trout, wild boar and wild deer.[693]

Monitoring survey results of agricultural, forestry and fishery products in Fukushima Prefecture are summarized in Table 10.[694]

Since the results demonstrated a decline in the share of foods that exceeded the legal limits, on 24 March 2017, MHLW revised the guidelines on shipping restrictions on food.[695] From then

690 - *The Mainichi*, "Experts divided on causes of high thyroid cancer rates among Fukushima children", 7 March 2016, see https://mainichi.jp/english/articles/20160307/p2a/00m/0na/022000c, accessed 28 June 2017.

691 - Dennis Normile, "Mystery cancers are cropping up in children in aftermath of Fukushima", *Science*, 4 March 2016, see http://www.sciencemag.org/news/2016/03/mystery-cancers-are-cropping-children-aftermath-fukushima, accessed 28 June 2017.

692 - MHLW, "Levels of radioactive contaminants in foods reported on 15–21 March 2017 (Test results carried out since 1 April 2012)", Government of Japan, see http://www.mhlw.go.jp/english/topics/2011eq/dl/15-21_May_2017.pdf, accessed 5 August 2017.

693 - MHLW, "Restriction of shipment for foods based on the Act on Special Measures Concerning Nuclear Emergency Preparedness", Government of Japan, 31 March 2017, (in Japanese), see http://www.mhlw.go.jp/file/04-Houdouhappyou-11135000-Shokuhinanzenbu-Kanshianzenka/0000160151_1.pdf, accessed 1 May 2017.

694 - Compiled by the authors based on the following materials: Fukushima Prefecture, "Monitoring results of agricultural, forestry and fishery products, FY2011 - FY 2016", (in Japanese), see http://www.pref.fukushima.lg.jp/site/portal/89-4.html, accessed 1 May 2017.

695 - Nuclear Emergency Response Headquarters of the Cabinet Office, "Concept of the inspection plan and concept of the setting and cancelling of shipping restriction items and areas", 24 March 2017, (in Japanese), see http://www.mhlw.go.jp/file/04-Houdouhappyou-11135000-Shokuhinanzenbu-Kanshianzenka/0000156398.pdf, accessed 1 May 2017.

on, each local government can relax the inspection subjects and can decrease the inspection frequency, if the measured values of radioactive materials in food stuffs continue to be less than half of the limit (50 Bq/kg) in all of the samples analyzed within the past three years. However, wild mushrooms, birds, wild animals and freshwater fish are excluded from this rule.

However, citizens remain concerned. The Consumer Affairs Agency has been conducting a survey on "harmful rumors" since 2013. In the report of October 2016, 16.6 percent of the respondents were hesitant to purchase products grown in Fukushima Prefecture and 21.0 percent of them responded that they would not take any radiation risk, even if the level of radiation is so low that it cannot be detected. These survey results are almost identical to those of the past years.[696]

Table 10 | Total Cesium Measured in Food Products in Fukushima Prefecture

Fiscal Year (Period)	Number of items	Number of inspections	Number of items exceeding the standard (100 Bq/kg)	Percentage of total
FY2011 (March 2011-March 2012)	542	19,971	681 [a]	3.4%
FY2012 (April 2012-March 2013)	509	61,531	1106	1.8%
FY2013 (April 2013-March 2014)	469	28,770	419	1.5%
FY2014 (April 2014-March 2015)	488	26,041	113	0.4%
FY2015 (April 2015-March 2016)	496	23,855	18	0.08%
FY2016 (April 2016-March 2017)	530	21,180	6	0.03%

Sources: Fukushima Prefecture, 2011-2017, Compiled by WNISR, 2017[697]

a - Only for monitoring in FY 2011, the provisional regulation value (500 Bq/kg) was applied.

Decontamination[698]

Decontamination work of areas contaminated by radioactive materials is still in progress. Decontamination areas are divided into two categories:

- the Decontamination Special Area that targets areas of severe contamination near the Fukushima Daiichi nuclear power plant;
- the Decontamination Implementation Area that targets wide-spread areas across several prefectures.

The Decontamination Special Area consists of places with a calculated cumulative dose for one year after the accident that exceeds 20 mSv and the area within a 20-km radius of the Fukushima Daiichi site. According to the government, decontamination in all these areas was completed by the end of March 2017 as scheduled in the original plan. The target covered

696 - Consumer Affairs Agency, "The 8th survey of consumer awareness on harmful rumors —Results of the 8th survey of consumer awareness on radioactive materials in foods", 5 October 2016, (in Japanese), see http://www.caa.go.jp/earthquake/understanding_food_and_radiation/pdf/161005kouhyou_1.pdf, accessed 1 May 2015.

697 - Based on the following sources: Fukushima Prefecture, "Monitoring results of agricultural, forestry and fishery products", FY2011 - FY 2016, (in Japanese).

698 - Ministry of the Environment, "Progress on Off-site Cleanup and Interim Storage Facility in Japan", Government of Japan, April 2017, see http://josen.env.go.jp/en/pdf/progressseet_progress_on_cleanup_efforts.pdf, accessed 1 May 2017.

22,000 residential areas, 8,500 hectares (ha) of farmland, 5,800 ha of forest and 1,400 ha of roads.

The Ministry of Environment claims that the decontamination work has been effective. For example, the air dose rate at the height of 1 m above the ground was reportedly decreased on average from 1.28 µSv/h to 0.37 µSv/h (71 percent reduction) at residential lands and from 1.10 µSv/h to 0.43 µSv/h (61 percent reduction) on roads. However, as for forest target areas, only forests near houses (within 20 meters from a human-inhabited area) were decontaminated.

In addition, seven municipalities out of the eleven municipalities targeted for decontamination have difficult-to-return areas, in which no decontamination work has been carried out so far.

The total amount of contaminated soil and waste collected has reached approximately 16 million m³. If this quantity was placed on a football field (100 m x 70 m), the radioactive waste column would be over 2 km high.

This is one of the reasons, why there are many people, who refuse to go home even after the evacuation order is lifted.

The Decontamination Implementation Area consists of a part of Fukushima Prefecture excluding areas covered by the Decontamination Special Area and six other prefectures. The areas lead to an additional calculated radiation dose of 1 mSv/year due to the Fukushima accident. Decontamination of these areas is carried out by each local government, rather than by national authorities. The following buildings and areas were set as the targets:

- *Inside* Fukushima Prefecture: 421,000 homes, 11,700 public facilities, 19,000 km of roads, 31,500 ha of farmland and meadowland and 4,700 ha of forests (located within human-inhabited areas);
- *Outside* Fukushima Prefecture: 147,700 homes, 1,591 schools and nursery schools, and 3,945 parks and sports facilities.

As of the end of March 2017, 80 of 92 municipalities had completed their decontamination projects. The cumulative cost of these decontamination projects reached approximately ¥2.6 trillion (US$23.6 billion) as of FY 2016.[699] The total amount of contaminated soil and waste collected has reached approximately 16 million m³. If this quantity was placed on a football field (100 m x 70 m), the radioactive waste column would be over 2 km high.

The government is planning to install interim storage facilities for the Decontamination Special Area in Fukushima Prefecture. They plan to place these facilities around the Fukushima Daiichi nuclear power plant site, but there has been a delay in the procedure to acquire the land. So far, the government has been able to sign contracts for only 18 percent (287 ha) of the privately-owned land (1,270 ha) necessary to build the facilities.[700] Moreover, Fukushima Prefecture has permitted interim storage for only about 30 years. Although the government

699 - Ministry of the Environment, "Current status, outcomes and prospects of decontamination / intermediate storage facility / radioactive waste disposal", Government of Japan, 3 March 2017, (in Japanese), see http://josen.env.go.jp/material/pdf/outcome_outlook_170303.pdf, accessed 1 May 2017.

700 - Ministry of the Environment, "Situation of intermediate storage facilities sites as of the end of March 2017", Government of Japan, (in Japanese), see http://josen.env.go.jp/plaza/info/weekly/pdf/weekly_170407f.pdf, accessed 1 May 2017.

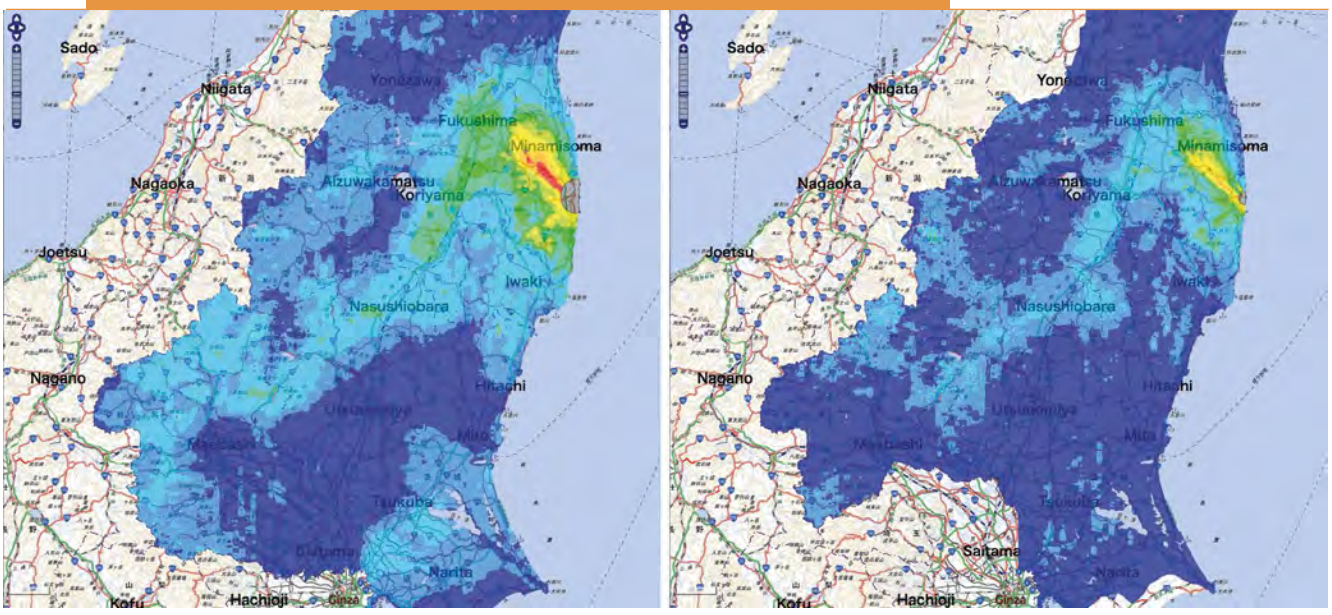
intends to find a final disposal site outside the prefecture, no progress has been made in implementing this plan.

Decontamination waste in the Decontamination Implementation Area is to be stored and disposed of by each local government. However, no disposal site plan has been finalized by any local government due to opposition of local citizens.

The Ministry of the Environment has defined decontamination waste with cesium concentration of 8,000 Bq/kg and above as designated waste. The ministry is currently planning to reuse the waste with concentrations below that limit.[701]

As of March 2017, the ministry is evaluating the possibilities of reusing the waste for roads, tide embankments and open spaces such as parks. However, the government had set the standard—the clearance level—of radioactive cesium concentration in 2005 as 100 Bq/kg for waste that is not required to be treated as radioactive waste to reduce the amount of disposal waste from the decommissioning of nuclear power plants. Many people are opposing the reuse of decontamination waste from the Fukushima accident because the standard is much higher than this clearance level.

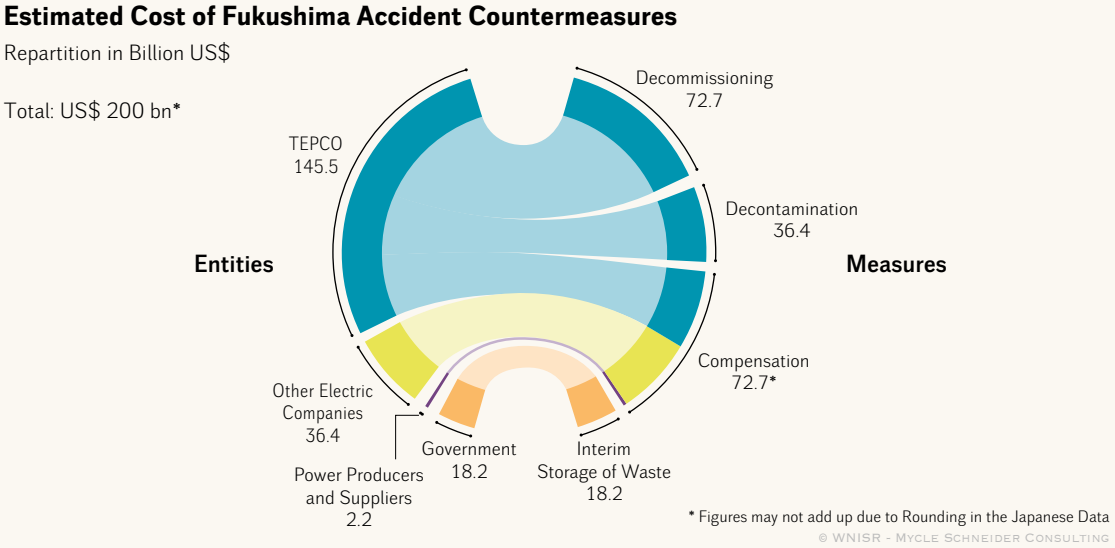
Figure 38 | Distribution of Radiation Doses According to Airborne Monitoring



Sources: Compiled by WNISR, based on MEXT, "Extension site of distribution map of radiation dose, etc.", 2017

701 - Ministry of the Environment, "Technology development strategy review committee for volume reduction/recycling of soil from the interim storage", Government of Japan, 2017, (in Japanese), see http://josen.env.go.jp/chukanchozou/facility/effort/investigative_commission/, accessed 1 May 2017.

Figure 39 | Estimated Cost of Fukushima Accident Countermeasures



Sources: Compiled by WNISR, based on Committee for Reforming TEPCO and Overcoming 1F Challenges, "TEPCO's reform proposal", 20 December 2016.

Note: 1US$=110JPY as of 29 July 2017

COSTS INVOLVED

In the fall of 2016, METI established a committee to discuss the management reform of TEPCO.[702] Through this committee, on 9 December 2016, METI officially presented a cost estimate for settling all problems caused by the Fukushima accident for the first time.[703] According to the committee's estimate, the total cost would reach about ¥22 trillion (US$200 billion), of which ¥8 trillion (US$72.7 billion) required for decommissioning and contaminated water countermeasures, ¥8 trillion (US$72.7 billion) for compensation, ¥4 trillion (US$36.4 billion) for decontamination and ¥2 trillion (US$18.2 billion) for interim storage sites for decontamination wastes (see Figure 39).

METI stated in its recommendations that the cost will be recovered over a 30-year period. There are many problems regarding the methods to cover these costs. For example, the committee assumes that the costs will be partially recovered by the revenue from Kashiwazaki-kariwa nuclear power plant in Niigata prefecture owned by TEPCO (estimated to generate 0.1 trillion yen (US$0.91 billion) in revenues for two units). However, there is no clear prospects of restarting operations at this nuclear power plant, as it is under review by NRA, and Niigata Prefecture is strongly opposed to any restart.

The decommissioning cost was calculated by taking examples from the Three Mile Island accident on 28 March 1979 in the United States. However, since the method for removing and disposing of debris from Fukushima Daiichi is not decided yet, its validity is unknown.

702 - METI, "Committee for Reforming TEPCO and Overcoming 1F Challenges (TEPCO Committee) to be Established", Government of Japan, 20 September 2016, see http://www.meti.go.jp/english/press/2016/0920_002.html, accessed 1 May 2017.

703 - Committee for Reforming TEPCO and Overcoming 1F Challenges, "TEPCO's reform proposal", METI, Government of Japan, 20 December 2016, (in Japanese), see http://www.meti.go.jp/committee/kenkyukai/energy_environment/touden_1f/pdf/161220_teigen.pdf, accessed 1 May 2017.

In addition to power companies that have nuclear power plants other than TEPCO, the new power companies that have newly entered the market due to the liberalization of electricity—independent power producers and suppliers—are also required to contribute to cost coverage.

In a questionnaire-based survey conducted by *Kyodo News* in April 2017, 29 out of 44 new power companies, that entered the market following liberalization of electric power retailers, are objecting to this policy, claiming that it affects their business.[704]

According to another survey conducted by *Asahi Shimbun* in February 2017, it was found that additional charges added to the consumers' power bill range from ¥587 to ¥1,484 (US$5.3–13.5) per household per year. According to the example of TEPCO described in this survey, the cost covered by every household in 2016 was ¥0.25/kWh (US$c2.3) with a total annual additional "Fukushima fee" to the average Tokyo household reaching ¥1,160 (US$10.5).[705]

This "Fukushima fee" might need to increase dramatically, according to an independent assessment of the potential costs of the disaster. The Japan Center for Economic Research (JCER) considers that the Japanese government seriously underestimates the costs for contaminated water management, decommissioning and waste management.[706] JCER bases its numbers on industry practice at other nuclear sites and expert interviews. The result is astonishing as total costs could range anywhere between close to ¥50 trillion (US$453 billion) and ¥70 trillion (US$635 billion), respectively 2.3 and 3.2 times the official government estimate. However, JCER does not consider this an upper boundary as many questions remain open, in particular, there is no guarantee that the corium can actually be recovered. No scenario has been calculated that would include the design and construction of some kind of sarcophagus (as in Chernobyl) or entombment.

Since the cost of damages caused by the Fukushima accident turns out much higher than expected, the Japan Atomic Energy Commission is currently reviewing the nuclear damages compensation system. Under the current system, except for natural disasters and warfare, nuclear power companies are fully responsible for accidents (unlimited liability). Electric power companies are obliged to join an insurance plan and insurance benefits of up to 120 billion yen (US$1.1 billion) is used as a source of compensation.

In the discussion, electric power companies insisted for a change to limited liability; that is, to shift to a system in which compensation payments exceeding a certain amount are covered by the government. However, on the basis that the burden on citizens through taxes would increase, the government decided to retain the unlimited liability policy, which keeps electric power companies fully responsible.[707] The above described complicated mechanism seems to have been put in place for the government to escape from liability rather than to salvage

704 - *Tokyo Shimbun*, "Compensation burden of nuclear accident—60% of new electric companies are against it as 'It affects business management'", 3 April 2017, (in Japanese), see http://www.tokyo-np.co.jp/article/economics/list/201704/CK2017040302000103.html - print, accessed 1 May 2017.

705 - Keishi Nishimura, "The hidden costs households must pay for nuclear disaster in 2011", *The Asahi Shimbun*, 27 February 2017, see http://www.asahi.com/ajw/articles/AJ201702270056.html, accessed 5 August 2017.

706 - JCER, "Accident Cleanup Costs May Rise to 50–70 Trillion Yen—It's Time to Examine legal liquidation of TEPCO-Higher Transparency is Needed for the Reasons to Maintaining Nuclear Power", 7 March 2017, see https://www.jcer.or.jp/eng/research/policy.html, accessed 2 August 2017.

707 - JAEC, "The 15th nuclear damages compensation system special committee", 16 November 2016, (in Japanese), see http://www.aec.go.jp/jicst/NC/senmon/songai/siryo15/index.htm, accessed 1 May 2017.

TEPCO. However, the responsibility of TEPCO is, after all, also covered by the electricity fee paid by the public.

Table 12 | Government and Independent Assessments of Cleanup and Remediation Costs of the Fukushima Daiichi Nuclear Disaster (in billion US$)

Measures	Previous Government Estimate US$ bn	Latest Government Estimate US$ bn	JCER Estimate [a] US$ bn	JCER Estimate [b] US$ bn
Decommissioning and Contaminated Water Management	18	72.7	288	99
Compensation	45	72.7	72	75
Decontamination	36	54.6	270	270
Total	**≈ 100**	**≈ 200**	**≈ 630**	**≈ 444**

a - includes the cost of cleaning up the tritiated water (USD180,000/ton, 1 million tons of stored water) based on interviews with experts in decommissioning nuclear reactors and cleaning up contaminated water.

b - includes diluting the tritiated water including one million tons of stored water, and releasing all of it into the ocean (not included as the costs are small), and US$2.7 billion to compensate fishermen—in a degressive way over a period of 40 years—for damage caused to the reputation of fishing goods.

The processing costs for the final disposal of 22 million cubic tons of rubble and soil arising from the decontamination is based on the unit price for processing low-level radioactive waste at Rokkasho in Aomori Prefecture.

Source: Japan Center for Economic Research, March 2017[708]

CONCLUSION ON FUKUSHIMA STATUS REPORT

Now that six years have passed since the Fukushima disaster began, problems specific to nuclear power plant accidents have become clearer. One issue is the size of the economic burden caused by the accidents. The large amount of accident-related expenses has become a factor that hinders economic development policies in Japan.

The second issue is the attitude of the government to avoid taking responsibility and escaping liability for the accident. The government has taken actions actively, such as implementing decommissioning measures and lifting evacuation orders, in efforts to erase the memories and lower the financial burden of the accident for the state.

The third issue is the impact on economically and socially vulnerable people. The burden on economically weak areas, such as regions with nuclear power stations or evacuees, and socially vulnerable people, such as women and children who are worried about potential health effects, is becoming increasingly burdensome.

708 - Ibidem.

NUCLEAR POWER VS. RENEWABLE ENERGY DEPLOYMENT

INTRODUCTION

The comparison between nuclear and renewable energies has for a long time been a tale of "too big to fail" on the one hand, and "too small to matter" on the other. But things have changed at a frenetic pace in the past few years. Once overlooked as a technological "niche", renewable energies are now becoming an increasingly dominant player in the global energy landscape. Data for the year 2016 shows the extent to which renewables have overtaken nuclear power as a means of developing electricity generating capacities:

- Even though overall investment volume decreased, new renewable electricity generating capacity additions reached an all-time high of 161 GW in 2016, representing 62 percent of total power production capacities added worldwide. In the EU alone, 86 percent of new generating capacity connected to the grid in 2016 came from wind, solar, biomass and hydro, with wind power representing more than half of the added capacity.[709]
- In 2016 and early 2017, new projects highlighted a drop in generating costs that many believed would only happen around 2030 such as a US$24/MWh for a 350 MW solar project in Abu Dhabi.[710] In Morocco, 850 MW of onshore wind were signed for the strike price of US$30/MWh.[711] And even offshore wind projects might soon deploy without additional subsidies, as illustrated by a recent tender in Germany, where utility EnBW made a bid for a 900 MW project relying only on future revenues from the wholesale market.[712]
- And in the meantime, only three nuclear reactors started construction in 2016, for a total of 3 GW of generating capacity, which will take years to produce their first kilowatt-hours (see previous chapters).

The shifting roles of nuclear power and renewables have also been acknowledged in the fight against climate change, as highlighted by the 21st Conference of the Parties in Paris in December 2015. For the Paris Agreement 162 national pledges called Intended National Determined Contributions (INDCs) were submitted to the UNFCCC covering around 95 percent of global emissions in 2010 and 98 percent of the global population. The extent to which nuclear power is included within these plans is limited, as just the 31 countries currently operating commercial reactors, plus Turkey and Egypt, refer to nuclear power, or only around one in five Paris pledges. Furthermore, expansion of the sector, through construction of new

709 - WindEurope, "Wind in power—2016 European statistics", February 2017, see https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2016.pdf, accessed 20 June 2017.

710 - Anthony Dipaola, "Cheapest Solar on Record Offered as Abu Dhabi Expands Renewables", *Bloomberg*, 19 September 2016, see https://www.bloomberg.com/news/articles/2016-09-19/cheapest-solar-on-record-said-to-be-offered-for-abu-dhabi, accessed 20 June 2017.

711 - Michael Liebreich and Angus McCrone, "Liebreich and McCrone: 10 renewable energy predictions for 2017", BNEF, 18 January 2017, see https://about.bnef.com/blog/10-renewable-energy-predictions-2017/, accessed 20 June 2017.

712 - OffshoreWind.biz, "EnBW Wins Construction of 900MW German OWF by Bidding EUR 0/MWh", 13 April 2017, see http://www.offshorewind.biz/2017/04/13/enbw-wins-construction-of-900mw-german-owf-by-bidding-eur-0-per-mwh/, accessed 20 June 2017.

reactors, is taking place in only 12 of these countries with an additional two countries, Belarus and United Arab Emirates, building for the first time.

Within the actual INDCs only eleven countries mentioned that they were operating or considering to operate nuclear power as part of their mitigation strategy and even fewer (five) actually state that they were proposing to expand its use (Belarus, India, Japan, Turkey, and UAE). This compares with 144 that mention the use of renewable energy and 111 that explicitly mention targets or plans for expanding its use.[713] This highlights the extent to which nuclear power is a niche carbon abatement strategy, compared to the use of renewables which is universal.

In the longer term, while most global models assume that a decarbonized energy sector will include a combination of renewables, nuclear and fossil fuels with carbon capture, there are a significant number of well-respected studies that assume a nuclear- and fossil-free energy future. These include:

- The "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 139 Countries of the World", published by Stanford University.[714]
- The "Global Energy Assessment 2012", published by Cambridge University press, states "that it is also feasible to phase-out nuclear and still meet the sustainability targets".[715]
- The "Special Report of the International Panel on Climate Change [IPCC]" on renewable energy sources from 2012, reviews a number of scenarios, which limit the use of different supply options, including renewables, nuclear power and Carbon Capture and Storage (CCS). Some of these scenarios show no additional costs associated with the nuclear-free option, while meeting global mitigation targets.[716]
- Global Energy Revolution, published and regularly updated by Greenpeace International, is a comprehensive 100-percent renewable energy scenario.[717]

Therefore, it is not so much a question of having to deploy nuclear in order to decarbonize, but whether or not Governments choose to actively support nuclear power—in particular through some kind of subsidy mechanism—as a means of climate mitigation.

While no energy source comes without economic costs and environmental impacts, what has been seen clearly over the past decade, and particularly in the past few years, is that choosing to decarbonize with nuclear turns out as an expensive, slow, risky and potentially hazardous pathway that few countries are pursuing. In contrast, some renewable energy sources, particularly wind and solar photovoltaics (PV), are being deployed at rates significantly in excess

713 - UNFCCC, "Intended Nationally Determined Contributions", United Nations Framework Convention on Climate Change, 2015, see http://unfccc.int/focus/indc portal/items/8766.php, accessed 20 June 2017.

714 - Marc Z. Jacobson, et al., "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 139 Countries of the World", Stanford University, November 2016, see https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf, accessed 20 June 2017.

715 - GEA, "Global Energy Assessment—Toward a sustainable future", International Institute for Applied Systems Analysis, Cambridge University Press, 2012.

716 - IPCC, "Renewable Energy Sources and Climate Change Mitigation—Special Report of the Intergovernmental Panel on Climate Change", February 2012.

717 - Greenpeace International, Global Wind Energy Council and SolarPower Europe, "Energy [R]evolution—A sustainable world—Energy Outlook 2015", September 2015, see http://www.greenpeace.org/international/Global/international/publications/climate/2015/Energy-Revolution-2015-Full.pdf, accessed 20 June 2017.

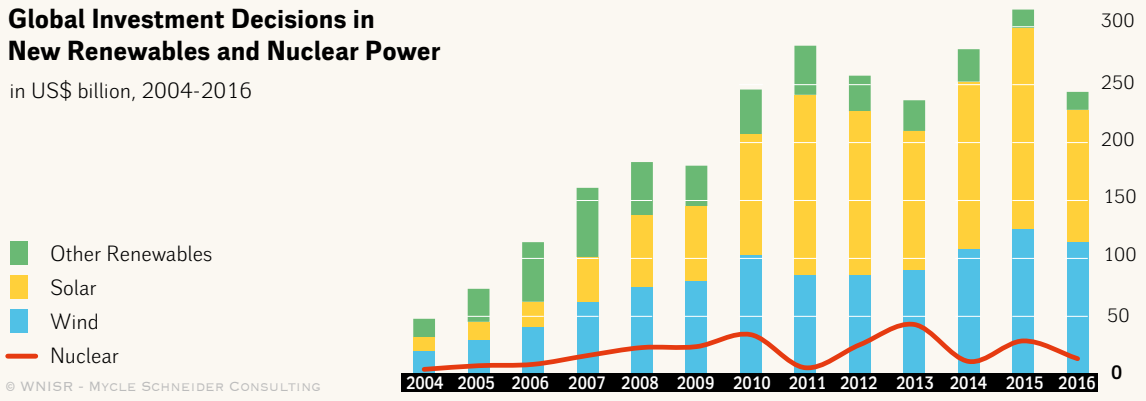
of those forecasted even in recent years, causing production and installation costs to fall even faster than expected.[718]

This section highlights the differences between the deployment rates and associated investment and cost levels for nuclear power and some renewable energy technologies on the global level and in key regions and markets.

INVESTMENT

The investment decisions taken are not only an important indicator of the future power mix, but they also highlight the confidence that the technology-neutral financial sector has in different power generation options. Consequently, they can be seen as an important barometer of the current state of policy certainty and costs of technologies on the global and regional levels.

Figure 40 | Global Investment Decisions in Renewables and Nuclear Power 2004-2016



Sources: FS-UNEP, 2017 and WNISR Original Research

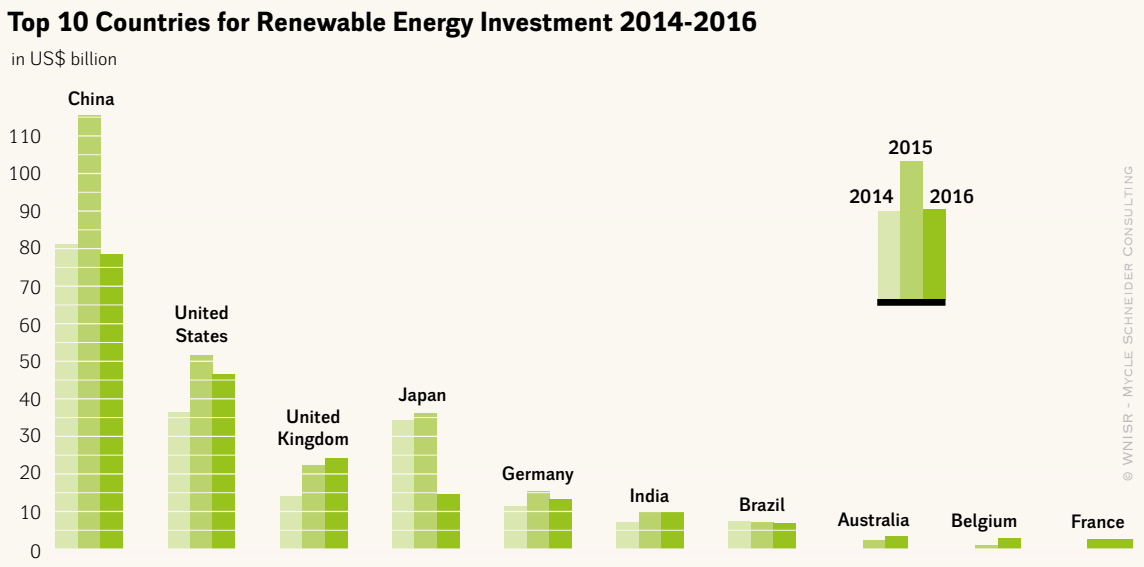
According to data published by Bloomberg New Energy Finance (BNEF) and United Nations Environment Programme (UNEP), global investment in renewable energy—excluding large hydro—was US$241.6 billion in 2016, down from a record high 312.2 billion in 2015.[719] But the 23 percent fall in total investment volume mainly reflects the rapid reduction in investment costs per MW as total renewable capacities installed in 2016 (excluding large hydro) added up to 138.5 GW, greater than 127.5 GW the year before. Thus, the average investment costs per installed MW across all renewable technologies were 29 percent lower in 2016: US$1.74 per W, against US$2.45 per W in 2015. According to UNEP-FS, global average generating costs for solar PV decreased by 17 percent to US$101/MWh within just one year, those for onshore wind by 18 percent to US$68/MWh and offshore wind went one step ahead with an average levelized cost of US$126/MWh, down 28 percent.

718 - IEA, "Commentary: The success of wind and solar is powered by strong policy support", International Energy Agency, 1 June 2017, see https://www.iea.org/newsroom/news/2017/june/commentarythe-success-of-wind-and-solar-is-powered-by-strong-policy-support.html, accessed 20 June 2017.

719 - FS-UNEP and BNEF, "Global trends in renewable energy investment 2017", March 2017, see http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf, accessed 20 June 2017. Please note that figures for previous years have been corrected in the 2017 report due to new data, resulting in a significant increase in renewable investments in 2015 at US$312.2 billion, compared to US$285.9 billion in the 2016 report.

Figure 40 compares the annual investment decisions for the construction of new nuclear with renewable energy excluding large hydro since 2004. Regarding nuclear, only three new power plants started construction in 2016—comparing to eight new projects in 2015—two in China and one in Pakistan (built by a Chinese company), totaling 3 GW of capacity and about US$10 billion in total investment. In the absence of comprehensive, publicly available investment estimates for nuclear power by year, and in order to simplify the approach, WNISR includes the total projected investment costs in the year in which construction was started, rather than spreading them out over the entire construction period. Furthermore, the nuclear investment figures do not include revised budgets if cost overruns occur. However, despite all of these uncertainties, it is clear that the investment decisions in nuclear construction are about one order of magnitude lower than that in solar or wind alone, each attracting over US$110 billion investments in 2016.

Figure 41 | Top 10 Countries for Renewable Energy Investment 2014-2016



Source: FS-UNEP 2017, 2016, 2015

Globally, the importance of Europe and North America for renewable energy investments is diminishing, with the rise of Asia, especially China, India and Japan. Chinese nominal-dollar renewable investment rose 13.9-fold from 2005 (US$8.3b) to 2015 (US$115.4b). Figure 41 shows the evolution of nominal-dollar renewable energy investment in major economies from 2014. Overall, developing and emerging countries make up an increasing share of total renewable investments, even though the decrease in total investment volume was stronger in these countries, falling by 30 percent compared to the previous year, compared to 14 percent for industrialized countries. 2016 also shows some significant changes at the bottom of the Top-10 countries for investments, with Australia, Belgium, and France replacing South Africa, Mexico, and Chile. Various reasons explain this, notably uncertainty over public funding (South Africa, where the national utility ESKOM has been blocking project approvals), delays due to limited access to project finance (Mexico), and bottlenecks in the transmission grids (Chile).

RECORD-LOW PRICE LEVELS ACROSS THE WORLD

Across the world, new records have been achieved in generation cost reductions for renewable energy projects. Indeed, both solar PV and wind power present exceptional learning rates. For solar, this is estimated at up to 24.3 percent per doubling of cumulative production, with real prices plummeting by 90 percent since 2009 alone. For wind power, an estimated learning curve of 19 percent has resulted in a 50 percent reduction in real prices between 2009 and 2016.[720] This comes in stark contrast to the negative learning curve generally associated to nuclear construction projects over the past decades.[721] Thus renewables are not only increasingly competitive compared to new nuclear power plants, but also becoming a serious challenger to coal and gas power plants in many countries.

solar plus overnight storage for "significantly less" than US$45/MWh

The rapid decrease in costs for major renewable generation technologies can be illustrated through project examples across the world. According to the Renewable Energy Auctions study published by the International Renewable Energy Agency (IRENA) in 2017, the average prices resulting from auctions have decreased significantly since 2010: by a factor of five for solar PV (from US$250/MWh in 2010 to US$50/MWh in 2016), and by a factor of two for onshore wind power (from US$80/MWh in 2010 to US$40/MWh in 2016). As a matter of comparison, after the announcement of the latest cost increase in early July 2017,[722] the two EPR reactors at the Hinkley Point C site in the UK have estimated overnight construction costs (excluding financing costs) of £20.3 billion (US$26.2 billion) or US$8,200/kW, with a negotiated strike price of £92.5/MWh (US$118/MWh) indexed on inflation. Examples of record low prices for renewable projects achieved in 2016-17 include the following:[723]

- In the **USA**, in May 2017, prices for solar PV came in below US$30/MWh for a power-purchase agreement signed between the Tucson Electric Power and NextEra Energy for a 100 MW plant. The system will integrate a 120 MWh storage facility and solar plus overnight storage for "significantly less" than US$45/MWh over 20 years.[724]
- **Mexico** organized two large-scale auctions for new electricity generation capacities between April and September 2016. A total of 2,085 MW (81 percent solar, 19 percent wind power) were

720 - Michael Liebreich, "Syndicat des Énergies Renouvelables", BNEF, as presented at the Syndicat des Énergies Renouvelables Conference in Paris, 31 January 2017, see http://ser-evenements.com/IMG/pdf/2._m._liebreicht_-_bnef.pdf, accessed 20 June 2017.

721 - Benjamin K. Sovacool, Alex Gilbert and Daniel Nugent, "An international comparative assessment of construction cost overruns for electricity infrastructure", *Energy Research & Social Science*, 1 September 2014, see http://www.qualenergia.it/sites/default/files/articolo-doc/1-s2.0-S2214629614000942-main(1).pdf, accessed 22 July 2017.

722 - Adam Vaughan, "Hinkley Point C is £1.5bn over budget and a year behind schedule, EDF admits", *The Guardian*, 3 July 2017, see https://www.theguardian.com/uk-news/2017/jul/03/hinkley-point-c-is-22bn-over-budget-and-a-year-behind-schedule-edf-admits, accessed 5 July 2017.

723 - Prices according to the following reference, unless otherwise noted: IRENA, "Renewable Energy Auctions—Analysing 2016", International Renewable Energy Agency, June 2017, see http://www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_Energy_Auctions_2017.pdf, accessed 21 June 2017.

724 - *Utility Dive*, "How can Tucson Electric get solar + storage for 4.5c/kWh", 30 May 2017, see http://www.utilitydive.com/news/how-can-tucson-electric-get-solar-storage-for-45kwh/443715/, accessed 10 August 2017.

awarded in the first round, with an average striking price of US$55/MWh for wind and US$45/MWh for solar. Only a few months later, the second round of auctions for a total of 3462 MW saw a spectacular drop in prices: a total of 1,573 MW of solar was awarded at an average price of US$32/MWh, along with 900 MW of wind power at only US$36/MWh.

- In **Chile**, Spanish developer Solarpack Corp. Tecnologica won contracts to sell power from a 120 MW PV power plant for US$29.10/MWh.
- Similarly, in **Peru** a 162 MW wind power project by Spanish developer Grenergy was awarded for US$37/MWh, with solar coming in at US$48/MWh for a total of 144 MW awarded by Enel Green Power.
- In **Morocco**, an 850 MW onshore wind project was signed at an average strike price of US$30/MWh in January 2016.
- In the **United Arab Emirates**, the Masdar conglomerate won a first solar project in May 2016 at a price of US$29.9/MWh. This was later surpassed by another 350 MW project in Abu Dhabi, which came in at US$24/MWh.
- In Europe, prices have dropped quickly as well. In **France**, a recent tender for 500 MW solar PV resulted in a strike price of €62.5/MWh (US$68/MWh).[725] In a cross-border tender for solar PV in **Germany**, several projects for 50 MW in Denmark made a winning bid with a strike price of US$59/MWh (about twice recent prices in North American sites with roughly twice as much sun). In another tender for offshore wind projects, German utility EnBW made a bid for a 900 MW project relying only on future revenues from the wholesale market without any price guarantee.[726]
- In **India,** a 750 MW PV project (currently considered as the world's largest) has been awarded at an average price of US$46/MWh (Rs 2,970/h).[727]

INSTALLED CAPACITY AND ELECTRICITY GENERATION

Globally, renewable energy continues to dominate new capacity additions. In total 161 GW of renewables capacity was added in 2016, according the REN21, which was the largest increase ever.

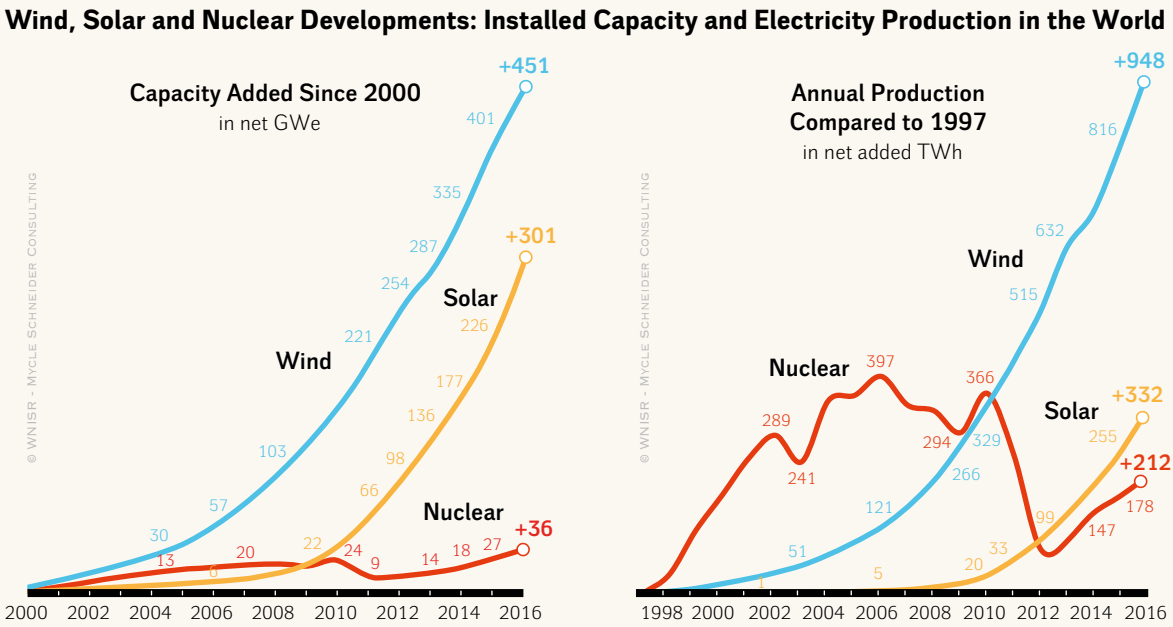
In 2016, renewables accounted for 62 percent of net additions to global power generating capacity. Net capacity additions of wind power slowed down a bit (55 GW in 2016 compared to 64 GW in 2015), while solar PV reached a new record growth of 75 GW (51 GW in 2015), com-

725 - Tecsol, "Appel d'offres CRE4 : JPee dans le trio de tête des lauréats avec 62 MW obtenus", Tecsol, 14 March 2017, (in French), see http://tecsol.blogs.com/mon_weblog/2017/03/appel-doffres-cre4-jpee-dans-le-trio-de-tête-des-lauréats-avec-62-mw-obtenus.html, accessed 21 June 2017.

726 - *OffshoreWind.biz*, "EnBW Wins Construction of 900MW German OWF by Bidding EUR 0/MWh", 13 April 2017, see http://www.offshorewind.biz/2017/04/13/enbw-wins-construction-of-900mw-german-owf-by-bidding-eur-0-per-mwh/, accessed 20 June 2017.

727 - Mayank Aggarwal and Utpal Bhaskar, "Tariffs for world's biggest solar power plant hit all-time low of Rs2.97/unit", *Livemint*, 11 February 2017, see http://www.livemint.com/Industry/zW5Lf10kn054cFug5yKGsL/Madhya-Pradesh-solar-bids-hovering-at-Rs3-per-unit-in-revers.html, accessed 21 June 2017.

Figure 42 | Wind, Solar and Nuclear Capacity and Production in the World



Sources: WNISR, IAEA-PRIS, BP Statistical Review, 2017

Notes pertaining to the Figures above

BP data used for this graph were modified in 2017, in particular due to switching for IRENA primary data for solar capacity and switching primary sources (India's CEA and China Electricity Council), as well as various revisions in national statistics. Nuclear capacity was revised according to WNISR status changes, which can be retroactively applied.

pared to 9 GW for nuclear. Together, wind power and solar PV represent over 80 percent of all renewable power capacity added in 2016 worldwide.[728]

Figure 42 illustrates the extent to which renewables have been deployed at scale since the new millennium, an increase in capacity of 451 GW for wind and of 301 GW for solar, compared to the stagnation of nuclear power capacity, which over this period increased by only 36 GW, including all reactors in LTO. Taking into account the fact that 36 GW of nuclear power were in LTO as of the end of 2016, and thus not operating, the balance is plus-minus zero compared to 2000.

The characteristics of electricity generating technologies vary due to different load factors. In general, over the year, operating nuclear power plants tend to produce more electricity per MW of installed capacity than renewables.

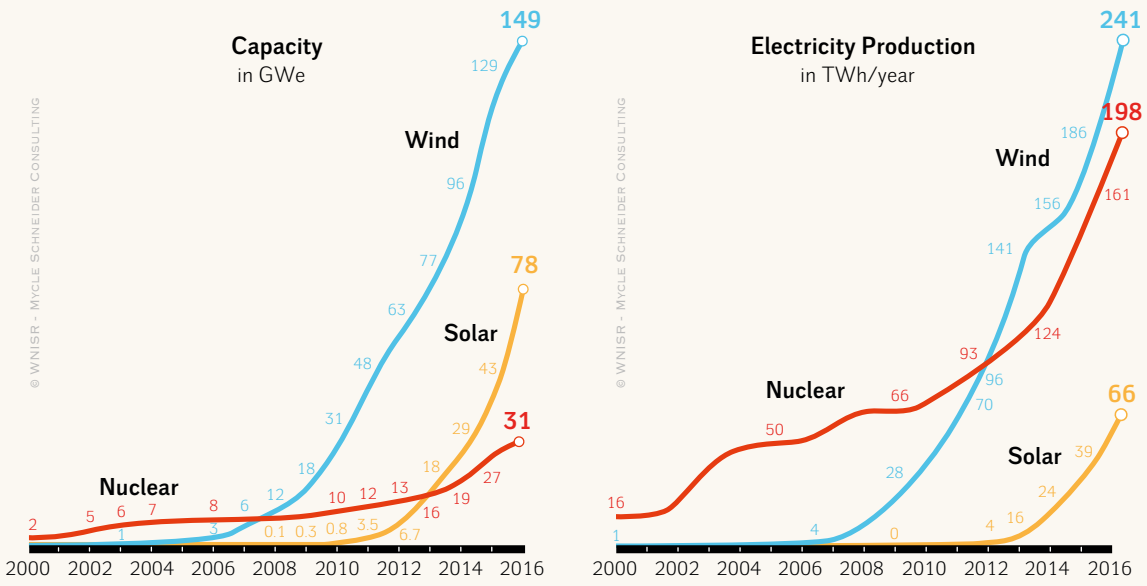
However, as can be seen, since 1997, the signing of the Kyoto Protocol, there has been an additional 948 TWh in 2016 of wind power, 332 TWh more power from solar photovoltaics, and just an additional 212 TWh of nuclear electricity (see Figure 42). In 2016, annual growth rates for the generation from wind power were 15.8 percent globally, 30 percent for solar PV, and 1.4 percent for nuclear power. Nine of the 31 nuclear countries—Brazil, China, Germany, India, Japan, Mexico, Netherlands, Spain and U.K.—generated more electricity in 2016 from non-hydro renewables than from nuclear power.

728 - REN21, "Renewables 2017—Global Status Report", June 2017, see http://www.ren21.net/gsr_2017_full_report_en, accessed 20 June 2017.

STATUS AND TRENDS IN CHINA, THE EU, INDIA, AND THE U.S.

China continues to be a global leader for the deployment of most energy technologies. In 2016 alone, China roughly doubled its solar PV capacities to reach 78 GW, representing 50 percent of the world market and added some 20 GW of wind power capacity, totaling 149 GW, more than all of Europe together (see Figure 43). This can be compared to the current 2020 objectives: 110 GW of solar PV and 210 GW of wind power. Having started up five of the world's ten reactors (for 4.6 GW of capacity), as in the previous year, China also installed more nuclear capacity in 2016 than any other country.

Figure 43 | Wind, Solar and Nuclear Capacity and Production in China 2000-2016



Sources: BP, IAEA-PRIS, WNISR, 2017

Notes pertaining to the Figure above

BP data used for the capacity graph were modified in 2017, in particular due to BP switching primary sources from GWEC to IRENA for solar, and other revisions based on a new IRENA database. On the generation graph, BP data used were modified from previous years, in particular for solar, where IEA estimates were replaced with new data from the China Electricity Council starting in 2012.

China's investment in renewables was by far the largest in the world with a total of US$78.3 billion, dropping from US$115.4 billion the previous year (but, as for the world, more capacity installed in 2016 than in 2015 as costs fell more than investment). In 2016, investment in solar PV was US$39 billion and wind power was US$35 billion,[729] that compares to the start of construction on only two new nuclear reactors (six in 2015) with a reported, total investment of US$5 billion.

The 13th Five Year Plan (2016-2020) proposes new targets for energy efficiency, the reduction of carbon intensity as well as diversification away from fossil fuels, whereby non-fossil fuels are

729 - FS-UNEP and BNEF, Global Trends in Renewable Energy Investment 2017 (ref. 11).

to provide 15 percent of primary energy consumption by 2020, up from 7.4 percent in 2005.[730] Consequently, the explosive growth of renewables is expected to continue. In 2016, a total of 34.5 GW of solar PV were installed, almost double the forecasted 15 to 20 GW per year indicated by the National Energy Administration (NEA).[731] In November 2016, NEA announced an update of the 13th Five Year Plan for the power sector (2016-2020). The target for wind power (210 GW) is higher than the previous announcement (200 GW), while the target for solar (110 GW) is considerably lower than previous announcements (up to 150 GW). Given the current rhythm of deployment, these are however considered minimum targets and could be exceeded. Indeed, the main bottleneck for further renewable development in China is grid infrastructure, resulting in significant curtailment levels for existing wind and solar power plants.[732]

The 13th Five Year Plan is also proposing to increase nuclear capacities to a total of 58 GW by 2020. However, only 31.4 GW are currently operating and another 19.3 GW are under construction for a total of 50.7 GW. Many of the units under construction are encountering significant delays and only 5 GW of new capacity got connected to the grid in 2016. Achieving the 2020 nuclear target thus seems impossible. A tender in late 2016 achieved a price of US$78/MWh for solar and wind power at an estimated average generation cost of US$60/MWh,[733] while nuclear currently gets a guaranteed support tariff of US$70/MWh.[734] With electricity demand nearly flat and overcapacity rising steeply, Chinese authorities increasingly regard the thermal-generation pipeline as pre-stranded assets.

In the **European Union**, between 2000 and 2016, the net changes in installed generating capacities highlight the shift towards renewables and highly efficient gas power plants. With respectively 142.6 GW and 101.2 GW, wind and solar power are the generation technologies that saw the biggest development over 16 years, with gas power plants coming in at 93.5 GW. On the other end, nuclear capacities decreased by 15.5 GW over the same period, coal by 37.3 GW and fuel oil plants by 37.6 GW.[735] In 2016 alone, renewables accounted for 86 percent of new capacities in the EU, with wind claiming the lion's share with 51 percent, now representing the second largest installed generating capacity (behind natural gas). With a total of US$60 billion invested, the European market for renewables also showed a slight increase (3 percent) despite the global slowdown (see section on Investments).

Other highlights in terms of renewable generation in Europe in 2016 include:

- A significant drop in generating costs for new projects, as illustrated by several tenders for offshore wind and solar PV (see section above).

730 - *chinadialogue*, "Climate, energy and China's 13th Five-Year Plan in graphics", 18 March 2017, see https://www.chinadialogue.net/article/show/single/en/8734-Climate-energy-and-China-s-13th-Five-Year-Plan- in-graphics, accessed 22 June 2017.

731 - Richard Martin, "China is on an epic solar power binge", *MIT Technology Review*, 22 March 2016, see https://www.technologyreview.com/s/601093/china-is-on-an-epic-solar-power-binge/, accessed 22 June 2017.

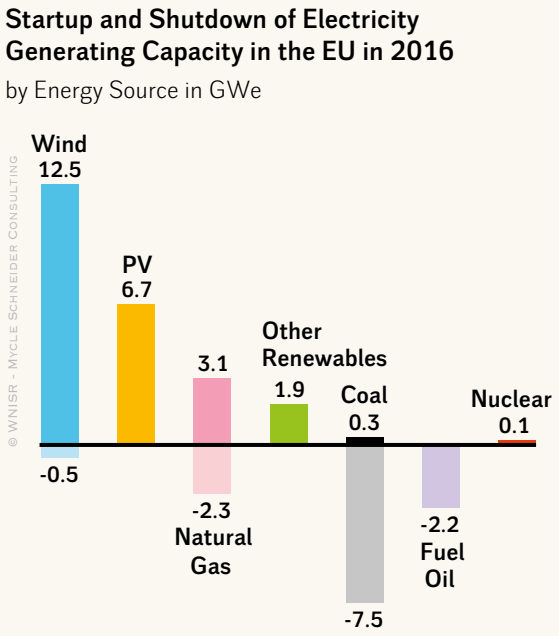
732 - Ma Tianjie, "China's Ambitious New Clean Energy Targets", *The Diplomat*, 14 January 2017, see http://thediplomat.com/2017/01/chinas-ambitious-new-clean-energy-targets/, accessed 22 June 2017.

733 - IRENA, "Wind Power—Technology Brief", March 2016, see http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP_Tech_Brief_Wind_Power_E07.pdf, accessed 22 July 2017.

734 - World Nuclear Association, "Nuclear Power in China", Updated June 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx, accessed 22 June 2017.

735 - WindEurope, "Wind in power—2016 European statistics", February 2017, see https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2016.pdf, accessed 20 June 2017.

Figure 44 | Startup and Shutdown of Electricity Generating Capacity in the EU in 2016



Sources: WindEurope, WNISR, 2017

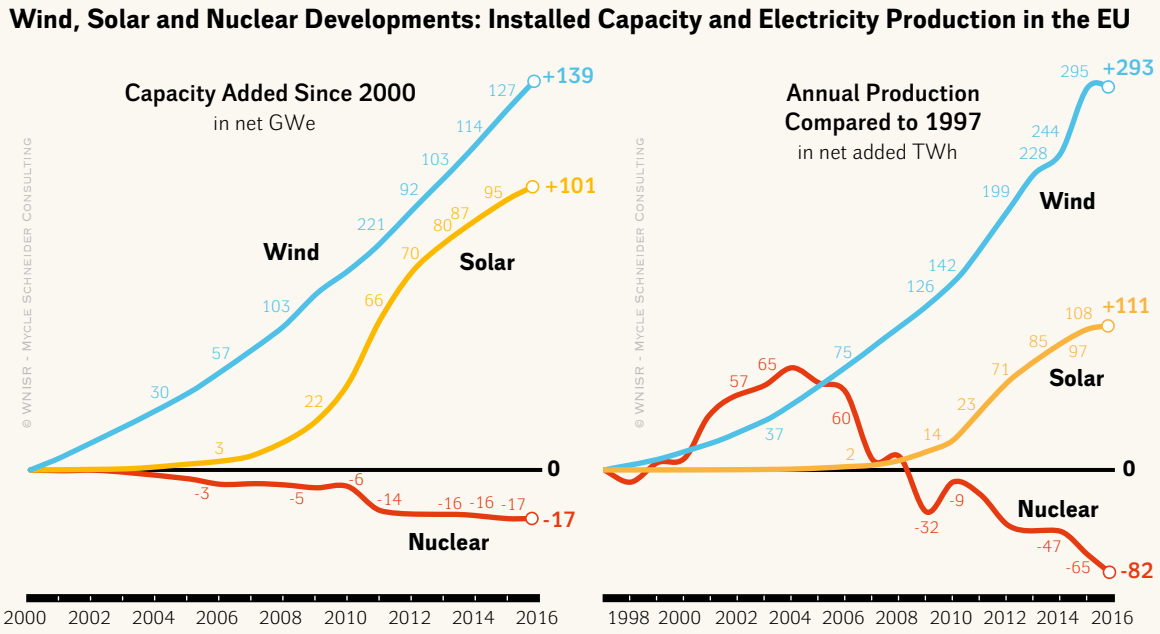
- Starting with a renewable share in power generation of only 16 percent in 2005, Portugal has come a long way. Renewables now account for over 60 percent of electricity consumption. In April 2016, renewable sources provided 95.5 percent of the electricity demand and at the beginning of May 2016, the country ran on renewable electricity exclusively for 107-hours straight.[736]
- In Germany, renewable generation represented a share of 33 percent of gross inland consumption, becoming the leading electricity-generating source of the country. On 11 May 2016, renewables accounted for 88 percent of gross inland power consumption.
- On 22 February 2017, Denmark powered the whole country on wind power alone, paving the way to achieve entirely renewable electricity and heating by 2035.
- In the UK, in 2016, wind turbines generated more electricity than coal power plants for the first time.

Compared to Kyoto Protocol Year 1997, in 2016 wind added 293 TWh and solar 111 TWh, while nuclear power generation declined by 82 TWh across the EU as can be seen in Figure 45.

This growth in renewable electricity production is set to continue beyond the current 2020 targets, as in preparation of the UN climate meeting in Paris in December 2015, the EU has agreed a binding target of at least 27 percent renewables in the primary energy mix by 2030, which is likely to mean 50 percent of power coming from renewables. By 2050, the EU aims for a completely carbon-free electricity system. This will require speeding the current rate of renewable electricity deployment. There is no EU-wide nuclear deployment target and the nuclear share has been shrinking for decades.

736 - Energiewende, "Portugal—Moving to 100% renewables", Energy Transition, The global Energiewende, 6 June 2016, see https://energytransition.org/2016/06/portugal-moving-to-100-renewables/, accessed 22 June 2017.

Figure 45 | Variations in Installed Capacity and Electricity Generation in the EU



Sources: BP, IAEA-PRIS, WNISR, 2017

Notes pertaining to the Figure above

BP data used for this graph were modified in 2017, with a lower estimate for wind power generation in 2015.

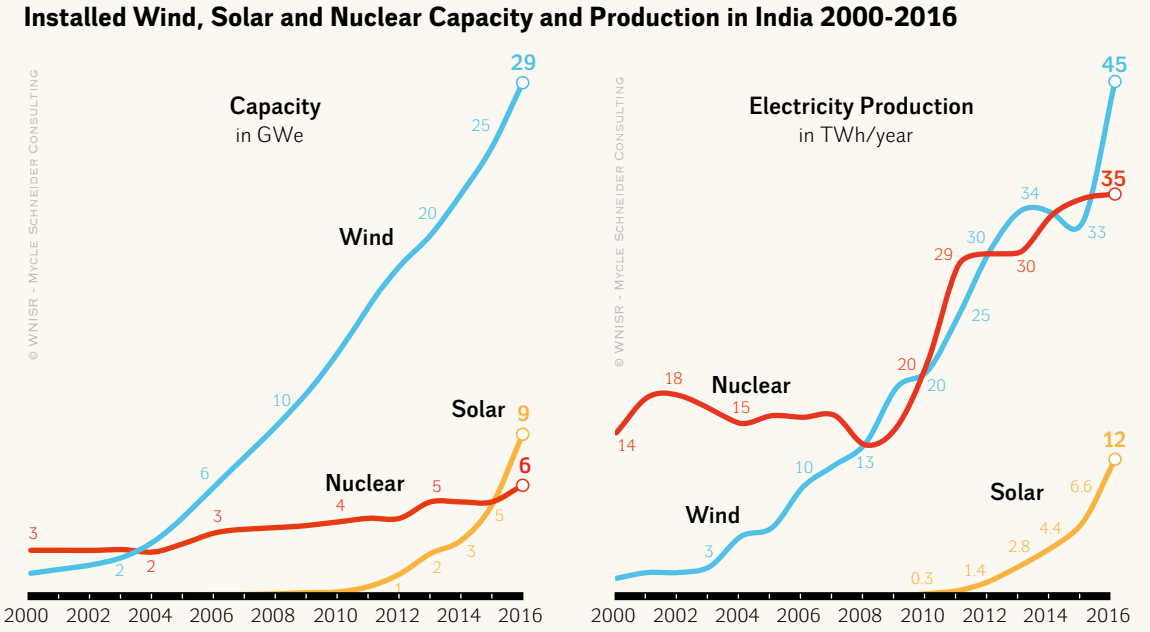
India has one of the oldest nuclear programs, starting electricity generation from fission in 1969. It is also one of the most troubled nuclear sectors in the world and has encountered many setbacks (see India section). This is in stark contrast to the more recent but steady development of the renewable energy sector. Figure 46 shows, how, since the turn of the century, the wind sector has grown rapidly and has overtaken nuclear's contribution to electricity consumption since 2012, while solar is also growing rapidly. At the end of 2016, the country exceeded the 50 GW mark of installed capacities for renewables. India was also the 5th biggest investor worldwide into renewable energies in 2016 with US$9.7 billion and the 4th biggest nation world-wide in installed wind capacity. While the 2022 target of 175 GW of installed renewable capacity was initially considered overly optimistic, the recent deployment has cast away many of those doubts. Following recent price falls in solar auctions—US$50/MWh for a 750 MW plant in Madhya Pradesh—analysts expect solar capacities to double in 2017 alone, reaching about 18 GW, like at even lower prices.[737] In its intended nationally determined contribution to the Paris Agreement, India set itself a target of achieving a share of 40 percent in fossil-free generating capacity by 2030. This target should however be exceeded, with a new official document highlighting a 57 percent share by 2027, including 275 GW of renewables and only 15 GW of nuclear.[738] Energy Minister Piyush Goyal was recently quoted in the press as saying 60–65 percent of India's total generating capacity would be renewable by 2023–2025.[739]

737 - Climate Action Programme, "India's solar capacity to double in 2017", UNEP, 9 January 2017, see http://www.climateactionprogramme.org/news/indias_solar_capacity_to_double_in_2017, accessed 22 June 2017.

738 - Central Electricity Authority, "Draft National Electricity Plan (Volume 1)—Generation", Government of India, December 2016, see http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf, accessed 22 June 2017.

739 - *Deccan Chronicle*, "Renewables to be over 60 per cent of India's generation capacity: Goyal", 25 March 2017, see http://www.deccanchronicle.com/business/economy/250317/renewables-to-be-over-60-per-cent-of-indias-generation-capacity-goyal.html, accessed 10 August 2017.

Figure 46 | Wind, Solar and Nuclear Capacity and Production in India 2000-2016



Sources: BP, IAEA-PRIS, WNISR, 2017

Notes pertaining to the Figure above

BP data used for this graph were modified in 2017, in particular due to BP switching primary sources for wind power statistics.

While negotiations on the construction of up to six EPRs in India are stalling, even French utility EDF announced that it plans to invest US$2 billion in renewable projects in India in the coming year.[740]

In the **United States**, the incoming president Donald Trump's support for the fossil fuel and nuclear industries, and his climate change denial have raised concerns about the future of renewable-energy development and climate policies, and have received harsh criticism from civil society, politicians and major business leaders inside and outside the country.[741]

According to the US Energy Information Administration's (EIA) annual Energy Outlook, power consumption has remained flat for the past decade, peaking in 2007, and should increase only moderately until 2040.[742] Recent years have been marked by the switch from coal to gas use for power generation and the progressive deployment of renewable sources. The share of coal in the electricity mix decreased from 49 percent in 2007 to 30 percent in 2016 with a 133 TWh (or 10 percent) generation drop in 2016 alone. Gas power plants rose from 22 to 34 percent over the same period, largely due to the production of shale gas, now becoming the dominant generation fuel. And renewables doubled their share to 15 percent over the past 10 years. The year 2016 saw a new record in renewable capacity additions, with a total of 21.5 GW. Solar capacity

740 - Michael Safi, "India plans nearly 60% of electricity capacity from non-fossil fuels by 2027", *The Guardian*, 22 December 2016, see https://www.theguardian.com/world/2016/dec/21/india-renewable-energy-paris-climate-summit-target, accessed 22 June 2017.

741 - Hiroko Tabuchi, "U.S. Companies to Trump: Don't Abandon Global Climate Deal", *The New York Times*, 16 November 2016, see https://www.nytimes.com/2016/11/17/business/energy-environment/us-companies-to-trump-dont-abandon-global-climate-deal.html, accessed 22 June 2017.

742 - EIA, "Annual Energy Outlook 2017—with projections to 2050", 5 January 2017, see https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf, accessed 22 June 2017.

alone rose 73 percent over the previous year with 12.5 GW added, while wind additions remained stable at 8.5 GW.[743] This rapid growth was spurred by the anticipated expiration of the Investment Tax Credit (ITC) for renewables, which unexpectedly won a five-year extension in Congress. Wind power could exceed generation from hydro in 2018 if development levels remain constant; wind plus solar power did so in 2016. Even in the case of decreasing federal policy support, renewable capacities should enjoy exponential growth over the next years. (The main potential obstacle is a peculiar trade case that could give the President an opportunity to impose substantial tariffs on mainly-Chinese imported PV modules; however, according to analysis provided by *Bloomberg*, unsubsidized average generating costs for wind fell to US$56/MWh in 2016 and as low as US$37/MWh in Texas (tax credit not included). For solar, the average Levelized Cost of Electricity (LCOE) reaches US$79/MWh, coming in as low as US$50/MWh in Texas without the tax credits.[744]

In contrast, new nuclear would represent an LCOE of US$150/MWh, according to *Bloomberg*. The EIA foresees a progressive reduction in nuclear capacities until 2040. Additional capacities taken into account are limited to the four reactors currently under construction, two of which (the Virgil Summer units in South Carolina) were cancelled in late July 2017, and the other two—even if completed—will not compensate for the projected shut-downs of at least 20 GW until 2040.[745]

CONCLUSION ON NUCLEAR POWER VS. RENEWABLE ENERGIES

Stronger than ever before, 2016 highlighted the diverging trends in the deployment of new renewable energy sources and nuclear power. While new records have been set for renewables in many fields, from capacity additions to cost reductions, no significant developments have been registered on the nuclear front. The record-low prices achieved for solar and wind power are particularly groundbreaking: on a full-cost basis, renewable generation is becoming cheaper than new nuclear power plants in most regions of the world, and is even competing with the cheapest conventional generation technologies (generally coal and some U.S. gas) and wholesale market prices in some countries.

Considering these new economic fundamentals and the national objectives set out in the Paris climate agreement, the gap between the rising development of renewable sources and the decline of nuclear power can be expected to accelerate even further in the coming years. This is naturally true for the 163 U.N. Member States that don't use nuclear power. But even in countries that do, or are considering adding nuclear power, it should play an even smaller role compared to renewable energies.

743 - BCSE and BNEF, "Sustainable Energy in America—Factbook 2017", February 2017.

744 - Including the Investment tax credit, solar prices have reached record lows of $40/MWh in Nevada and California while some wind projects fetched below $20/MWh in Texas and Oklahoma. See BCSE / BNEF (2017).

745 - EIA, "Annual Energy Outlook 2017—with projections to 2050", U.S. Energy Information Administration, 5 January 2017, see https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf, accessed 22 June 2017.

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ANNEX 1
OVERVIEW BY REGION AND COUNTRY

This annex provides an overview of nuclear energy worldwide by region and country. Unless otherwise noted, data on the numbers of reactors operating and under construction (as of early July 2017) and nuclear's share in electricity generation are from the International Atomic Energy Agency's Power Reactor Information System (PRIS) online database. Historical maximum figures indicate the year that the nuclear share in the power generation of a given country was the highest since 1986, the year of the Chernobyl disaster.

AFRICA

South Africa operates two French (Framatome/AREVA) 900 MW reactors. They are both located at the Koeberg site, east of Cape Town, and generated 15.2 TWh in 2016. Nuclear power provided 6.6 percent of the country's electricity in 2016 (the historical maximum was 7.4 percent in 1989). The Koeberg plant is the only nuclear power station on the African continent.

The Koeberg reactors are increasingly struggling with ageing issues, having started up in 1984 and 1985 respectively. The decision to replace all six steam generators of the two units was taken in 2010. The plant has been operating at low temperatures to reduce the pace of corrosion in the steam generator tubes. Replacement work was to begin in 2018. But, in August 2016, it was announced that the planned work would no longer take place, due to an ongoing legal conflict between two competing supplier firms, French AREVA and Toshiba-owned Westinghouse. Both parties are in financial trouble and badly need the 5 billion rand (US$324 million) business. AREVA, reportedly, has already started working on steam-generator fabrication at its Chinese subcontractor Shanghai Electric.[746] In December 2015, South Africa's Supreme Court unanimously ruled in favor of Westinghouse, which had argued that the contract had not been allocated according to fairness rules. Both companies have appealed to the Constitutional Court, the country's highest court. Hearings started on 18 May 2016,[747] and were concluded in December 2016, dismissing the Westinghouse claims.[748]

The state-owned South African utility and Koeberg operator Eskom had considered acquiring additional large PWRs and had made plans to build 20 GW of generating capacity by 2025. However, in November 2008, Eskom scrapped an international tender because the scale of investment was too high and threatened its credit-rating. In February 2012, the Department of Energy (DOE) published a Revised Strategic Plan that contained a 9.6 GW target, or six

746 - Phil Chaffee, "South African Court Upends Koeberg Steam Generator Contract", *NIW*, 11 December 2015.

747 - Constitutional Court of South Africa, "Areva NP Incorporated v Eskom Holdings SOC Std and Another, and Westinghouse Electric Belgium Société Anonyme v Areva NP Incorporated & Another—Media Summary", 18 May 2016, see http://www.judiciary.org.za/doc/Court-Case-17-May-2016_Pre-hearing-media-summary_CCT-20-16-and-CCT-24-16-Areva-Eskom-v-Westinghouse-Electric-Belgium-Societe-Anonmye-.pdf, accessed 2 August 2017.

748 - Gia Nicolaides, "Eskom Welcomes Concourt Ruling On Koeberg Contract", *Eye Witness News*, 21 December 2016, see http://ewn.co.za/2016/12/21/eskom-welcomes-concourt-ruling-on-koeberg-contract, accessed 10 July 2017

nuclear units, by 2030. Startup would be one unit every 18 months beginning in 2022.[749] The total price of the project is estimated to be in the range of US$37-100 billion.[750] The price of the nuclear programmed and the recognition of the viability of alternatives globally is changing the debate in some of the media. In July 2016, reporting on the publication of the previous WNISR edition, the *Business Day* stated: "The world nuclear industry status report for 2016 may give SA pause for thought about its ambitions to build nuclear power capacity."[751]

However, Eskom is continuing to discuss nuclear new-build with international vendors and in December 2016 they issued a Request for Information, which received a response from 27 international firms on a proposed new-build program, including, from China, France, Russia and South Korea.[752] It was planned that Eskom would later in 2017 publish a request for proposals and evaluate these by the end of year. The main stumbling blocks for nuclear construction remains finances and conformity to the country's public consultation process.

In November 2014, Moody's downgraded Eskom to "junk". In the latest rating action, of June 2017, Moody's downgraded Eskom to Ba2 from Ba1-rating, even deeper into junk territory. While in December 2016, both, Fitch and Standard and Poor's rating agencies, downrated the country's sovereign debt to junk status after a ministerial shake-up and the removal of the finance minister. The new finance minister Malusi Gigaba said that the nuclear program would proceed but "at a pace and scale that the fiscus can afford" and that the funding model was yet to be "finalized".[753]

However, in parallel to the Eskom developments, the South African government is reviewing the expected demand and need for different energy sources. The November-2013 edition of the Integrated Resource Plan (IRP) for Electricity, concluded that "the nuclear decision can possibly be delayed".[754]

In October 2016, the Department of Energy began consultations on a revision of the IRP, in which it is suggested that commissioning of new nuclear would, under their base-case scenario, be only in 2037, and then only 1,359 MWe, equivalent to one reactor. However, the plan then assumes a massive commissioning program with 20 GW of new nuclear capacity by 2050. The updated IRP is expected to be published in 2018. The Nuclear Industry Association of South Africa, has said that any delay in the implementation of the new-build program "could be devastating to the viability of the nuclear industry".[755] The revised IRP also assumes a considerable increase in the installation of renewable energy with wind providing 29 percent of power, requiring 37 GW and solar 13.5 percent with 17.6 GW.

749 - DOE, "Revised Strategic Plan – 2011/12-2015/16", Republic of South Africa, February 2012, see http://www.energy.gov.za/files/publications_frame.html, accessed 2 August 2017.

750 - *NEI*, "Eskom Plans RFP for New Reactors by mid-year", *Nuclear Engineering International*, 15 March 2017, see http://www.neimagazine.com/news/newseskom-plans-rfp-for-new-reactors-by-mid-year-5761595/, accessed 14 July 2017.

751 - Mark Allix, "Nuclear sector in crisis as SA weights options", *Business Day, Business Live*, 15 July 2016, see https://www.businesslive.co.za/bd/companies/energy/2016-07-15-nuclear-sector-in-crisis-as-sa-weighs-options/, accessed 15 July 2017.

752 - Eskom, "Eskom receives a good response to its request for information on the nuclear programme", 2 February 2017, see http://www.eskom.co.za/news/Pages/Febb1.aspx, accessed 14 July 2017.

753 - *AFP*, "South Africa to rethink nuclear deal after junk status", published on *African Independent*, 10 April 2017, see https://www.africanindy.com/business/south-africa-to-rethink-nuclear-deal-after-junk-status-8575408, accessed 15 July 2017.

754 - DOE, "Integrated Resource Plan for Electricity (IRP) 2010-2030—Update Report 2013", Republic of South Africa, 21 November 2013, see http://www.doe-irp.co.za/content/IRP2010_updatea.pdf, accessed 2 August 2017.

755 - *WNN*, "The Status of South Africa's nuclear program", 22 December 2016, see http://www.world-nuclear-news.org/V-The-status-of-South-Africas-nuclear-program-22121601.html, accessed 14 July 2017.

However, problems with the revised draft of the IPR include an over-estimated increase in power consumption and caps on the rate of roll-outs of renewables.[756] Furthermore, it remains to be seen, whether there will be any unbundling of the transmission or distribution networks.

In April 2017, the Western Cape division of South Africa's High Court agreed with two NGOs, the Southern African Faith Communities Environment Institute (SAFCEI) and Earthlife Africa, that two legal determinations made by the energy minister had to be stopped. These were, a December 2015 decision to proceed with the procurement of 9.6 GW of new nuclear capacity and that this was to be led by Eskom rather than the Department of Energy, and the nuclear co-operation agreements that the government had signed with Russia, South Korea and the United States. The court concluded that the lack of public consultation on the decisions "rendered its decision procedurally unfair" and breached its statute.[757] In May 2017, the Government announced that it would not appeal the decision of the court.[758] It has yet to be seen if and how Eskom will proceed with its discussions with the nuclear vendors and finance community.

THE AMERICAS

Argentina operates two nuclear reactors that in 2016 provided 7.7 TWh or 5.6 percent of the country's electricity (down from a maximum of 19.8 percent in 1990). A third reactor is in LTO.

Historically Argentina was one of the countries that embarked on an ambiguous nuclear program, officially for civil purposes but backed by a strong military lobby. Nevertheless, the operating nuclear plants were supplied by foreign reactor builders: Atucha-1, which started operation in 1974, was supplied by Siemens, and the CANDU (CANadian Deuterium Uranium) type reactor at Embalse was supplied by the Canadian Atomic Energy of Canada Limited (AECL) and started operating in 1983.

The Embalse plant was shut down at the end of 2015 for major overhaul, including the replacement of hundreds of pressure tubes, to enable it to operate for up to 30 more years. Reportedly, contracts worth US$440 million were signed in August 2011 and at the time, the work was expected to start by November 2013.[759] According to the Argentinian Press Agency *Agencia Diarios et Noticias*, it is now expected to be back in service only at the end of the first semester of 2018.[760] *Nuclear Engineering International* (*NEI*) had already estimated back in 2013 that the whole refurbishment project could take up to five years and cost about US$1.5 billion, warning: "It must be noted, however, that the various Candu refurbishment projects in Canada (Bruce, Pickering and New Brunswick) have tended to overrun on both time and budget."[761]

756 - Piet Van Staden, "Beyond patronage politics: Where is South Africa going with Eskom?", Energy Intensive User Group of Southern Africa, *EE Publishers*, 28 June 2017, see http://www.ee.co.za/article/beyond-patronage-politics-south-africa-going-eskom.html, accessed 14 July 2017.

757 - Phil Chaffee, "Legal, High Court Upends South African Newbuild Plans", NIW, 28 April 2017.

758 - *NIW*, "Briefs—South Africa", 19 May 2017.

759 - Research and Markets, "Nuclear Power Market in Argentina", May 2012.

760 - Agencia Diarios y Noticias, "Avanza proceso de extension de vida util de central nuclear Embalse, que reingresara al servicio en 2018", 5 May 2017.

761 - Steve Kidd, "Argentina—a possible return to new nuclear?", *NEI*, 15 October 2013, see http://www.neimagazine.com/opinion/opinionargentina-a-possible-return-to-new-nuclear/, accessed 4 August 2017.

The Embalse reactor enters the LTO category in WNISR2017 as the unit had not restarted by mid-2017.

Atucha-2 was ordered in 1979 and was listed as "under construction" in 1981. Finally, on 3 June 2014, first criticality of the reactor was announced and grid connection was established on 27 June 2014. It took until 19 February 2015 for the unit to reach full capacity[762] and until 26 May 2016 to enter commercial operation.[763]

In early May 2009, Julio de Vido, then Argentina's Minister of Planning and Public Works, stated that planning for a fourth nuclear reactor would begin and that construction could start within a year,[764] however, little progress was made. Then, in February 2015, Argentina and China ratified an agreement to build an 800 MW CANDU-type reactor at the Atucha site, when Atucha-3 was expected to cost US$5.8 billion.[765] In November 2015, a contract was signed between state-controlled Nucleoelectrica and China National Nuclear Corporation (CNNC) for assistance on building Atucha-3. While only supplying about 30 percent of the work, CNNC is expected to bring along 85 percent of the financing while Nucleoeléctrica would act as designer, architect, engineer, builder and operator of the plant.

A framework agreement was also signed in 2015 between the two companies for the construction of a Hualong One reactor, China's new, and as yet untested, Generation III design.[766] In May 2017, a co-operation agreement was signed between Argentina and China, whereby China would help build and mainly finance the construction of the two reactors, with the CANDU-6 starting construction in 2018 and the Hualong reactor in 2020.[767] It is reported that China will provide loans worth US$10.6 billion with the total project cost expected to be US$12 billion. The loans are reported to have a 20-year payback period, with a potential 8-year extension. The negotiation is scheduled to be completed by the end of 2017, with construction on Atucha-3 expected to commence as soon as funding is available.

In addition to the importance of the foreign construction of the Hualong reactor, it is reported by *Nuclear Intelligence Weekly* (*NIW*), that this is the first nuclear loan undertaken by the Industrial and Commercial Bank of China—the world's largest bank by total assets.[768] While this is a step forward for the project, its future may not be secured as some press reports suggest that funding is dependent on the Argentinian Governments continuation with two, Chinese financed, controversial dams in the Patagonia region.[769]

762 - *WNN*, "Atucha 2 reaches 100% rated power", 19 February 2015, see http://www.world-nuclear-news.org/NN-Atucha-2-reaches-100-percent-rated-power-19021502.html, accessed 4 August 2017.

763 - *WNN*, "Atucha 2 receives full operating licence", 31 May 2016, see http://www.world-nuclear-news.org/RS-Atucha-2-receives-full-operating-licence-3105165.html, accessed 4 August 2017.

764 - Marketwire.com, "Argentina to Reinforce Nuclear Energy by Adding 700 MW and Building Fourth Nuclear Plant", 7 May 2009.

765 - *WNN*, "Argentina-China talks on new nuclear plants", 8 May 2015, see http://www.world-nuclear-news.org/NN-Argentina-China-talks-on-new-nuclear-plants-08051501.html, accessed 4 August 2017.

766 - Phil Chaffee and Jason Fargo, "Moving closer to Atucha-3 and HPR1000 Newbuilds", *NIW*, 6 November 2015.

767 - CNNC, "CNNC to build heavy water reactor and HPR 1000 units in Argentina", Press Release, Updated 19 May 2017, see http://en.cnnc.com.cn/2017-05/19/c_77725.htm, accessed 1 August 2017.

768 - NIW, "China and Argentina Move Forward with Newbuilds", 25 May 2017.

769 - Daniel Gutman, "China Drives Nuclear Expansion in Argentina, but with Strings Attached", *Inter Press Service*, 27 June 2017, see http://www.ipsnews.net/2017/06/china-drives-nuclear-expansion-argentina-strings-attached/, accessed 1 August 2017.

After repeated delays, construction of a prototype 27 MWe PWR, the domestically designed CAREM25 (a type of pressurized-water Small Modular Reactor with the steam generators inside the pressure vessel) began near the Atucha site in February 2014, with startup initially planned for 2018. The reactor is said to cost US$450 million,[770] or about US$17,000 per installed kWe. Construction is now expected to be completed by the end of 2018, with operation in the 2nd half of 2019.[771]

Brazil operates two nuclear reactors that provided the country with 15 TWh or 2.9 percent of its electricity in 2016 (down from a maximum of 4.3 percent in 2001). Construction of a third reactor has been suspended in late 2015.

As early as 1970, the first contract for the construction of a nuclear power plant, Angra-1, was awarded to Westinghouse. The reactor went critical in 1981. In 1975, Brazil signed with Germany what remains probably the largest single contract in the history of the world nuclear industry for the construction of eight 1.3 GW reactors over a 15-year period. However, only the first reactor, Angra-2, was finally connected to the grid in July 2000, 24 years after construction started.

Preparatory work for the construction of Angra-3 was started in 1984 but abandoned in June 1991. However, in May 2010, Brazil's Nuclear Energy Commission issued a construction license and the IAEA noted that a "new" construction started on 1 June 2010. In early 2011, the Brazilian national development bank (BNDES) approved a 6.1 billion reais (US$3.6 billion) loan for work on the reactor.[772] Reportedly, in November 2013, Eletrobras Eletronuclear signed a €1.25 billion (US$1.425 billion) contract with French builder AREVA for the completion of the plant.[773] According to AREVA, in the first quarter of 2015, 13 percent of the "work packages" had been approved for delivery to Brazil. "Progress on the project is dependent on the securing of project financing by the customer", AREVA added.[774] Commissioning was previously planned for July 2016 but was delayed to May 2018 in 2015[775] and then to May 2019.[776] However, there is no confidence in these timetables as construction was halted in the fall of 2015, as a consequence of a huge corruption scandal. On 5 July 2016, 19 people were arrested that were part of graft scheme around the Angra-3 project. Eletrobras executives were allegedly paid more than 200 million reais (US$60 million) in bribes and, in return, let large construction companies inflate costs. Part of the kickback was distributed to politicians and political parties. Dozens of people were convicted of bribery and money laundering.[777] Amongst the people

770 - Gary Peach, "Russia—Cost Overruns Put Mobile Breeder Project in Quandary", *NIW*, 7 November 2014.

771 - *WNN*, "Contract for Prototype CAREM balance of plant", 6 September 2016, see http://www.world-nuclear-news.org/NN-Contract-for-Contract-for-prototype-CAREM-balance-of-plant-0609164.html, accessed 1 August 2017.

772 - However, it is surprising to note that AREVA's 400-page Reference Document 2012 does not even contain the word "Angra".

773 - *NucNet*, "Brazil Releases Production Figures For Angra Nuclear Station", 20 January 2014, see http://www.nucnet.org/all-the-news/2014/01/20/brazil-releases-production-figures-for-angra-nuclear-station; and WNN, "Areva contracted to complete Angra 3", 8 November 2013, see http://www.world-nuclear-news.org/C-Areva-contracted-to-complete-Angra-3-081134.html; both accessed 4 August 2017.

774 - AREVA, Press Release, 29 April 2015.

775 - *NIW*, "Briefs—Brazil", 9 January 2015.

776 - *NIW*, "NEWBUILD: Sobriety, Secrecy and Reluctance", 24 June 2016.

777 - Jeb Blount, "Brazil police arrest 19 in Eletrobras nuke-plant bribe probe", *Reuters*, 6 July 2016, see http://www.reuters.com/article/us-brazil-corruption-idUSKCN0ZM13N, accessed 7 August 2017.

arrested was Othon Luiz Pinheiro da Silva, former CEO of Eletronuclear, considered the "father" of the Brazilian nuclear program, and a retired admiral. On 3 August 2016, da Silva was convicted of corruption, money laundering, organized crime and obstruction of justice, and sentenced to serve 43 years in prison.[778]

Figure 47 | Suspended Angra-3 Construction Site in November 2015

Source: Eletrobras, August 2016[779]

In January 2017, the Brazilian Official Journal registered Electronuclear's decision to annul the bidding process and the contracts for the electromechanical assembly of Angra-3.[780]

In July 2017, the Brazilian publication *Valor* reported that the government intended to restart the construction of Angra-3, and that they were four interested consortia: Rosatom (Russia), CNNC (China), Kepco (South Korea) and EDF/Areva/Mitsubishi (France and Japan). It was estimated that the cost was still US$17 billion reais (US$5.4bn), with 40 percent of the plant still to complete. It is suggested that the government may retain a control interest but allow a

778 - *Reuters*, "Brazil Eletronuclear CEO gets 43-year sentence for corruption – paper", 4 August 2016, see http://www.reuters.com/article/brazil-corruption-eletrobras-idUSL1N1AL16E, accessed 7 August 2017.

779 - Eletrobras, "Central Nuclear Almirante Alvaro Alberto (cnaaa) – Unidade 3", 24 August 2016.

780 - *WNN*, "Daily", 1 February 2017.

third party to own up to 49 percent of the future plant.[781] If construction of the plant was to resume, it is not expected to come online until at least 2023,[782] forty years after construction first began.

Canada operates 19 reactors, all of which are CANDU (CANadian Deuterium Uranium). In 2016, they provided 95.7 TWh or 15.6 percent of the country's total electricity generation for the year (this fraction is down from a maximum of 19.1 percent in 1994). With 18 reactors, most of the nuclear capacity is concentrated in the Province of Ontario, where it contributes around 60 percent of all electricity generated.[783]

The bulk of Canada's electricity comes from hydropower. Canada also has "considerable non-hydro renewable resources including wind, biomass, solar, tidal, wave, and geothermal. In the last few years, policy incentives and declining costs have spurred significant growth in the use of these technologies. Between 2010 and 2014, non-hydro renewables were the fastest growing generation source in percentage terms, with an annual growth rate of 20 per cent".[784]

Although there are periodic assertions of potential new nuclear construction in Canada, especially by building small modular reactors of different kinds,[785] there is no realistic prospect for the construction of new reactors in the foreseeable future. Canada's National Energy Board's latest "Canada's Energy Future 2016" report that projects supply and demand to 2040 states: "No new nuclear units are anticipated to be built in any province during the projection period" and "Annual nuclear generation declines from 98 TWh in 2014 to 77 TWh in 2040".[786] The corresponding report from 2009, on the other hand, projected an increase in nuclear capacity and output by 2020, the former by 3,170 MW and the latter increasing to 102 TWh.[787]

The latter projection of an increase in nuclear capacity was partially a result of plans for a revival of nuclear power during the first decade of this century. In 2008, the government of the province of Ontario invited reactor vendors to participate in the procurement process to construct two reactors at the Darlington site.[788] Once the bids came in, the government put

781 - *Leaders Lead*, "Brazil Seeks $17 Billion Investment for Nuclear Power Plant", 25 July 2017, see http://www.leadersleague.com/en/news/brazil-seeks-17-billion-investment-for-nuclear-power-plant, accessed 4 August 2017.

782 - Michael Place, "Brazil bans Angra engineering firms for 5 years", BN Americas, 23 March 2017, see https://www.bnamericas.com/en/news/electricpower/brazil-bans-angra-3-builders-for-5-years/, accessed 4 August 2017.

783 - IESO, "2016 Year-End Data", Independent Electricity System Operator, 26 January 2017, see http://ieso.ca/corporate-ieso/media/year-end-data - yearenddata, accessed 9 May 2017.

784 - National Energy Board (NEB), "Canada's Energy Future 2016: Update-Energy Supply and Demand Projections to 2040", Government of Canada, October 2016, see https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html, accessed 25 December 2016.

785 - James Maloney, "The nuclear sector at a crossroads: Fostering innovation and energy security for Canada and the world—Report of the Standing Committee on Natural Resources", Standing Committee on Natural Resources, House of Commons, Canada, June 2017, see https://www.cns-snc.ca/media/pdf_doc/position_papers/RNNR_Report_Nuclear.pdf, accessed 15 July 2017; and *NEI*, "Ontario eyes Pan-Canadian SMR fleet to fill 2030s supply gap", *Nuclear Energy Insider*, 19 April 2017, see http://analysis.nuclearenergyinsider.com/ontario-eyes-pan-canadian-smr-fleet-fill-2030s-supply-gap, accessed 10 May 2017.

786 - National Energy Board (NEB), "Canada's Energy Future 2016: Update-Energy Supply and Demand Projections to 2040", Government of Canada, October 2016, see https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html, accessed 25 December 2016.

787 - National Energy Board (NEB), "2009 Reference Case Scenario: Canadian Energy Demand and Supply Projections to 2020—An Energy Market Assessment July 2009", Government of Canada, 2009, see https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/archive/2009/2009rfrnccsscnr/2009rfrnccsscnr-eng.pdf, accessed 25 December 2016.

788 - *WNN*, "Darlington site selected to host two new reactors", 16 June 2008, see http://www.world-nuclear-news.org/NN-Darlington_site_selected_to_host_two_new_reactors-1606085.html, accessed 25 December 2016.

these plans on hold, and then eventually cancelled the idea in 2013.[789] The main reason was similar to why so many reactor-construction plans have been cancelled around the world: it was too expensive. The bid from Canada's own Atomic Energy of Canada Limited was reported to be CA$26 billion (US$$_{2009}$20.4 billion) for two 1200 MW CANDU reactors, more than three times the amount that the government had assumed in its plans.[790]

Instead, the Ontario government has supported refurbishment of the older heavy water reactors. The task involves the removal and replacement of hundreds of highly radioactive pressure tubes from the reactor core, as well as the replacement of other life-limiting components, such as steam generators, and the upgrading of plant systems to meet modern regulatory requirements. All the four reactor units at the Darlington nuclear station and units 3 to 8 at the Bruce nuclear power station are due to undergo refurbishment.

In October 2016, Ontario Power Generation (OPG) took the first of the Darlington units offline to prepare it for refurbishment.[791] The currently estimated cost for the refurbishment of Darlington nuclear generating station is CA$12.8 billion (US$10 billion) and the current timeline calls for all four units to be done with refurbishment by 2026. The current cost estimate is significantly greater than the estimate of CA$6–10 billion (US$5.6–9.3 billion) made in 2013, when the project was granted environmental clearance.[792]

In **Mexico**, two General Electric (GE) reactors operate at the Laguna Verde power plant, located in Alto Lucero, Veracruz. The first unit was connected to the grid in 1989 and the second unit in 1994. In 2016, nuclear power produced 10.3 TWh providing 6.2 percent of the country's electricity. An uprating project boosted the nameplate capacity of both units by 20 percent to 765 MW each. The power plant is owned and operated by the Federal Electricity Commission (Comisión Federal de Electricidad).

In September 2015, Cesar Hernandez, deputy energy minister for electricity, said in a *Reuters* interview that his ministry was reviewing "the potential to add a pair of reactors" to the Laguna Verde site. "It is a decision that is being considered. Our planning shows it is efficient for the country."[793] However, he did not indicate anything on timelines, technologies or costs involved and the low price of gas and renewable energy deployment reduce the likelihood of any further nuclear power development. Despite this, it is expected that, by the end of 2017, the U.S. and Mexico will conclude a formal nuclear co-operation agreement, (a "123 agreement"), which is necessary before any nuclear material or equipment export from the U.S. can take place.[794]

789 - Keith Leslie, "Ontario nixes building two nuclear reactors; will rebuild existing reactors", *Global News*, 10 October 2013, see http://globalnews.ca/news/894709/ontario-nixes-building-two-nuclear-reactors/, accessed 25 December 2016.

790 - Tyler Hamilton, "$26B cost killed nuclear bid", *The Toronto Star*, 14 July 2009, see http://www.thestar.com/business/2009/07/14/26b_cost_killed_nuclear_bid.html, accessed 1 June 2015.

791 - Ministry of Energy, "Nuclear Refurbishment Begins At Darlington Generating Station", Government of Ontario, 14 October 2016, see https://news.ontario.ca/mei/en/2016/10/nuclear-refurbishment-begins-at-darlington-generating-station.html, accessed 10 May 2017.

792 - *Reuters*, "Ontario Darlington nuclear refurbishment gets environmental OK", 15 March 2013, see http://www.reuters.com/article/utilities-opg-darlington-idUSL1N0C79UN20130315, accessed 25 May 2017.

793 - Adriana Barrera, "UPDATE 1-Mexico eyes construction of two new nuclear reactors -official", *Reuters*, 24 September 2015, see http://www.reuters.com/article/mexico-nuclear-idUSL1N11U2WA20150924, accessed 4 August 2017.

794 - Daniel Horner, "Multiple drivers for US 123 Talks", *NIW*, 5 August 2016.

Energy Minister Pedro Joaquín Coldwell had confirmed in May 2014 the country's aim to double the share of renewable energy in the electricity generating capacity from 17 percent to 33 percent by 2018.[795] Solar PV is expected to boom, with proposal for 5.4 GW of installed capacity by the end of 2019, 20 times the current capacity.[796] In March 2017, the Italian company ENEL, through its local subsidiary ENEL Green Power Mexico, launched the Americas' largest solar PV project with 754 MW. The US$650-million investment is to become operational in the second half of 2018 and generate over 1.7 TWh per year.[797]

ASIA AND MIDDLE EAST

China continues to be the leading builder of reactors in the world. As of 1 July 2017, China had 37 operating reactors[798] with a total net capacity of around 32 GW, and a further 20 reactors with a total capacity of a little over 20 GW are under construction, about 40 percent of the global total. In 2016, nuclear power contributed 197.8 TWh, which constituted 3.6 percent of all electricity generated in China, up from 3 percent in 2015. The nuclear fraction has been gradually increasing since 2010. In 2016, wind energy contributed 241 TWh, up by 30.1 percent from 2015, while solar energy contributed 66.2 TWh, up by 72 percent from 2015.[799] With an average age of seven years, China's reactors constitute by far the youngest of any major nuclear fleet in the world (see Figure 48).

Among the reactors under construction, a number have been delayed. The most globally significant of these delays are the cases of the imported AP1000 reactors being constructed at Haiyang and Sanmen, and the imported EPR reactors being constructed at Taishan. Commercial operation of Taishan-1 is now expected to occur sometime towards the end of 2017, whereas the second unit is scheduled for the first half of 2018,[800] which represents an additional delay of at least six months for each of the reactors, compared to WNISR2016 status. In October 2011, when the dome of the reactor building was placed on the first unit, the estimated start times for the two units were 2013 and 2014 respectively, and the construction of two further EPR units at the same site was "expected to begin by 2015".[801]

795 - *Solar Server*, "Mexico sets goal for renewables to grow to 33% of installed capacity", 21 May 2014, see http://www.solarserver.com/solar-magazine/solar-news/archive-2014/2014/kw21/mexico-sets-goal-for-renewables-to-grow-to-33-of-installed-capacity.html, accessed 4 August 2017.

796 - Blanca Diaz Lopez, "PV capacity in the country could be increased 20-fold from the 270 MW currently installed by the end of 2019", *PV Magazine*, 2 January 2017, see https://www.pv-magazine.com/2017/01/02/mexico-targets-addition-of-5-4-gw-of-pv-in-next-3-years/, accessed 4 August 2017.

797 - ENEL, "ENEL begins construction of the Americas' largest solar photovoltaic plant", 29 March 2017, see https://www.enelgreenpower.com/en/media/press/d201703-enel-begins-construction-of-the-americas-largest-solar-photovoltaic-plant.html, accessed 7 August 2017.

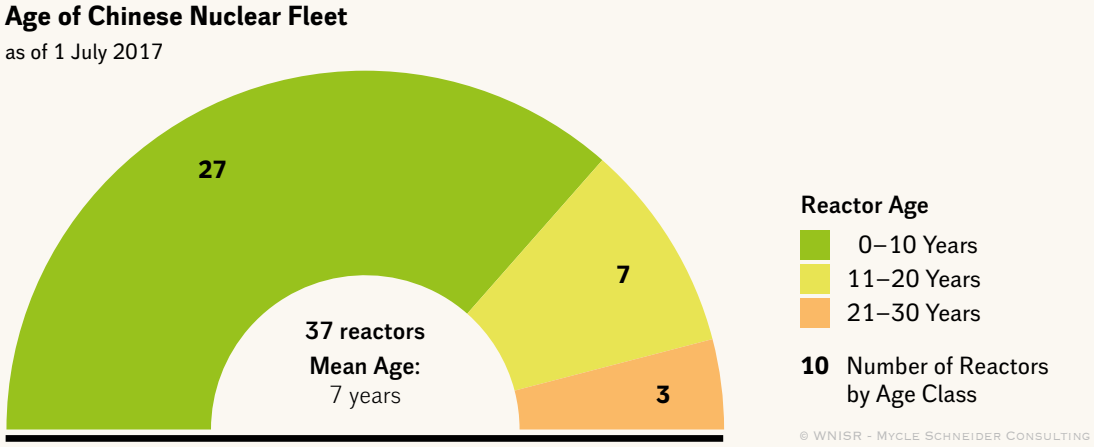
798 - This number includes the China Experimental Fast Reactor (CEFR). There have been many reports that the CEFR has been operating only intermittently at best, but there is no precise information available as to the annual or cumulated power generation. Most recently, a professor at the China Institute of Atomic Energy told an IAEA-sponsored conference in Russia in June 2017 that "in 2016, with Russian assistance, the CEFR underwent an overhaul, which included work on the primary and secondary sodium loops and the instrumentation and control systems" and that "the reactor operated only 23 days last year". Source: C. F. Yu and Gary Peach, "Is the Breeder Timetable Unrealistic?", *Nuclear Intelligence Weekly*, 28 July 2017.

799 - Alvin Lin, "Understanding China's New Mandatory 58% Coal Cap Target", NRDC, 17 March 2017, see https://www.nrdc.org/experts/alvin-lin/understanding-chinas-new-mandatory-58-coal-cap-target, accessed 1 April 2017.

800 - Eric Ng, "China General Nuclear vows to meet new deadline for world's first EPR reactor", *South China Morning Post*, 26 March 2017, see http://www.scmp.com/business/companies/article/2082227/china-general-nuclear-vows-meet-new-deadline-worlds-first-epr, accessed 19 June 2017.

801 - *WNN*, "Reactor dome installed on Chinese EPR", 24 October 2011, see http://www.world-nuclear-news.org/NN-Reactor_dome_installed_on_Chinese_EPR-2410115.html, accessed 19 June 2017.

Figure 48 | Age Distribution of Chinese Nuclear Fleet



Source: WNISR, with IAEA-PRIS, 2017

The AP1000s at the Sanmen and Haiyang sites were the very first constructions of this design anywhere in the world. When construction started at Sanmen, the Shaw Group, one of the partners in the consortium building the reactor, proudly proclaimed: "As with the successful, on-time and on-schedule pour of the first nuclear concrete for the Reactor Building mat earlier this spring, we have again shown that next generation nuclear power plants can be, and are being built in an efficient and timely manner" and looked forward "to bringing this plant on line as scheduled in 2013".[802] That was not to be.

According to an announcement from Westinghouse in May 2017, the first of the Sanmen units is to be "completed in the first quarter of 2018".[803] This is already later than what was announced by China's National Energy Administration (NEA) in its Energy Work Guidance Opinion for 2017. In that document, NEA projected completion of "the Sanmen 1 and Haiyang 1 AP1000 units, the Taishan 1 EPR and the Fuqing 4 and Yangjiang 4 CPR-1000 units".[804] So far, Yangjiang-4 has been connected to the grid,[805] and Fuqing-4 reached first criticality in July 2017.[806] It is not clear, if other imported reactors, besides Sanmen-1, will also be delayed beyond this year.

One of the underlying causes for the delays is that the construction of the Sanmen and Haiyang power plants had begun well before the engineering of the plant's design was completed.[807] New problems have continued to surface. One such problem was observed during tests conduc-

802 - Shaw Group, "Shaw and Westinghouse Announce Successful Placement of Major Structural Module at Sanmen Nuclear Site in China", *Business Wire*, 13 August 2009, see http://www.businesswire.com/news/home/20090813005451/en/Shaw-Westinghouse-Announce-Successful-Placement-Major-Structural, accessed 26 February 2017.

803 - David Stanway, "Westinghouse says first AP1000 reactor to be completed in China in early 2018", *Reuters*, 17 May 2017, see http://af.reuters.com/article/commoditiesNews/idAFB9N1IA023, accessed 27 July 2017.

804 - *NEI*, "China to launch eight new units in 2017", 9 March 2017, see http://www.neimagazine.com/news/newseight-new-units-to-be-launched-in-2017-5759126, accessed 22 June 2017.

805 - Xin Zheng, "Nuclear unit goes online at Yangjiang", *China Daily*, 16 March 2017, see http://www.chinadaily.com.cn/business/2017-03/16/content_28574462.htm, accessed 22 June 2017.

806 - *WNN*, "First criticality achieved at Fuqing 4", 19 July 2017, see http://www.world-nuclear-news.org/NN-First-criticality-achieved-at-Fuqing-4-1907174.html, accessed 25 July 2017.

807 - Brian Spegele, "Troubled Chinese Nuclear Project Illustrates Toshiba's Challenges", *Wall Street Journal*, 29 December 2016, see https://www.wsj.com/articles/troubled-chinese-nuclear-project-illustrates-toshibas-challenges-1483051382, accessed 27 July 2017.

ted at the first AP1000 unit at Sanmen-1. The problem involved neutron shield blocks that are supposed to stop neutrons from the nuclear core from escaping into the rest of the reactor. During these tests, the material that was in the shield blocks had "volumetrically expanded and extruded out of the shield blocks into the nozzle gallery" and there was "internal pressurization of the shield blocks," according to a heavily redacted report on the issue presented by Westinghouse to the U.S. Nuclear Regulatory Commission in February 2017.[808]

Cost estimates for these delayed reactors have naturally increased. According to one report, each of the AP1000 projects at Sanmen and Haiyang are "over 10 billion Chinese yuan (US$1.5 billion)" over budget.[809] As for the EPR reactors at Taishan, China General Nuclear Power (CGN) announced in November 2016 that it "will inject 2.94 billion yuan [US$496 million] into its 51 percent-held unit Taishan Nuclear Power Joint Venture, which will see the unit's total registered capital to 28.6 billion yuan [US$4.2 billion] from 24.4 billion yuan [US$3.6 billion]", which amounts to a 17 percent increase in the capital cost of the project.[810] An official from an investment bank in Hong Kong, Daiwa Capital Markets, expects "the plant's investment cost to rise to between 22 and 23 yuan per watt [US$c3.3–3.4]"— that translates to around US$3,300/kW—whereas the company originally budgeted 14 yuan per watt (US$c2.1/W).[811]

These cost escalations are making it harder for the Chinese nuclear utilities, which are under pressure from the Chinese government's efforts to subject electricity to market pricing. *Nuclear Intelligence Weekly* (*NIW*) reports:

Even without the reforms, several regional governments have already pushed nuclear operators to lower their wholesale prices as coal-fired power prices continue to decline. For example, the Guangxi government issued a new ruling this year [2016] requesting CGN to lower its price for output from Fangchenggang-1 and -2 to 0.41 yuan/kWh (US$c6/kWh). With competition increasing, nuclear developers will be under more and more pressure to cut costs and margins to survive.[812]

In April, the other large nuclear enterprise, China National Nuclear Corporation (CNNC) warned that nuclear power's competitiveness against coal was falling and argued that the only way to "cut costs and boost its competitiveness" was to take advantage of expected economies of scale and "approve the large-scale construction of the country's home-grown third-generation 'Hualong One' reactor".[813] Such large-scale construction does not seem in the offing and it is increasingly obvious that China will miss its 58 GW by-2020-target. In March 2017, former chairman of CNNC, Sun Qin, warned that the country needed to "speed up building planned

808 - Stephanie Cooke, "Sanmen Testing Raises Disturbing Design Questions", *NIW*, 24 February 2017.

809 - C. F. Yu, "Soothing Nerves After Westinghouse Bankruptcy", *NIW*, 31 March 2017.

810 - Eric Ng, "Taishan nuclear project draws a further 2.9b yuan capital injection from state-owned CGN Power", *South China Morning Post*, 16 November 2016, see http://www.scmp.com/business/companies/article/2046591/taishan-nuclear-project-draws-further-29b-yuan-capital-injection, accessed 23 June 2017.

811 - Ibidem.

812 - C. F. Yu, "Power Market Liberalization—More Challenges to Nuclear?", *NIW*, 24 June 2016.

813 - David Stanway, "China nuclear firm urges more homegrown reactors to cut costs", *Reuters*, 28 April 2017, see http://af.reuters.com/article/commoditiesNews/idAFL4N1HZ7V3, accessed 22 June 2017.

nuclear reactors and make quick new approvals over the next few years", if it had to meet this target.[814]

The poor prospects for financial growth of some of China's nuclear utilities has become clearer in recent years, ever since some of them started trading on stock exchanges in Shanghai or Hong Kong or on the debt market.[815] Earlier this year *Nuclear Intelligence Weekly* examined the annual reports for the 2016 fiscal year for China National Nuclear Power Corporation (CNNPC, a 97-percent-owned subsidiary of CNNC), China Nuclear Engineering Corp. (CNEC), the country's leading nuclear construction firm, CGN, and the State Power Investment Corporation, which resulted from the merger of China Power Investment Corporation and State Nuclear Power Technology Corporation.[816] This examination showed that gross margin rates—defined as total sales revenue minus the cost of goods sold, divided by total sales revenue—for all of these companies dropped, especially in the case of CNEC, whose gross margin rates declined from 25.4 percent in 2015 to only 14.7 percent in 2016. CNEC's diagnosis for this drop was that the "Chinese nuclear industry has stepped into a declining cycle" because the "State Council approved very few new-build projects in the past years".[817]

The second problem that nuclear plants in China face is a combination of overcapacity in the power market and a reduced rate of demand growth. As a result, many power plants have been operating at low capacity factors. *Nuclear Intelligence Weekly* cites "the latest quarterly report of the China Nuclear Industry Association" to highlight that "average load factors of Chinese nuclear reactors dropped to an all-time low of 75.2 percent in the first quarter" of 2017.[818] Even this load factor was achieved because Chinese nuclear companies like CGN offered their power at steep discounts, up to 35 percent lower than the normal governmental tariff for nuclear electricity. With rapid increases in renewable energy capacity, this problem is only going to become worse.

China's reactor export plans moved further along slowly. In recent years, the country has placed much emphasis on establishing itself as a potential supplier of reactors and its vendors have been competing for orders on almost every continent.[819] At the Belt and Road Forum for International Cooperation in Beijing in May 2017, CNNC made the ultra-optimistic projection that "countries involved in the initiative would build 100 reactors between now and 2030 and China would build between 20 percent and 30 percent of them".[820] Given the rapidly declining economic competitiveness of nuclear power around the world, the only reasonable explanation for this unrealistic projection is the expectation that such claims would create greater interest among Chinese policy makers in the fortunes of the nuclear sector in the country itself to ease some of the severe challenges in the Chinese electricity market.

814 - Chen Aizhu, "China needs to accelerate nuclear power development to meet 2020 target: ex-official", *Reuters*, 17 March 2017, see http://www.reuters.com/article/us-china-nuclear-idUSKBN16O0EA, accessed 17 July 2017.

815 - C. F. Yu, "The Struggle for Profitability in China's Nuclear Companies", *NIW*, 5 May 2017; and *NIW*, "Weekly Roundup", 29 May 2015.

816 - C. F. Yu, "The Struggle for Profitability in China's Nuclear Companies", *NIW*, 5 May 2017.

817 - Ibidem.

818 - C. F. Yu, "Reactor Operators Facing Competitive Markets", *NIW*, 16 June 2017.

819 - Steve Thomas, "China's nuclear export drive: Trojan Horse or Marshall Plan?", *Energy Policy*, 2017.

820 - C. F. Yu, "Belt and Road Forum Generates Bullish Nuclear Export Forecast", *NIW*, 19 May 2017.

The same month, May 2017, China signed yet another agreement with Argentina to export two reactors, a 700 MW Pressurized Heavy Water Reactor (PHWR) and a 1000 MW Hualong-1 reactor (the CNNC version).[821] The significance of this agreement is not clear; the two countries have signed contracts earlier. In September 2014, Nucleoeléctrica Argentina and China National Nuclear Corporation signed a "commercial framework contract for the construction of a third reactor at the Atucha plant".[822] Even earlier, in 2011, Argentina entered into an agreement with Russia, and that positioned "Rosatom as a prequalified bidder for a contract to build Argentina's planned Atucha-3 reactor".[823]

The other national market that China has been exploring assiduously is the United Kingdom. CGN and CNNC have between them taken a 33.5 percent share in the construction of the Hinkley Point C EPR project. As is seen in the UK section of this report, the construction costs continue to rise and are now expected to be at least £19.6 billion (US$25.7 billion), excluding financing costs; the total Chinese investment is likely to be in the order of US$10 billion, including financing. CGN also hopes to build its Hualong reactor at Bradwell, and in January 2017, the UK nuclear regulator began the Generic Design Assessment process for the Chinese design.[824] The process was started in response to the application submitted by CGN and EDF through their joint venture company; the reference plant for the design is CGN's Fangchenggang-3 reactor in China.

India operates 20 nuclear power reactors, with a total net generating capacity of 5.9 GW. Although the Rajasthan-1 reactor is still listed as operational by the IAEA and counted by the Indian nuclear establishment in its list of reactors, it has not generated any power since 2004 and, according to WNISR criteria, was moved to the LTO (Long Term Outage) category in 2014 joined this year by the Kakrapar-2 reactor which was shut down in July 2015. According to a Department of Atomic Energy press release in July 2017, both Kakrapar-1 and -2 are "under long shutdown for Enmasse Coolant Channel Replacement and Enmasse Feeder Replacement".[825] Nuclear power generated 35 TWh in 2016, marginally more than the 34.6 TWh generated in 2015, but the fraction of total electricity generated constituted by nuclear power declined slightly to 3.4 percent.

The figures cited by the Central Electric Authority (CEA), India's apex planning body for electricity, are slightly different because it reports gross figures and annual results for the fiscal year (April to March). For April 2016 to March 2017, CEA reports that nuclear power generated 37.9 TWh, in comparison to 37.4 TWh during the previous fiscal year.[826] CEA reports that renewable energy sources, other than large hydro, together generated 81.9 TWh in 2016-17 as

821 - Yan Li, "China exports 2 nuclear reactor units to Argentina", *People's Daily Online*, 18 May 2017, see http://en.people.cn/n3/2017/0518/c90000-9217432.html, accessed 13 June 2017.

822 - *Nuclear Exchange*, "Nucleoeléctrica, CNNC sign Atucha 3 Contract", 15 September 2014, see http://www.nuclear-exchange.com/news/49192/nucleoeléctrica-cnnc-sign-atucha-3-contract.html, accessed 13 June 2017.

823 - *NIW*, "Briefs—Argentina", 31 May 2011.

824 - CGN, "Generic Design Assessment process to begin for UK HPR1000 nuclear technology", Press Release, 10 January 2017, see http://en.cgnpc.com.cn/n1305391/n1305404/c1312843/content.html, accessed 22 June 2017.

825 - Press Information Bureau, "Construction of New PHWR", Department of Atomic Energy, Government of India, Press Release, 19 July 2017, see http://pib.nic.in/newsite/PrintRelease.aspx?relid=168650, accessed 25 July 2017.

826 - CEA, "Monthly Generation Report", Ministry of Power, Government of India, March 2017, see http://cea.nic.in/reports/monthly/generation/2017/March/actual/actual.html, accessed 26 May 2017.

compared to 65.8 TWh in 2015-16.[827] For 2016-17, the separate contributions were wind 46 TWh, solar 13.5 TWh, bagasse (sugar cane) 9.9 TWh, small hydro 7.9 TWh, biomass 4.2 TWh, and waste to energy sources 0.3 TWh.

During 2016, one reactor, the second unit of Kudankulam, was connected to the grid.[828] The reactor had attained criticality on 10 July 2016, eight years later than planned, when construction started. Since being connected to the grid, the reactor has operated erratically, being shut down multiple times.[829] One assessment of its performance notes that "during the 47 days of its commercial operation, the reactor was on full power for 1 day, on low power for 23 days and on trip for 24 days".[830]

Five reactors are under construction with a total net capacity of 3 GW. These include the Prototype Fast Breeder Reactor (PFBR), whose construction started in October 2004, and four Pressurized Heavy Water Reactors (PHWRs) at Kakrapar (KAPP 3&4) and Rajasthan (RAPP 7&8), whose construction started in 2010 and 2011. All of these are delayed.

Most egregious among these delays has been that of the PFBR that has been under construction since 2004 and was supposed to reach criticality in 2010. Just a little before construction of the reactor started, the head of the Indira Gandhi Centre for Atomic Research had confidently asserted: "We are trying to see whether we can achieve criticality in less than the stipulated time of seven years".[831] Now more than double the originally "stipulated time of seven years", the official target for criticality is October 2017. But "sources in the Department of Atomic Energy" told the *Deccan Herald* newspaper in April 2017 "that the middle of 2018 was being looked at a more realistic target to put the new reactor into operation".[832]

The four PHWRs are the first of the 700 MW design that the Indian nuclear establishment had evolved over the decades, starting with the original 220 MW design imported from Canada.[833] All these PWHR projects were to be commissioned between 2015 and late 2016.[834] In December 2016, an Executive Director at the Nuclear Power Corporation of India told the media that Kakrapar-3 would become critical by November 2017, and to start commercial ope-

827 - CEA, "Renewable Energy Generation Report", Ministry of Power, Government of India, March 2017, see http://cea.nic.in/monthlyresgeneration.html, accessed 26 May 2017.

828 - IANS, "Second nuclear power unit at Kudankulam connected to grid", *The Financial Express*, 29 August 2016, see http://www.financialexpress.com/india-news/second-nuclear-power-unit-at-kudankulam-connected-to-grid/360522/, accessed 30 May 2017.

829 - *Indo Asian Service News*, "Kudankulam-II Nuclear Plant To Restart Generation On Friday", *NDTV.com*, Updated 4 April 2017, see http://www.ndtv.com/world-news/kudankulam-ii-nuclear-plant-to-restart-generation-on-friday-1677060; and *Hindustan Times*, "Kudankulam nuclear plant's 2nd unit shut down due to water, steam leakage", 6 May 2017, see http://www.hindustantimes.com/india-news/kudankulam-nuclear-plant-s-2nd-unit-shut-down-due-to-water-steam-leakage/story-SNsC8ia4IqmbfkckbU4c8N.html ; both accessed 30 May 2017.

830 - V. T Padmanabhan and Sankar Ray, "Koodankulam Nuclear Power Plant: Second Reactor Also Commissioned Illegally", *Countercurrents*, 23 May 2017, see http://www.countercurrents.org/2017/05/23/koodankulam-nuclear-power-plant-second-reactor-also-commissioned-illegally/, accessed 30 May 2017.

831 - T. S. Subramanian, "Work on PFBR to begin soon", *The Hindu*, 30 May 2004, see http://www.thehindu.com/2004/05/30/stories/2004053003421000.htm, accessed 18 May 2017.

832 - Kalyan Ray, "Fast breeder nuclear reactor delayed by 8 yrs", *Deccan Herald*, 15 April 2017, see http://www.deccanherald.com/content/606431/fast-breeder-nuclear-reactor-delayed.html, accessed 18 May 2017.

833 - S. A Bhardwaj, "The future 700 MWe pressurized heavy water reactor", *Nuclear Engineering and Design*, 2006.

834 - MoSPI, "37th Report on Mega Projects (Rs. 1000 Crores and above) June, 2012", Ministry of Statistics and Programme Implementation, 2012.

rations early 2018; Unit 4 would start six to seven months after that.[835] Rajasthan's "unit 7 is scheduled for completion by the end of 2018".[836] According to a statement in the Parliament in July 2016, "KAPP 3&4 and RAPP 7&8 had achieved an overall physical progress of 75.5 percent and 61.5 percent respectively" (as of June 2016), and the delay in commissioning these reactors was said to be "mainly on account of delays in receipt of critical equipment like Steam Generators, Endshields etc".[837] Another statement in the Parliament in November 2016 stated that the four PHWRs "are progressively expected to be completed by 2019".[838]

Despite the delays and problems with the first 700 MW units, in May 2017, the Indian Government cabinet approved construction of ten more 700 MW PHWRs.[839] All of these sites had been identified earlier and in 2012 the government announced in the Parliament that construction of eight 700 MW PHWRs was to start by 2017.[840] None of the announced reactor constructions have started so far.

According to the government, building 10 PHWRs will "be a major step towards strengthening India's credentials as a major nuclear manufacturing powerhouse".[841] This appears to be an attempt by the Indian nuclear complex to position itself as a reactor exporter as part of an effort to gain membership of the Nuclear Suppliers Group.[842] India's Department of Atomic Energy's efforts to construct a large number of PHWRs in the past spectacularly failed.[843]

The decision is being taken when the country's top electricity planning agency has noted that there was already an excess of power capacity in the country.[844] Demand growth in India has been falling. Estimates for annual energy demand and peak electricity capacity demand in 2021-22 in the latest draft National Electricity Plan put out by the CEA are 15.4 percent and 17 percent lower respectively than what was estimated about five years ago. Likewise, the estimates for energy demand and peak electricity capacity demand in 2026-27 are 21.3 percent and

835 - IANS, "Trial run of India's first 700 MW reactor in 2017", *The Economic Times*, 31 December 2016, see http://economictimes.indiatimes.com/industry/energy/power/trial-run-of-indias-first-700-mw-reactor-in-2017/articleshow/56270382.cms, accessed 23 May 2017.

836 - Phil Chaffee, "Potential and Existing Global Nuclear Newbuild Projects (non-Generation IV)", *NIW*, 24 June 2016.

837 - Jitendra Singh, "Unstarred Question No. 653 to the Minister of Atomic Energy—Under Construction Atomic Plants", Minister of State for Personnel, Public Grievances and Pensions and Prime Minister's Office, Lok Sabha, Parliament of India, Ministry of Atomic Energy, Government of India, Answered 20 July 2016, see http://164.100.47.194/Loksabha/Questions/QResult15.aspx?qref=35962&lsno=16, accessed 2 August 2017.

838 - Jitendra Singh, "Unstarred Question No. 1300—Construction of Nuclear Power Plants", Minister of State for Personnel, Public Grievances and Pensions and Prime Minister's Office, Lok Sabha, Parliament of India, Department of Atomic Energy, Government of India, Answered 23 November 2016, see http://164.100.47.190/loksabhaquestions/annex/10/AU1300.pdf, accessed 2 August 2017.

839 - IANS, "India to build 10 heavy water reactors to boost nuclear power", *Hindustan Times*, 17 May 2017, see http://www.hindustantimes.com/india-news/india-to-build-10-heavy-water-reactors-to-boost-nuclear-power/story-acIr6MwKGwe5hrZSqIKQ9K.html, accessed 17 May 2017.

840 - V. Narayanasamy, "Unstarred Question No. 2949: Nuclear Power Plants in the Twelfth Plan", Rajya Sabha, December 2012.

841 - Press Information Bureau, "Press Release on Cabinet's decision to transform domestic nuclear industry", Department of Atomic Energy, Government of India, 17 May 2017, see http://dae.nic.in/?q=node/973, accessed 19 May 2017.

842 - M. V. Ramana and Suvrat Raju, "The needless quest for NSG membership", *The Telegraph*, 28 July 2016, see http://www.telegraphindia.com/1160728/jsp/opinion/story_99060.jsp, accessed 21 May 2017.

843 - Comptroller and Auditor General of India, "Report by the comptroller and auditor general of India", 1999; and M. V. Ramana, "The Power of Promise: Examining Nuclear Energy in India", Penguin India, 2012.

844 - *The Economic Times*, "India won't need extra power plants for next three years, says government report", 2 June 2016, see http://economictimes.indiatimes.com/industry/energy/power/india-wont-need-extra-power-plants-for-next-three-years-says-government-report/articleshow/52545715.cms, accessed 17 May 2017.

20.7 percent lower than estimated five years ago.[845] According to the CEA, renewable energy is expected to contribute about 20 percent and 24 percent of the total energy requirement in 2021-22 and 2026-27 respectively, whereas the projected nuclear capacity in 2027 is only 14.8 GW, which consists of the reactors that are currently under construction becoming operational by 2022, as well as two new 1000 MW LWRs from Russia at Koodankulam and four 700 MW heavy water reactors coming online in the 2022-27 period. In other words, nuclear power, even according to official planning bodies, will continue to represent only a small share of electricity for India.

Iran has one operating nuclear power plant at Bushehr, a PWR, imported from Russia. Bushehr-1 has a net capacity of 915 MW and took 36 years to go from construction start to grid connection. In 2016, Bushehr-1 supplied 5.92 TWh to the grid, up from 3.2 TWh in 2015.[846] Nuclear power supplied 2.1 percent of Iran's electricity in 2016, higher than the 1.3 percent in 2015.

Construction of a second unit started at the same site in 1976, but was interrupted in 1978 and eventually abandoned. In September 2016, a second attempt at constructing more plants at the Bushehr site was launched, this time with two Russian VVER-1000 reactors[847] Construction and installation work formally started in March 2017,[848] but pouring of concrete had not started as of July 2017. The project is already delayed; in its 2014 Annual Report, Rosatom had announced that it was planning for "direct start of work" in the "3-4" quarter of 2015.[849]

Iran has currently limited renewable energy capacity and production, but plans for expanding wind and solar energy are moving rapidly.[850] In September 2016, the government announced that it would introduce competitive tenders for large-scale wind projects in order to reduce costs.[851] Earlier, in July 2016, the government also announced that it was planning to auction 1 GW of wind and up to 3 GW of solar-energy projects.[852]

Pakistan operates five reactors, four PWRs from China and one PHWR (CANDU) from Canada, that have a net total capacity of 1,320 MW. Nuclear plants provided 5.4 TWh in 2016, up from 4.3 TWh in 2015 and contributed 4.4 percent of the country's electricity in 2016, the

845 - CEA, "Draft National Electricy Plan (Volume 1)—Generation", Ministry of Power, Government of India, December 2016, see http://www.cea.nic.in/reports/committee/nep/nep_dec.pdf, accessed 21 December 2016.

846 - IAEA, "Nuclear Power Reactors in the World: 2017 Edition", International Atomic Energy Agency, 2017.

847 - *Reuters*, "Iran, Russia start construction of new Iranian nuclear plant", 10 September 2016, see http://www.reuters.com/article/us-iran-russia-nuclearpower-idUSKCN11G0EB, accessed 26 May 2017.

848 - *WNN*, "Iran starts building unit 2 of Bushehr plant", 15 March 2017, see http://www.world-nuclear-news.org/NN-Iran-starts-building-unit-2-of-Bushehr-15031701.html, accessed 26 May 2017.

849 - Rosatom, "Annual Public Report", 2014, see http://www.rosatom.ru/en/resources/f5c602004b033aa8bf58ff4fcd16eef4/rosatom_integrated_offer_en.pdf, accessed 27 September 2015.

850 - Maysam Bizaer, "Why renewable energy is booming in Iran", *Al-Monitor*, 4 October 2016, see http://www.al-monitor.com/pulse/originals/2016/10/iran-renewable-energy-bushehr-wind-solar-development-plan.html, accessed 26 May 2017.

851 - Jan Dodd, "Iran eyes tenders for large-scale installations", *Wind Power Monthly*, 1 September 2016, see http://www.windpowermonthly.com/article/1406851, accessed 26 May 2017.

852 - Anna Hirtenstein, "Iran Plans First Tender to Draw $12 Billion Green Investment", *Bloomberg*, 15 July 2016, see https://www.bloomberg.com/news/articles/2016-07-15/iran-plans-first-tender-to-draw-12-billion-green-investment, accessed 26 May 2017.

same as in 2015.[853] The construction of the second of two Hualong reactors imported from China started at the Karachi nuclear power plant (Kanupp) during 2016. Two Chinese-built 315-MW-units started up at the Chashma nuclear power plant, with Chasnupp-3 and -4 connected to the grid respectively in October 2016 and in June 2017.

In March 2017, the IAEA approved the safeguards application for the two units being constructed at Kanupp.[854] Independent analysts continue to highlight the dangers that come from building these two units near Karachi, a city with over 20 million people, including the risks and consequences of spent fuel fires that was not considered by the Preliminary Safety Analysis Report.[855]

Pakistan continues to seek membership to the Nuclear Suppliers Group (NSG) and has been lobbying different countries for support to this effort.[856] So far, these efforts have been unsuccessful. Pakistan also continues to produce highly enriched uranium and plutonium for nuclear weapons; in September 2016, *Jane's Defence Weekly* revealed, on the basis of satellite imagery, that Pakistan might be building a new uranium enrichment facility.[857]

Although Pakistan is known to have immense potential for renewables, especially solar energy, growth of this sector has been limited. This state of affairs might change soon, with the World Bank and the Pakistan government's Alternative Energy Development Board developing high-quality resource-maps and several generation projects being constructed.[858] Another important development was the promulgation of an order by the National Electric Power Regulatory Authority calling for the adoption of a transparent, competitive bidding process for solar photovoltaic power projects.[859] However, a cut in the feed-in tariff for solar plants may have slowed down investments, at least temporarily.[860]

Taiwan has three twin units at Chinshan (also spelled Jinshan), Kuosheng and Maanshan, all owned by Taipower, the state-owned utility monopoly. Only three of the reactors were connected to the grid throughout 2016 and generated 30.5 TWh, a reduction from 35.1 TWh in 2015, providing 13.7 percent of the country's electricity (compared with its maximum share of 41 percent in 1988). The past year has seen further forced shutdowns of nuclear reactors in Taiwan, with four reactors non-operational in the first week of June 2017. The new government, elected in May 2016, is committed to a nuclear phase-out by 2025.

853 - IAEA, "Nuclear Power Reactors in the World: 2017 Edition", International Atomic Energy Agency, 2017.

854 - *The Express Tribune*, "IAEA approves safeguards for K-2, K-3 nuclear power plants", 8 March 2017, see https://tribune.com.pk/story/1349869/iaea-approves-safeguards-k-2-k-3-nuclear-power-plants/, accessed 25 May 2017.

855 - A. H. Nayyar and Zia Mian, "Hidden dangers", *Dawn*, 13 August 2016, see http://www.dawn.com/news/1277161, accessed 26 May 2017.

856 - Joel Lee, "Pakistan bids to join Nuclear Suppliers Group", *The Korea Herald*, 21 August 2016, see http://www.koreaherald.com/view.php?ud=20160821000320, accessed 25 May 2017.

857 - Karl Dewey and Charlie Cartwright, "CBRN Assessment—Satellite imagery suggests Pakistan building uranium enrichment facility", *Jane's 360*, IHS Markit 16 September 2016, see http://www.janes.com/article/63891/satellite-imagery-suggests-pakistan-building-uranium-enrichment-facility, accessed 25 May 2017.

858 - Rina Saeed Khan, "Is Pakistan's solar power poised to take off amid energy crisis?", *Reuters*, 8 May 2017, see http://www.reuters.com/article/pakistan-solar-idUSL8N1I528F, accessed 25 May 2017.

859 - Tom Kenning, "Pakistan to adopt competitive bidding for new solar PV projects", *PV-Tech*, 7 March 2017, see https://www.pv-tech.org/news/pakistan-to-adopt-competitive-bidding-for-new-solar-pv-projects, accessed 25 May 2017.

860 - Aamir Saeed, "Solar scale-up in Pakistan hits roadblock after payments slashed", *Reuters*, 19 September 2016, see http://www.reuters.com/article/us-pakistan-solar-energy-idUSKCN11P1IE, accessed 25 May 2017.

As in 2015, the Chinshan-1 reactor failed to operate during 2016, and therefore remains in the WNISR category of LTO. Originally shut down for refueling on 10 December 2014, inspections of Chinshan-1 revealed a break in a connecting bolt in an AREVA-made fuel assembly. The Atomic Energy Council (AEC) later approved the reactor for restart, but lawmakers required the issue to be addressed by the national parliament prior to restart.[861] As of 1 July 2017, the unit remains offline. While the AEC is required to prepare a safety assessment for the legislative assembly prior to restart, it looks increasingly unlikely that Chinshan-1 will ever restart as it is due to be permanently shut down in December 2018.

In March 2017 the Minister of Economic Affairs, Lee Chih-kung, had stated he would not consider restarting Chinshan-1 or Kuosheng-2, which had also been shut down for months due to technical problems, "unless all other alternatives were exhausted."[862] Before reactivating either of them, the government would first seek public support and secure the approval of the legislature.[863] As of 3 June 2017, only two reactors out of Taiwan's six were in operation as peak summer electricity demand loomed, with nuclear power only supplying 3 percent of the nation's electricity.

On 2 June 2017, Jinshan-2 had been automatically shut down after one of the main transmission line towers at the plant collapsed during a heavy rainstorm.[864] Taipower stated that the reactor will remain offline indefinitely until an investigation reveals more details about the cause of the collapse. Both Jinshan and Kuosheng plant's continued operation has been under threat due to lack of spent fuel storage capacity. In April 2017, the AEC approved plans for the conversion of the fresh fuel loading pools into spent fuel storage pools at Kuosheng-1, with engineering work completed in May. The work involved converting the fresh fuel loading pools by installing new racks and cooling systems. The AEC assessed storage capacity at Kuosheng-1 and was approved for restart on 9 June 2017.[865] In total the new capacity will permit storage for an additional 440 fuel assemblies from Kuosheng-1, sufficient for two fuel cycles or a total of three years' operation. This is insufficient to allow the reactor to operate to the end of its operating license in December 2021.[866] Dry cask storage has been installed at the Jinshan and Kuosheng-1 plants and approved by the AEC and the Environmental Protection Administration. However, the New Taipei City government has to date refused to let them become operational.[867]

The lack of spent fuel storage can be traced back to Taiwan's reluctance to install interim dry cask storage. The New Taipei City municipal government under the opposition Kuomintang, or KMT, party has refused to allow dry cask storage within city limits without a clear path towards final disposal of spent fuel. Taiwan currently has no plan for such disposal. A pro-

861 - *NW*, "Chinshan-1 might not restart until after September: lawmakers", 2 July 2015.

862 - *NEI*, "Taiwan sees mass anti-nuclear protests", 13 March 2017, see http://www.neimagazine.com/news/newstaiwan-sees-mass-anti-nuclear-protests-5761594, accessed 12 July 2017.

863 - Ibidem.

864 - Kuan-lin Liu, "Emergency shutdown at nuke plant after rain brings down power tower", *The China Post*, 2 June 2017, see http://www.chinapost.com.tw/taiwan/national/national-news/2017/06/02/498234/emergency-shutdown.htm, accessed 12 July 2017.

865 - Tim Ferry, "Nukes and Uncertainty Charge Taiwan's Energy Debate", *Taiwan Business Topics*, American Chamber of Commerce in Taipei, 14 June 2017, see https://topics.amcham.com.tw/2017/06/nukes-uncertainty-charge-taiwans-energy-debate/, accessed 13 July 2017.

866 - *NW*, "Taiwan's Kuosheng-1 faces closure due to lack of spent fuel storage space", 22 September 2016.

867 - Tim Ferry, "More Obstacles for Nuclear Power", *Taiwan Business Topics*, American Chamber of Commerce in Taipei, 6 June 2017, see https://topics.amcham.com.tw/2017/06/obstacles-nuclear-power/, accessed 12 July 2017.

ject proposed in early 2015 to ship 1,200 spent fuel bundles to the French AREVA La Hague reprocessing plant was terminated following environmental group opposition to the resultant extension of nuclear reactor lifetimes as well as the estimated cost of US$356.4 million.

Two General Electric 1300 MW Advanced Boiling Water Reactors (ABWR) had been listed as "under construction" at Lungmen, near Taipei, since 1998 and 1999 respectively. According to the AEC, as of the end of March 2014, unit 1 of Lungmen construction was 97.7 percent complete,[868] while unit 2 was 91 percent complete. The plant is estimated to have cost US$9–9.9 billion so far.[869] After multiple delays, rising costs, and large-scale public and political opposition, on 28 April 2014, the then Premier Jiang Yi-huah announced that Lungmen-1 will be mothballed after the completion of safety checks, while work on unit 2 at the site was to stop. With the official freeze of construction, WNISR took the units off the listing in 2014, where they remain as of 1 July 2017.

The Presidential election victory of Tsai Ing-wen on 12 March 2016 has proven decisive in leading Taiwan to phase out nuclear power. The victory of the Democratic Progressive Party (DPP) candidate, over the Chinese Nationalist Party (KMT), was in part linked to the former's environmental agenda including a commitment to end nuclear power, which, always controversial in Taiwan, has led to mass citizen protests since the Fukushima events began. The DPP is committed to phasing out nuclear power by 2025 through four policy directions:

- Halting construction of the two reactors at Lungmen;
- No plant life extension for Chinshan, Kuosheng and Maanshan reactor units—all operating licenses of Taiwan's existing six nuclear reactors are due to expire between 2018 and 2025, as they reach their forty-year lifetimes;
- Increased focus on nuclear safety and a requirement by Taipower to prepare a decommissioning plan; and
- Determination of a nuclear waste policy, in particular for spent-fuel management.

In the two years running up to the elections of May 2016, the DPP had committed to breaking up Taipower's monopoly, putting priority on renewable energies and establishing regional power-grid companies, fostering community-based power companies and allowing independent power producers and renewable-energy suppliers to sell power directly to individual consumers and not only to large-scale industrial or commercial users.

On the sixth anniversary of 3/11 in March 2017, the Taiwanese government restated its commitment to phase out nuclear power, stating that it was stepping up its efforts to move towards non-nuclear sustainable energy and lower carbon-dioxide emissions, announcing a two-year plan to boost photovoltaics and a four-plan to increase wind energy. President Tsai's administration recommitted itself to increase renewable-based electricity generation to 20 percent of total generation by 2025 with a target of installed capacity of 20 gigawatts (GW) of solar energy and 3 GW of offshore wind.

868 - Planning Department, "Status and Challenges of Nuclear Power in Taiwan", Atomic Energy Council, April 2014, see http://www.aec.gov.tw/english/whatsnew/files/20140506-5.pdf, accessed 13 July 2017.

869 - *WNN*, "Political discord places Lungmen on hold", 28 April 2014, see http://www.world-nuclear-news.org/NN-Political-discord-places-Lungmen-on-hold-2804144.html, accessed 13 July 2017.

The nuclear policy of the new Government was made clear in summer 2016, following the appointment on 20 May 2016 of the new President. Initial statements by the newly appointed Economics Minister Lee Shih-guang are clear: "There is no room for discussion. When 2025 comes, nuclear power will be abandoned."[870] One day later, it was reported that Taipower considers restarting Chinshan-1 and operating Chinshan reactors only during four summer months in 2016 and extend its operational life, which is threatened by acute shortage of spent fuel storage capacity.[871] On 5 June 2016, Premier Lin Chuan stated that the reactors shutdown date would not be extended beyond December 2018,[872] and the following day, Economics Minister Lee Chih-kung said that restarting the first reactor of Taiwan's first nuclear power plant would only be a last resort to deal with potential power shortages.[873] Environmental groups have launched a court case against the potential restart of Chinshan-1, calling it the "most dangerous reactor in the world".[874]

The New Energy Policy Vision announced by the administration of President Tsai in summer 2016 is aimed at establishing "a low-carbon, sustainable, stable, high-quality and economically efficient energy system" through an energy transition and energy industry reform. The strategies as detailed by the Ministry of Economic Affairs (MOEA) are:

- Achieving the goal of a nuclear-free Taiwan by 2025.
- Actively developing green energy and increasing the share of renewables in total electricity generation to 20 percent by 2025.
- Accelerating the construction of Taiwan's third LNG receiving terminal, and expanding the use of natural gas.
- Completing revision of the Electricity Act to facilitate energy transformation.[875]

On 12 January 2017, the Electricity Act Amendment completed and passed its third reading in the legislature, setting in place the mechanisms for Taiwan's energy transition, including nuclear phase-out.[876] The law also gives priority to the distribution of renewable energy, by which generators of renewable energy will be given preferential rates, and small generators of green energy will be exempt from having to prepare operating reserves. The monopoly of the state-run Taipower will also be terminated.[877]

870 - *China Post*, "Gov't to end nuclear power in 2025: MOEA", 26 May 2016, see http://www.chinapost.com.tw/taiwan/national/national-news/2016/05/26/467321/Govt-to.html, accessed 13 July 2017.

871 - Huang Chiao-wen and Y.F. Low, "Economics minister reaffirms goal of nuclear-free Taiwan by 2025", *Focus Taiwan*, *The Central News Agency* (*CNA*), 27 May 2016, see http://focustaiwan.tw/news/aeco/201605270025.aspx, accessed 13 July 2017.

872 - Tai Ya-chen, Chen Cheng-wei and Elizabeth Hsu, "Premier considers reactivating long-closed nuclear reactor", *Focus Taiwan*, *CNA*, 5 June 2016, see http://focustaiwan.tw/news/aipl/201606050006.aspx, accessed 13 July 2017.

873 - Huang Chiao-wen and Lilian Wu,"Restart of reactor a last resort: economics minister", *Focus Taiwan*, *CNA*, 6 June 2016, see http://focustaiwan.tw/news/aeco/201606060019.aspx, accessed 13 July 2017.

874 - Chen Wei-han, "Activists file suit over Jinshan reactor", *Taipei Times*, 31 May 2016, see http://www.taipeitimes.com/News/taiwan/archives/2016/05/31/2003647555, accessed 13 July 2017.

875 - MOEA, "Taiwan's New Energy Policy", 6 April 2017, see https://www.moea.gov.tw/Mns/ietc_e/content/Content.aspx?menu_id=21511, accessed 13 July 2017.

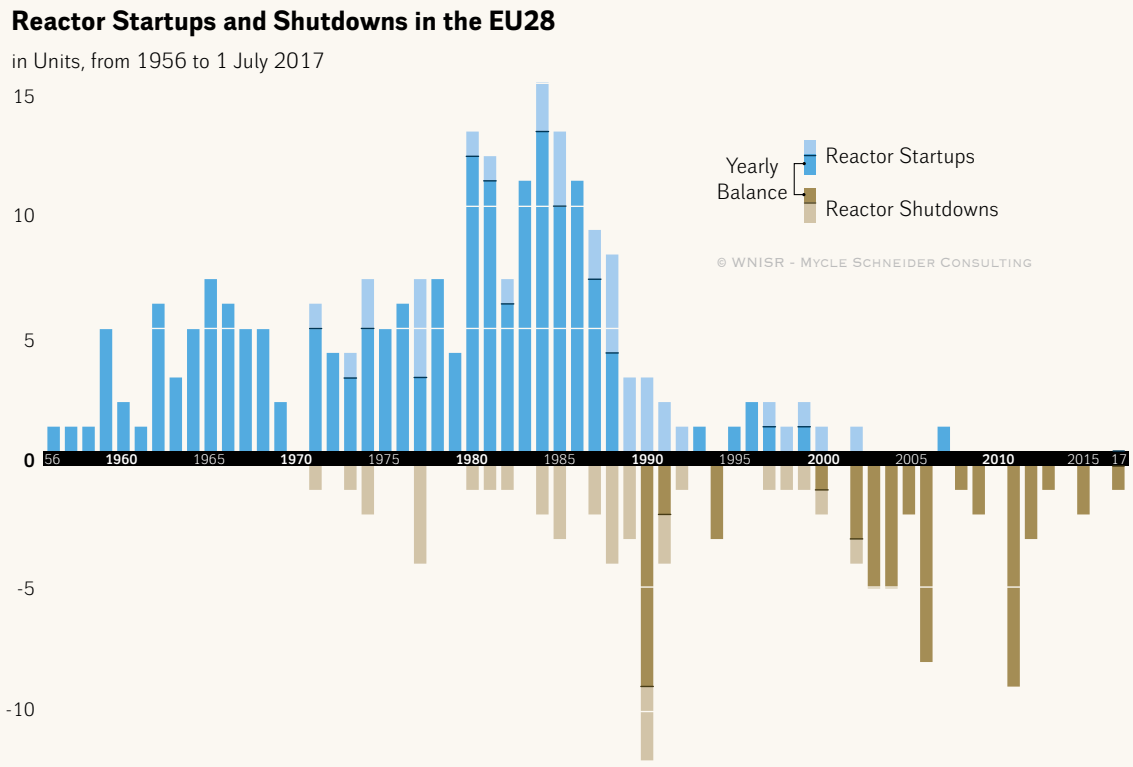
876 - Bureau of Energy, "The Three-Stage Reading Process for Electricity Act Amendment Completed Moving Towards the 2025 Target of Nuclear-Free Homeland", MOEA 1, March 2017, see http://web3.moeaboe.gov.tw/ECW/english/news/News.aspx?kind=6&menu_id=958&news_id=5628, accessed 13 July 2017.

877 - *The China Post*, "Lawmakers OK wide-ranging amendments to Electricity Act", 12 January 2017, see http://www.chinapost.com.tw/taiwan/national/national-news/2017/01/12/489175/lawmakers-ok.htm, accessed 13 July 2017.

According to the AEC, Chinshan-1 is scheduled to be decommissioned in December 2018 and Chinshan-2 in July 2019. Units 1 and 2 at Kuosheng are set for decommissioning in December 2021 and March 2023. The two reactors at the Maanshan NPP in Pingtung County, are scheduled to be decommissioned in July 2024 and May 2025. Taiwan's fourth nuclear plant at Lungmen has remained mothballed since 2014, following anti-nuclear protests and a hunger strike by former Democratic Progressive Party (DPP) Chairman Lin Yi-hsiung. There are no plans for its operation under the current government.

EUROPEAN UNION (EU28) AND SWITZERLAND

Figure 49 | Nuclear Reactors Startups and Shutdowns in the EU28, 1956–2017



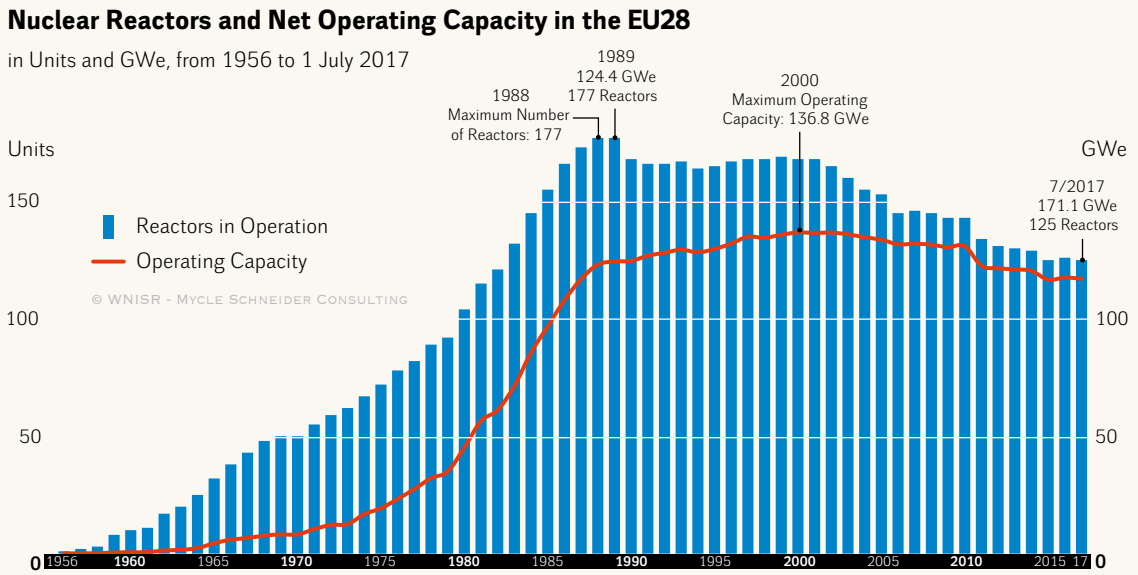
Sources: WNISR, with IAEA-PRIS, 2017

As shown in Figure 49 the European Union 28 member states (EU28) have gone through three nuclear construction waves—two small ones in the 1960s and the 1970s and a larger one in the 1980s (mainly in France).

The region has not had any significant building activity since the 1990s. There were no construction starts in Western Europe since 1991, prior to Olkiluoto-3 (2005) and Flamanville-3 (2007), and none after.

Only four reactors were connected to the EU-grid over the past 20 years, all in Eastern Europe (two in Slovakia and one each in Romania and Czech Republic), none since Cernavoda-2 started up in 2007.

Figure 50 | Nuclear Reactors and Net Operating Capacity in the EU28



Sources: WNISR, IAEA-PRIS, 2017

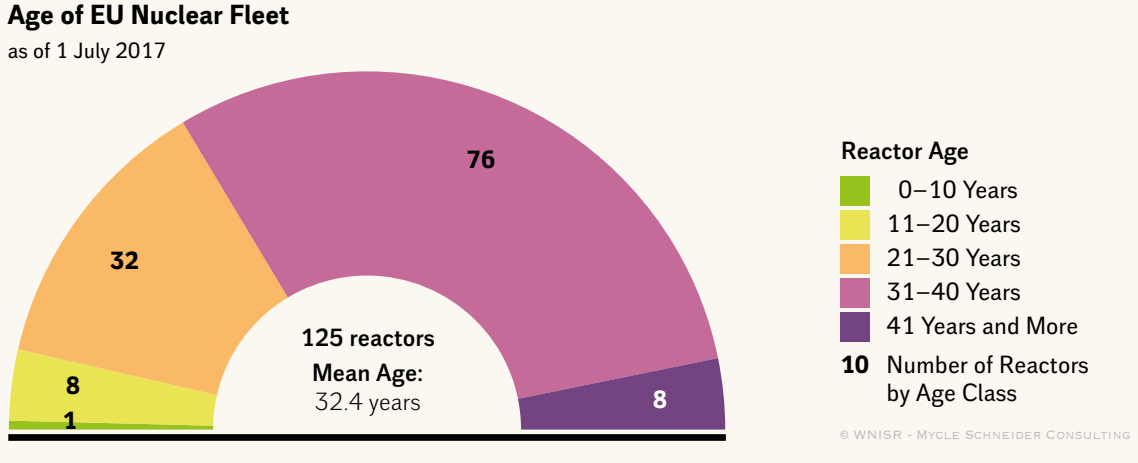
One reactor was closed since WNISR2016, Oskarshamn-1, Sweden's oldest reactor generated power for the last time on 17 June 2017.

As of 1 July 2017, the 28 countries in the enlarged EU operated 125 reactors—about one-third of the world total—52 less than the historic maximum of 177 units in 1989 (see Figure 50). The Swedish reactor Ringhals-2 was restarted in November 2016—and thus taken off the LTO list—after an outage for repairs of over two years.

Two French reactors, Bugey-5 and Paluel-2, entered the LTO category, as they have not provided any power all of 2016 and were not back online by mid-2017 (see France Focus for details).

The vast majority of the operating facilities, 106 units or over 80 percent, are located in eight of the western countries, and only 19 are in the six newer member states with nuclear power.

Figure 51 | Age Distribution of the EU28 Reactor Fleet



Sources: WNISR, with IAEA-PRIS, 2017

In the absence of any successful new-build program, the average age of nuclear power plants is increasing continuously in the EU and at mid-2017 stands at 32.4 years (see Figure 51). The age distribution shows that now 59 percent—84 of 125—of the EU's operating nuclear reactors have been in operation for 31 years and beyond.

Western Europe

As of July 2017, 106 nuclear power reactors operated in the EU15, 51 units fewer than in the peak years of 1988/89. As stated above, Ringhals-2 in Sweden restarted generating power and was thus moved from the LTO- to the operating-category. At the same time, the two French units Bugey-5 and Paluel-2 entered the LTO category.

Two reactors are currently under construction in the older member states, one in Finland (Olkiluoto-3) and one in France (Flamanville-3). Both projects are many years behind schedule and billions over budget (details are discussed in other chapters of the report). While the "Final Investment Decision" for EDF Energy's Hinkley Point C project in U.K. has finally been taken in the fall of 2016, construction is not scheduled to start before 2019.

The following section provides a short overview by country (in alphabetical order).

Belgium operates seven pressurized-water reactors that have generated 41.43 TWh in 2016 (maximum of 46.7 TWh in 1999) corresponding to 51.7 percent of the electricity (the maximum was 67.2 percent in 1986). In 2015, following a series of technical issues, the nuclear share had dropped to 37.5 percent. The average age of the Belgian fleet stands at 37.3 years.

Legally, the country is bound to a nuclear phase-out target of 2025: In January 2003, legislation was passed that requires the shutdown of all of Belgium's nuclear plants after 40 years, so based on their start-up dates, plants would be shut down progressively between 2015 and 2025 (see Table 11). Practically, however, after lifetime extension to 50 years was granted for three reactors, five of the seven reactors would go offline in the single year of 2025. This represents a challenging policy goal.

Following Fukushima, the phase-out legislation was left in place even though GDF-Suez (now Engie), that operates all seven PWRs in Belgium through its subsidiary Electrabel, was lobbying to postpone it via an extension of "at least 10 years".[878] In December 2013, the phase-out legislation was amended for the first time,[879] granting a 10-year extension for the Tihange-1 reactor, while imposing an additional operating tax that removed about 70 percent of its profit in excess of a guaranteed return of 9.3 percent on investment necessary for the lifetime extension.[880] The other shutdown dates were confirmed (see Table 11) and the law's Article 9, which enabled continued operation in case of security-of-supply concerns, was deleted.

878 - Gérard Mestrallet, et al., "Nuclear in Belgium: recent developments", GDF Suez, 4 November 2011.

879 - Moniteur Belge, "18 Décembre 2013—Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité et modifiant la loi du 11 avril 2003 sur les provisions constituées pour le démantèlement des centrales nucléaires et pour la gestion des matières fissiles irradiées dans ces centrales", 24 December 2013.

880 - Melchior Wathelet, "Avec la réserve stratégique, Melchior Wathelet finalise l'exécution de son plan", Energy Minister, Belgian Federal Government, 16 December 2013.

In summer 2012, the operator identified an unprecedented numbers of hydrogen-induced crack indications in the pressure vessels of Doel-3 and Tihange-2, with respectively over 8,000 and 2,000 previously undetected defects. After several months of analysis, the Belgian safety authority, the Federal Agency for Nuclear Control (FANC), in May 2013, FANC licensed restart[881] in spite of serious concerns by several scientists (see previous WNISRs). Then, on 25 March 2014, Electrabel announced the immediate shutdown of the Doel-3 and Tihange-2 reactors, declared as "anticipating planned outages". Additional inspections have raised the number of identified defects to over 13,000 in the Doel-3 pressure vessel (up to 40 per dm^3, up to 18 cm long, down to a depth of 12 cm in the vessel wall) and to over 3,000 at Tihange-2.[882]

Table 11 | Closure Dates for Belgian Nuclear Reactors 2022–2025

Reactor (Net Capacity)	First Grid Connection	End of License (Latest Closure Date)
Doel-3 (1006 MW)	1982	1 October 2022
Tihange-2 (1008 MW)	1982	1 February 2023
Doel-1 (433 MW)	1974	10-year lifetime extension to 15 February 2025
Doel-4 (1039 MW)	1985	1 July 2025
Tihange-3 (1046 MW)	1985	1 September 2025
Tihange-1 (962 MW)	1975	10-year lifetime extension to 1 October 2025
Doel-2 (433 MW)	1975	10-year lifetime extension to 1 December 2025

Sources: Belgian Law of 28 June 2015; Electrabel/GDF-Suez, 2015[883]

In spite of widespread concerns, and although no accountable explanation about the negative initial fracture toughness test results could be given, on 17 November 2015, FANC authorized restart of Doel-3 and Tihange-2.[884]

The Belgian government did not wait for the outcome of the Doel-3/Tihange-2 issue and decided in March 2015 to draft legislation to extend the lifetime of Doel-1 and Doel-2 by ten years

881 - FANC, "FANC experts give positive opinion on restart of Doel 3 & Tihange 2 reactor units", 17 May 2013, see http://www.fanc.fgov.be/GED/00000000/3400/3430.pdf, accessed 18 June 2016.

882 - FANC, "Doel 3/Tihange 2: clarifications regarding the detection, the position and the size of the flaw indications", 25 February 2015, see http://www.fanc.fgov.be/fr/news/doel-3/tihange-2-clarifications-regarding-the-detection-the-position-and-the-size-of-the-flaw-indications/753.aspx, accessed 2 July 2016.

883 - Moniteur Belge, "Loi modifiant la loi du 31 janvier 2003 sur la sortie progressive de l'énergie nucléaire à des fins de production industrielle d'électricité afin de garantir la sécurité d'approvisionnement sur le plan énergétique", Second Edition, 6 July 2015, (in French and Dutch), see http://www.ejustice.just.fgov.be/mopdf/2015/07/06_2.pdf;

➔ Doel-1&-2, see Electrabel, GDF Suez/Engie, "Note de Presse—Sécurité d'approvisionnement et transition énergétique—Accord sur la prolongation de Doel 1 et Doel", Press Release,1 December 2015, (in French), see corporate.engie-electrabel.be/wp-content/uploads/2016/03/note-de-presse-prolongation-doel-1-et-doel-2-securite-dapprovisionnement-en-belgique-fr-def.pdf, and "Doel Nuclear Power Plant—Profile of the 4 units", Updated 7 August 2017, see http://corporate.engie-electrabel.be/local-player/nuclear-3/doel/;

➔ For Tihange-1 : Engie/Electrabel, "Tihange", see http://corporate.engie-electrabel.be/local-player/nuclear-3/tihange/; all accessed 9 August 2017.

884 - Engie-Electrabel, "The Federal Agency for Nuclear Control approves safe restart of Doel 3 and Tihange 2", Press Release, 17 November 2015, see http://corporate.engie-electrabel.be/news/press-releases/the-federal-agency-for-nuclear-control-approves-safe-restart-of-doel-3-and-tihange-2/, accessed 2 July 2016.

to 2025.[885] The law was promulgated on 28 June 2015, and went into effect on 6 July 2015.[886] The government signed an agreement with Electrabel on 30 November 2015 that stipulates that the operator will invest €700 million (US$741.2 million) into upgrading of the two units[887] and an annual fee of €20 million (US$21.2 million), which will be paid into the national Energy Transition Fund, set up by the law of 28 June 2015. On 22 December 2015, FANC authorized the lifetime extension and restart of Doel-1 and -2.

On 5 January 2016, two Belgian NGOs filed a complaint against the 28 June 2015 law with the Belgian Constitutional Court, arguing in particular that the lifetime extension had been authorized without a legally binding public enquiry. In a 22 June 2017 pre-ruling decision, the Court addresses a series of questions to the European Court of Justice, in particular concerning the interpretation of the Espoo and Aarhus Conventions, as well as the European legislation.[888] The case is pending.

In May 2017, the Belgian Federal Nuclear Control Agency (FANC) announced that a series of ultra-sonic inspections on the pressure vessel of Tihange-2 did not show any evolution of the hydrogen flakes, nor any new defects. On the basis of these results, FANC authorized the restart of the reactor.[889] FANC later admitted that:

Just over 300 additional flaw indications at Doel 3 and 70 additional flaw indications at Tihange 2 also exceeded the recording threshold for the first time during the re-inspections carried out in 2016 and 2017 respectively.

However, arguing that the results were due to evolving complex inspection techniques rather than physical changes, FANC concluded:

Since we have been able to find scientific explanations for all these newly reported hydrogen flakes, or they have been accounted for by signals recorded in previous inspections, the analysis of these results allows us to conclude that no new hydrogen flakes have appeared and that there has been no change in the size of the hydrogen flakes already detected.

Surprisingly, at the same time:

FANC stresses that the characterisation of hydrogen flaw indications using a non-destructive ultrasonic testing method is an experimental technique with results that vary from measurement to measurement.[890]

It remains unclear how the experimental inspection technique has led to scientific certitude.

885 - Marie-Christine Marghem, "Measures which intend to assure the security of supply in Belgium", Minister of Energy, Environment and Sustainable Development, Belgian Federal Government, Press Release, 5 March 2015, see http://www.marghem.belgium.be/en/measures-which-intend-assure-security-supply-belgium, accessed 2 July 2016.

886 - Moniteur Belge, op.cit.

887 - Electrabel, "Sécurité d'approvisionnement et transition énergétique—Accord sur la prolongation de Doel 1 et Doel 2", Press Release, 1 December 2015.

888 - Cour Constitutionnelle, "Arrêt N°82/2017", 22 June 2017.

889 - FANC, "Pas d'évolution des flocons d'hydrogène à Tihange", 5 May 2017, (in French), see http://www.fanc.fgov.be/fr/news/pas-d-evolution-des-flocons-d-hydrogenea-tihange-2/878.aspx, accessed 3 August 2017.

890 - FANC, "Doel 3 & Tihange 2: flaw indications in the reactor pressure vessel steel", Updated 8 June 2017, (in French and Dutch), see http://afcn.fgov.be/fr/page/doel-3-tihange-2-flaw-indications-in-the-reactor-pressure-vessel-steel/1989.aspx, accessed 3 August 2017.

Only four months after the Tihange-2 restart authorization, Jan Bens, Director General of FANC expressed "our worries, if not our deep concern, when it comes to the management by Electrabel of its nuclear activities in Belgium" in a leaked, September-2016, three-page letter to Isabelle Kocher, Electrabel President of the Board and Engie CEO.[891] In particular, deteriorated safety culture and work conditions at Tihange-2 triggered the unusual warning. One example, as provided in the letter, to illustrate the seriousness of the situation: for months, the reactor has been understaffed and three or four engineers are expected to carry out the work of five staff positions in the organigram.

Meanwhile, "Engie wants to exit nuclear power", as *BFM Business* headlined a December-2016 story on the Electrabel owner.[892] The operator of the Belgian nuclear fleet has sold its stakes in UK new-build projects, tries to get out of a Turkish new-build project and would like to sell Electrabel. But who would buy outdated industrial facilities with an average age of over 37 years?

Finland operates four units that in 2016 supplied 22.28 TWh, almost identical to the previous year's 22.3 TWh generation, and close to the 2013 record of 22.67 TWh. The nuclear share remained stable at 33.7 percent of electricity production (with a maximum of 38.4 percent in 1986). Finland has adopted different nuclear technologies and suppliers, as two of its operating reactors are PWRs built by Russian contractors at Loviisa, while two are BWRs built by ABB (Asea Brown Boveri) at Olkiluoto. The average age of the four operating reactors is 38.3 years. In January 2017, operator TVO filed an application for a 20-year license extension for the respectively 39- and 37-year old units Olkiluoto-1 and -2.[893]

In December 2003, Finland became the first country to order a new nuclear reactor in Western Europe in 15 years. AREVA NP, then a joint venture owned 66 percent by AREVA and 34 percent by Siemens[894], is building a 1.6 GW EPR at Olkiluoto (OL3) under a fixed-price turnkey contract with the utility TVO. After the 2015 technical bankruptcy of AREVA Group, the majority shareholder, the French government, decided to integrate the reactor-building division into a subsidiary majority-owned by state utility EDF. However, EDF has made it clear repeatedly that it will not take over the billions of euros' liabilities linked to the costly Finnish AREVA adventure.[895] Thus, it was decided that the financial liability for OL3 and associated risks stay with AREVA S.A. after the sale of AREVA NP and the creation of a new company AREVA Holding, temporarily called NewCo that will focus on nuclear fuel and waste management services, very similar to the old COGEMA.

891 - Jan Bens, "Letter to Isabelle Kocher, President of the Board of Electrabel—Informations importantes quant à vos activités nucléaires en Belgique et en particulier à la central nucléaire de Tihange", General Director, Département Établissement et Déchets, Service Établissements Nucléaires de Base, FANC, dated 2 September 2016, (in French), see http://r9.llb.be/file/89/5833031bcd70d913edcf5989.pdf, accessed 4 August 2017.

892 - Matthieu Pechberty, "Engie veut sortir du nucléaire", *BFM Business*, 7 December 2016, (in French), see http://bfmbusiness.bfmtv.com/entreprise/engie-veut-sortir-du-nucleaire-1067637.html, accessed 3 August 2017.

893 - TVO, "New operating license applied for Olkiluoto 1 and 2 plant units", 26 January 2017, see http://tvo.fi/news/1830, accessed 4 August 2017.

894 - Siemens quit the consortium in March 2011 and announced in September 2011 that it was abandoning the nuclear sector entirely.

895 - Jean-Michel Bezat, "EDF pose ses conditions au rachat des réacteurs d'Areva", *Le Monde*, 19 May 2015, (in French), see http://www.lemonde.fr/economie/article/2015/05/19/edf-pose-ses-conditions-au-rachat-des-reacteurs-d-areva_4636164_3234.html, accessed 2 July 2016.

The OL3 project was financed essentially on the balance sheets of the Finland's leading firms and municipalities under a unique arrangement that makes them liable for the plant's indefinite capital costs for an indefinite period, whether or not they get the electricity—a capex "take-or-pay contract".

Construction started in August 2005 at Olkiluoto on the west coast. The project is at least nine years behind schedule and is at least about three times over budget. In its 2015 Annual Report, TVO[896] states: "According to the schedule updated by the Supplier, regular electricity production at OL3 will commence at the end of 2018". This planning schedule has remained valid as of July 2017. Fuel loading is to begin in April 2018, which also marks the beginning of TVO as official operator of the plant.[897]

As of the end of 2016, TVO compensation claims amount to about €2.3 billion (US$2.4 billion), while AREVA-Siemens in return claims €3.5 billion (US$ 3.7 billion).

The latest official cost estimate from early 2014—no doubt an underestimate by now, but it has not been officially raised since—had been given as €8.5 billion (US_{2017}10 billion) for an original "fix price" estimate of "around €3 billion" (US_{2017}3.6 billion).

It remains unclear who will cover the additional cost: the vendors and TVO blame each other and are in litigation. AREVA has cumulated €5.5 billion in losses on the project, increasing provisions by €905 million (US$988 million) in 2015. In February 2016, AREVA updated its claim against TVO to €3.4 billion (US$3.7 billion), while TVO had increased its own compensation claim against AREVA to €2.6 billion (US$2.85 billion) in August 2015.[898]

In May 2015, credit-rating agency Standard & Poor's downgraded TVO to BBB-, with a negative outlook, "owing to continued deterioration in market prices and increased risk of higher production costs related to TVO's third nuclear power plant, Olkiluoto-3".[899] In May 2016, S&P lowered its rating for the company to "junk" (speculative grade 'BB+/B', stable outlook). This was said to be both as a result of the deterioration in the Finish power prices and most damningly:

> Future prices are currently predicted by the market to be below TVO's expected costs of production when the third nuclear power plant Olkiluoto 3 (OL3) is commissioned in 2018/2019. (...)
>
> We assess TVO's financial risk as significant based on its high debt leverage, which has increased due to cost overruns in the OL3 project.[900]

The stable outlook is based, amongst others, on the assumption that there will be "no further cost overruns in the completion of OL3".[901]

896 - TVO, "Report of the Board of Directors and Financial Statements 2015", February 2016, see http://www.tvo.fi/news/1692, accessed 9 August 2017.

897 - AREVA, "2016 Reference Document", May 2017.

898 - *NW*, "Talks with TVO on Olkiluoto-3 'positive' and 'fast paced,' Areva CEO says", 3 March 2016.

899 - S&P, "Finnish Nuclear Power Producer TVO Downgraded To 'BBB-/A3'; Outlook Negative", 28 May 2015.

900 - S&P, "Finland-Based Nuclear Power Producer TVO Downgraded To 'BB+' From 'BBB-' On Reduced Cost Competitiveness; Outlook Stable", 23 May 2016.

901 - Ibidem.

From the beginning, the OL3 project was plagued with countless management and quality-control issues. Not only did it prove difficult to carry out concreting and welding to technical specifications, but the use of sub-contractors and workers from 55 nationalities made communication and oversight extremely complex (see previous WNISR editions).

The problems produced by the OL3 project have not prevented TVO from filing an application, in April 2008, for a decision-in-principle to develop "OL4", a 1.0–1.8 GW reactor to start construction in 2012 and enter operation "in the late 2010s".[902] However, in May 2015, TVO announced that it had decided not to apply for a construction license.[903]

In parallel, Fortum Power has been planning a similar project. In January 2009, the company Fennovoima Oy submitted an application to the Ministry of Employment and the Economy for a decision-in-principle on a new plant at one of three locations—Ruotsinpyhtää, Simo, or Pyhäjoki. This was narrowed down to the latter site. Startup was planned for 2020. In March 2014, Rosatom, through a subsidiary company ROAS Voima Oy, completed the purchase of 34 percent of Fennovoima, the price of which was not disclosed[904], and then in April 2014 a "binding decision to construct" an AES-2006 reactor was announced. In December 2014, the Finnish Parliament voted in favor of a supplement to the decision-in-principle to include Rosatom's reactor design.[905] A construction license application was submitted at the end of June 2015. In September 2015, the Finnish Safety Authority STUK began assessing the Hanhikivi-1 called project, which it stated would take until the end of 2017. Thus, STUK will not issue any construction license before 2018.[906] However, site preparation work and rock blasting reportedly already began in January 2016.[907] Actual construction is scheduled to start in 2018, with completion expected in 2024.[908] However, the schedule appears overly optimistic—just like in many other Rosatom projects—as the "first batch of documentation" for the construction license application has only been transmitted to the Finnish safety authorities on 1 November 2016.[909]

Finnish retailer Kesko Oyj decided back in 2014 to leave the project and dispose of its share of about 2 percent. However, it took an almost three years of legal struggles against the majority owner before Finland's Court of Arbitration settled the issue in January 2017 in favor of Kesko. Prior to the judgement, Hanhikivi-1 was 66-percent owned by Voimaosakeyhtio SF, which includes Finnish utilities and industrial companies, while Rosatom held 34 percent.[910]

902 - TVO, "Construction of a Nuclear Power Plant Unit at Olkiluoto—General Description—OL4", August 2008.

903 - TVO, "TVO's Board of Directors proposes that OL4 construction license will not be applied now", Press Release, 13 May 2015, see http://www.tvo.fi/news/1596, accessed 10 August 2017.

904 - Fennovoima, "Rosatom acquired 34% of Fennovoima", Press Release, 27 March 2014.

905 - *WNN*, "Parliament approves Fennovoima's amendment", 5 December 2014, see http://www.world-nuclear-news.org/NN-parliament-approves-Fennovoimas-amendment-5121401.html, accessed 18 June 2015.

906 - STUK, "STUK will start the Construction License safety review and assessment of Fennovoima's project", Press Release, 8 September 2015, see http://www.stuk.fi/web/en/-/stuk-will-start-the-construction-license-safety-review-and-assessment-of-fennovoima-s-project, accessed 9 June 2016.

907 - PIE, "PIE's New Power Plant Project Tracker", February 2016.

908 - *WNN*, "Daily", 21 March and 8 June 2017.

909 - *WNN*, "Daily", 2 November 2016.

910 - Jussi Rosendahl, "Finnish retailer Kesko allowed to exit nuclear project", *Reuters*, 10 January 2017, see http://www.reuters.com/article/finland-nuclear-kesko-idUSL5N1F01OO, accessed 4 August 2017.

The **Netherlands** operates a single, 44-year-old 480 MW PWR that provided 3.75 TWh or 3.4 percent of the country's power in 2016, about the same level as in 2015, but down from a maximum of 6.2 percent in 1986.[911] In late 2006, the operator and the Government reached an agreement to allow operation of the reactor until 2033.[912]

In January 2012, the utility DELTA announced it was putting off the decision on nuclear new-build "for a few years" and that there would be "no second nuclear plant at Borssele for the time being".[913] No utility is currently showing any interest in pursuing new build. On the contrary, the nuclear utilities are struggling with shrinking income and increasing costs. German utility RWE that holds 30 percent of Borssele operator EPZ, reports for 2016 a €58 million (US$62 million) impairment loss for EPZ.[914] Dutch utility Delta that holds the majority 70 percent of EPZ is losing money to a point that it fears bankruptcy. Delta has asked the Dutch government for support, but Economic Affairs Minister Henk Kamp ruled out to put money into Borssele, while he was prepared to offer financial guarantees for the company's "healthy parts" (network company Enduris and water company Evides), if they were put into a new company.[915] An assessment by financial management consultancy Spring Associates had demonstrated that electricity prices would have to double to make the nuclear plant profitable again, an unlikely scenario. The most economic scenario identified would be immediate shutdown of the reactor and delayed decommissioning, according to the analysts.[916]

In June 2014, EPZ started use of uranium-plutonium Mixed Oxide (MOX) fuel at Borssele. EPZ is currently the only remaining foreign customer for commercial spent fuel of AREVA's La Hague reprocessing plant. The plan to consume all of the plutonium that is separated in as much as 40 percent MOX in the core[917] could be jeopardized, if the reactor is closed in the short term.

As in other countries, the Dutch energy sector is undergoing profound restructuring. EPZ owner Delta has been renaimed PZEM (Provinciale Zeeuwse Energie Maatschappij N.V.) in early 2017, parts (not Borssele) of which then has been sold to Stedin Holding, as part of the unbundling of production and networking activities.[918]

In fact, Borssele has become synonym for some of the lowest offshore wind energy costs in Europe during 2016, coming in at approximately US$60/MWh for the Borssele 3&4 projects (about 700 MW). This new level not only reduced the cost of offshore wind energy by about

911 - BP, "Statistical Review of World Energy", June 2014.

912 - WNA, "Nuclear Power in the Netherlands", Updated February 2017, see http://www.world-nuclear.org/info/inf107.html, accessed 10 August 2017.

913 - DELTA, "DELTA puts off decision for a few years, no second nuclear plant at Borssele for the time being", Press Release, 23 January 2012.

914 - RWE, "Annual Report 2016", 14 March 2017, see http://www.rwe.com/web/cms/en/2957158/rwe/investor-relations/reports/2016/, accessed 9 August 2017.

915 - *DutchNews.nl*, "Government won't give financial support to Borssele nuclear plant", 21 October 2016, see http://www.dutchnews.nl/news/archives/2016/10/96743-2/, accessed 5 August 2017.

916 - *DutchNews.nl*, "Government investment in nuclear power plant financially risky: report", 4 October 2016, see http://www.dutchnews.nl/news/archives/2016/10/government-investment-in-nuclear-power-plant-financially-risky-report/, accessed 5 August 2017.

917 - Jan Wieman, "Borssele moves to MOX", Fuel Cycle Manager, EPZ, published in *NEI*, 11 March 2015, see http://www.neimagazine.com/features/featureborssele-moves-to-mox-4530062/, accessed 10 August 2017.

918 - Stedin Group, PZEM, "Delta Network Continues as Part of the Stedin Group", Press Release, 31 March 2017, see https://www.pzem.nl/sites/default/files/PRESS RELEASE STEDIN GROEP PZEM.pdf, accessed 5 August 2017.

half, "it also put the technology on the point of the price curve that was not forecasted to be reached before 2020-21", according to the Renewables 2017–Global Status Report.[919]

Spain operates seven reactors. Nuclear plants provided 56.1 TWh in 2016 or 21.4 percent of the country's electricity in 2016, compared with 54.8 TWh and 20.4 percent in 2015 (with a maximum of 38.4 percent in 1989). Beyond the de-facto moratorium that has been in place for decades, then Premier Jose Luis Zapatero announced in April 2004 that his government would "gradually abandon" nuclear energy, while increasing funding for renewable energy. The first unit (José Cabrera) was shut down at the end of 2006. Zapatero confirmed the nuclear phase-out goal following his reelection in 2008, and then Industry Minister Miguel Sebastian stated that "there will be no new nuclear plants".[920] In October 2016, after a ten-month period of inconclusive elections, a conservative government was established, which is more favorable to nuclear power, though it remains uncertain what this means in terms of medium-term operation of the aging reactor fleet.

Spanish nuclear operators have been implementing both upratings and life-extensions for existing facilities that increased nominal capacity by around 10 percent. Further minor upratings are planned.[921] The nuclear lobby organization Foro Nuclear claims that over 80 percent under the post-Fukushima National Action Plan scheduled safety measures had been implemented by March 2016.[922]

In February 2011—just prior to the Fukushima disaster—the Spanish parliament amended the Sustainable Energy Law, deleting from the text a reference to a 40-year lifetime limitation and leaving nuclear share and lifetime to be determined by the government.[923] Nevertheless, on 16 December 2012, Garoña was shut down. The operator Nuclenor (a joint-venture of Spanish utilities Iberdola and Endesa) has tried since, against significant local opposition, to re-open the reactor. On 8 February 2017, the Nuclear Safety Council (CSN) granted permission for a new 20-year license for Garoña, on the condition it undergoes retrofits, including installation of a filtered containment venting system, construction of alternative emergency management centers and installation of a passive autocatalytic hydrogen recombine.[924]

Garoña is 46 years old. At the same time Ignacio Galan, chairman of Iberdola, has said Garoña is not economically viable,[925] with investment to bring it back on line and its operation des-

919 - REN21, "Renewables 2017—Global Status Report", June 2017.

920 - *Reuters*, "Spain Insists on Energy Saving, Not Nuclear Plants", 21 January 2009.

921 - IEA, "Energy Policies of IEA Countries—Spain 2015 Review", 2015.

922 - Foro Nuclear, "Spanish nuclear plants 5 years after Fukushima", 4 March 2016, see http://www.foronuclear.org/en/news/latest-news/122104-spanish-nuclear-power-plants-5-years-after- fukushima, accessed 14 July 2017.

923 - *WNN*, "No Limits for Spanish Reactors", 17 February 2011, see http://www.world-nuclear-news.org/NP- No_limits_for_Spanish_reactors-1702117.html, accessed 14 July 2017.

924 - CSN, "El CSN establece las condiciones a la solicitud de renovación de la autorización de explotación de Santa María de Garoña", Nuclear Safety Council, 8 February 2017, (in Spanish), see https://www.csn.es/noticias-csn/-/asset_publisher/NLz0U-LWJQIbe/content/el-csn-establece-las-condiciones-a-la-solicitud-de-renovacion-de-la-autorizacion-de-explotacion-de-santa-maria-de-garona, accessed 13 July 2017.

925 - Jon Stibbs, "Spanish nuclear sector under threat as one Garona owner wants out", ICIS, 20 April 2017, see https://www.icis.com/resources/news/2017/04/20/10098983/spanish-nuclear-sector-under-threat-as-one-garona-owner-wants-out/, accessed 13 July 2017.

cribed as potentially ruinous to the utility.[926] Endesa, the joint owner of Garona, has not yet made its position public, stating that it is awaiting a final government decision, which is due by August 2017.

The utility is currently seeking to leverage the government to increase tax support for nuclear energy in Spain, seeking to counter the tax and renewable legislation introduced in 2013, which has been blamed for hitting profitability in the nuclear sector. Nuclenor's Board of Directors failed in April 2017 to reach a decision on whether to withdraw its application for operating Garoña.[927] The parent company has indicated that the reactor could be decommissioned assuming both its owners agreed to revoke the request to reopen the facility. Iberdrola has the option to try to sell its share in the reactor, though it is unlikely to find a buyer given the required retrofit investments.

Opposition has continued to be voiced in neighboring Portugal against the continued operation of the two aging 36- and 33-year-old reactors at Almaraz. The reactor lies 100 km from the Portuguese border on the River Tagus, which flows from Spain into Portugal. In September 2016, the Portuguese government called for an urgent meeting with its Spanish counterpart over possible plans to extend the operating license for the reactor, with the Portuguese environment minister stating, that, while it "respects Spain's sovereignty in relation to its energy policies, it is seeking to intervene to "guarantee scrupulous compliance with safety regulations".[928] In May 2017, the Portuguese parliament unanimously approved a Green Party motion calling on the Government to request the Government in Madrid to permanently close the Almaraz reactor.[929]

Sweden nuclear fleet provided 60.65 TWh or 40 percent of the country's electricity production in 2016, up from 54.5 TWh and 34.3 percent in 2015 (max. 52.4 percent in 1996). Ringhals-2, which had entered the LTO category in WNISR2016, was brought back on-line in November 2016, after over two years of shutdown for repairs. The reactor restarted in spite of a "corroded reactor containment liner" after the Swedish Radiation Safety Authority had granted an "exemption from its official regulations" for its remaining lifetime.[930] Ringhals-2 is scheduled for shutdown in 2019, followed by Ringhals-1 in 2020.

On the other hand, Sweden's oldest nuclear reactor, Oskarshamn-1, was closed permanently on 17 June 2017 after close to 46 years of service.[931] Thus the total number of operating reactors stands at eight as of mid-2017.

926 - Fernando Barciela, "Electricity Companies, Divided Over The Future Of Nuclear Energy In Spain", *The Corner*, 4 May 2017, see http://thecorner.eu/spain-economy/electricity-companies-nuclear-energy-spain/63987/, accessed 13 July 2017.

927 - *Nuclenor*, "Nuclenor does not reach agreement on proposal to withdraw the application for renewal", 26 April 2017, (in Spanish), see http://www.nuclenor.org/public/prensa/ni_20170426.pdf, accessed 13 July 2017.

928 - Natasha Donn, "Urgent meeting demanded with Spain over obsolete Almaraz nuclear plant", *Portugal Resident*, 29 September 2017, see http://portugalresident.com/urgent-meeting-demanded-with-spain-over-obsolete-almaraz-nuclear-plant, accessed 14 July 2017.

929 - *The Portugal News Online*, "Portugal Parliament votes to request closure of Spain's Almaraz nuclear plant", 25 May 2017, see http://www.theportugalnews.com/news/portugal-parliament-votes-to-request-closure-of-spains-almaraz-nuclear-plant/42052, accessed 14 July 2017.

930 - *WNN*, "Daily", 4 November 2016.

931 - *WNISR*, "Sweden Retires First Commercial Nuclear Reactor (Oskarshamn-1)", 20 June 2017, see https://www.worldnuclearreport.org/Sweden-Retires-First-Commercial-Nuclear-Reactor-Oskarshamn-1.html, accessed 9 August 2017.

State-utility Vattenfall co-owns seven reactors,[932] OKG[933] owns the eighth, Oskarshamn-3. The respective majority owner operates the plants. Vattenfall also holds participations in three German nuclear power plants, two that were closed after 3/11 (Brunsbüttel, Krümmel) and one scheduled for shutdown in 2021 (Brokdorf).

Sweden is a large power exporter with Finland representing the largest importer. In 2016, net exports stood at 11.7 TWh, equivalent to over 19 percent of the nuclear generation. Exports had reached a historic maximum of 22.6 TWh in 2015.[934]

Sweden decided in a 1980 referendum to phase out nuclear power by 2010. Sweden retained the 2010 phase-out date until the middle of the 1990s, but an active debate on the country's nuclear future continued and led to a new inter-party deal to start the phase-out earlier but abandon the 2010 deadline. The first reactor (Barsebäck-1) was shut down in 1999 and the second one (Barsebäck-2) in 2005.

In June 2010, the parliament voted by a tight margin (174–172) to abandon the phase-out legislation.[935] As a result, new plants could again be built—but only if an existing plant is shut down, so the maximum number of operating units will not exceed the then current ten. In January 2014, the Vattenfall started a "decade-long public consultation" on the construction of new nuclear power plants.[936] The latest "traditional Swedish compromise", according to Energy Minister Ibrahim Baylan[937], between the Red-Green Government and three opposition parties confirms the baseline of the 2010 agreement, and fixes a 2040 target for a 100 percent renewable electricity mix. It also allows for the building of new reactors, but, as in the previous agreement, only in replacement and not in addition to existing ones. In addition, the agreement stipulates: "Government support for nuclear energy, in the form of direct or indirect subsidies, can not be counted upon".[938]

In April 2015, Vattenfall decided "to change direction for operational lifetimes of Ringhals-1 and -2"[939] and by October 2015, it was decided that Ringhals-1 would shut down in 2020 and Ringhals-2 in 2019. The reasons given were continued low electricity prices and increasing production costs. As for Vattenfall's five other reactors, the previously planned "at least 60 years of operational lifetime, until the beginning of 2040s,"[940] remains. Following the energy agree-

932 - Ringhals-1–4 (Vattenfall 70.4%, E.ON 29.6%),
Forsmark-1–3 (FKG, Vattenfall 66%, Mellansvensk Kraftgrupp 25.5%, E.ON 8.5%)

933 - OKG is owned by Uniper Sverige (formerly Sydkraft), an E.ON spinoff, for 54.5% and Fortum for 45.5%.

934 - Svenska kraftnät, "Sveriges Import/Export Samt Transitering", 2017, see www.svk.se%2Fsiteassets%2Faktorsportalen%2Felmarknad%2Fstatistik%2Fimportexport%2Fimport-export-in--utforsel-transit-och-slingkraft--2017-i-sek.xls&usg=AFQjCNHIhBU3nqy3Yhq0M3maUYm00D63jw, accessed 18 August 2017.

935 - *NEI*, "Swedish Government Overturns Nuclear Ban", 21 June 2010.

936 - WNA, "Nuclear Power in Sweden", Updated June 2017, see http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Sweden/, accessed 10 August 2017.

937 - Richard Milne, "Boost to nuclear energy as Sweden agrees to build more reactors", *Financial Times*, 10 June 2016, see https://next.ft.com/content/b44e3214-2f13-11e6-bf8d-26294ad519fc, accessed 2 July 2016.

938 - Swedish Nuclear Society/Analysgruppen, "The Swedish energy policy agreement of 10 June 2016", unofficial translation provided by the BRILLIANT project, Euratom, European Commission, see balticbrilliantproject.eu/onewebmedia/Swedish_political_energy_agreement_2016.pdf, accessed 10 August 2017; or in the original Swedish, see http://www.regeringen.se/artiklar/2016/06/overenskommelse-om-den-svenska-energipolitiken/, accessed 10 August 2017.

939 - Vattenfall, "Vattenfall changes direction for operational lifetimes of Ringhals 1 and 2", Press Release, 28 April 2015, see http://corporate.vattenfall.com/news-and-media/press-releases/2015/vattenfall-changes-direction-for-operational-lifetimes-of-ringhals-1-and-2/, accessed 10 August 2017.

940 - Vattenfall, "Vattenfall will invest in Forsmark", 15 June 2016, see https://corporate.vattenfall.com/press-and-media/press-releases/2016/vattenfall-will-invest-in-forsmark/, accessed 10 August 2017.

ment, the Vattenfall Board of Directors decided to engage into the investments in independent core-cooling systems for the three Forsmark reactors, a prerequisite for continued operations beyond 2020 that was imposed by the safety authorities.[941]

Swedish operators have pushed uprating projects to over 30 percent. OKG, the second Swedish operator, implemented a 33 percent uprate at Oskarshamn-3 with a two-year delay. At Oskarshamn-2, shut down since June 2013, major uprating works were under way, but has been "indefinitely postponed" in June 2015.[942] Vattenfall had cancelled its planned uprate for Forsmark-3 in November 2014, profitability calculation had deteriorated over the year.[943]

While Vattenfall is still struggling with low prices on the European power markets, it has increased its customer base and improved operating results. Nuclear power generation went up by 17 percent (4.1 TWh) in the first half of 2017, compared to the same period in the previous year, mainly because Ringhals-2 came back online in late 2016. Vattenfall has now a modest total of 2.8 GW of renewables in operation in various countries but has another 7 GW under development. Over one third of all capital investment in the first half of 2017 went into new renewables (wind, solar, biomass).[944]

Switzerland is the only non-EU Western European country generating nuclear power. Output dropped by 8.4 percent to 20.2 TWh in 2016 or 32.8 percent of the country's electricity,[945] down from a maximum of 44.4 percent in 1996. With an average age of 42.2 years (see Figure 52), Switzerland operates the oldest nuclear fleet and—with Beznau-1, age 48—the oldest reactor in the world (by length of commercial operation). However, Beznau-1 entered the LTO category, as it has not generated any power in 2016 and was not reconnected to the grid by mid-2017.

On 21 May 2017, 58 percent of the Swiss voters adopted the Energy Strategy 2050 that provides a long-term policy framework based on the dynamic development of energy efficiency and renewable energies. The strategy does not fix any precise shutdown dates for nuclear power plants and aims to keep the existing reactors operating "as long as they are safe". However, it prohibits the construction of new nuclear power plants and the reprocessing of spent fuel. The final text of the Strategy was adopted by the plenary of the Federal Parliament on 30 September 2016. Applicable legislation will enter into force on 1 January 2018.[946]

941 - Ibidem.

942 - *WNN*, "Oskarshamn 2 uprate put on hold", 17 June 2015, see http://www.world-nuclear-news.org/C-Oskarshamn-2-uprate-put-on-hold-1706155.html, accessed 18 June 2016.

943 - *WNN*, "Forsmark 3 power uprate cancelled", 24 November 2014, see http://www.world-nuclear-news.org/C-Forsmark-3-power-uprate-cancelled-2411145.html, accessed 10 August 2017.

944 - Magnus Hall, Stefan Dohler, "Vattenfall H1 and Q2 Results 2017", Press Conference Presentation, Vatenfall, 21 July 2017, see https://corporate.vattenfall.com/globalassets/corporate/investors/presentations/2017/q2_presentation_2017.pdf, accessed 17 August 2017.

945 - Swiss Federal Office of Energy (SFOE), "Schweizerische Elektrizitätsstatistik 2016", June 2017, (in German and French), see http://www.bfe.admin.ch/themen/00526/00541/00542/00630/index.html?lang=en&dossier_id=00765, accessed 10 August 2017.

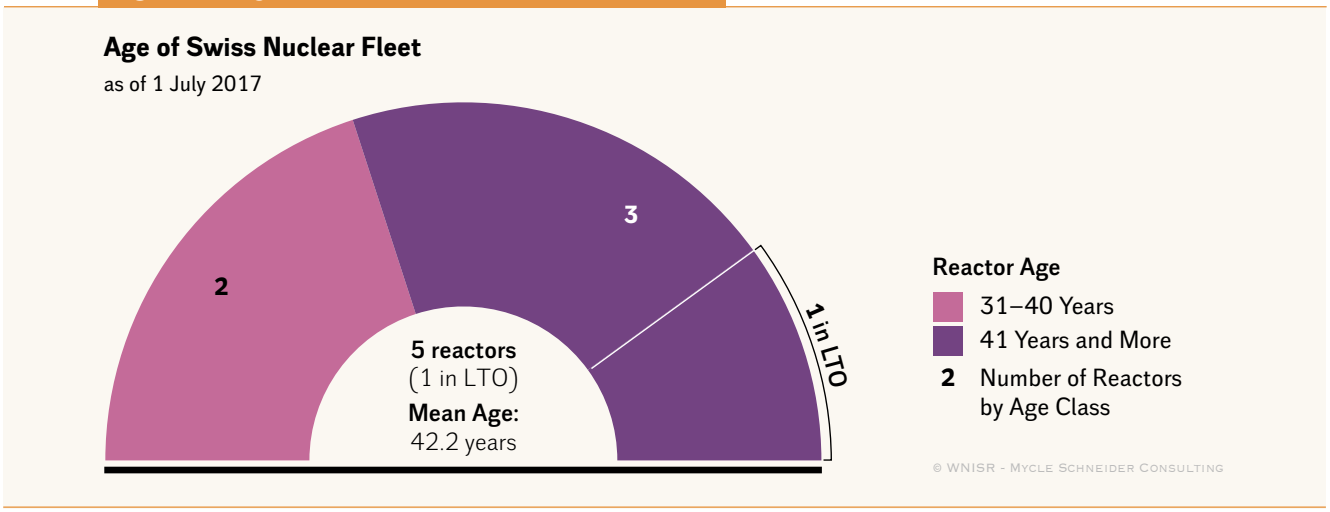
946 - SFOE, "Energy Strategy 2050 After the Popular Vote", Media And Political Affairs Division, 21 June 2017, Updated 4 August 2017, see http://www.bfe.admin.ch/energiestrategie2050/06450/index.html?lang=en&dossier_id=06702, accessed 6 August 2017.

The efficiency targets are ambitious, with reduction levels of per capita energy consumption—compared to the 2000 baseline—of 16 percent by 2020 and 43 percent by 2035, while electricity consumption is to decrease by 3 percent by 2020 and 13 percent by 2035. At that target date, domestic production of non-hydro renewable energy based electricity is to reach 11.4 TWh, while already well-developed hydro should generate 37.4 TWh.[947]

On 27 November 2016, a national referendum turned down by a majority of 54 percent a motion that aimed at the constitutional prohibition of nuclear power generation and the limitation to 45 years of the operating fleet.[948]

In October 2013, operator BKW announced that it would close its Mühleberg reactor in 2019, due to "indefinable and unquantifiable... technical, economic and political uncertainties [that] could increase the economic risks of long-term operation."[949] In January 2015, the federal regulator accepted the upgrades proposed by the operator in order to continue operating Mühleberg until 2019.[950] In December 2015, BKW officially began the closure procedure. According to cur-

Figure 52 | Age Distribution of Swiss Nuclear Fleet



Sources: WNISR, with IAEA-PRIS, 2017

rent planning, the Federal Energy Department will take the formal shutdown decision by the middle of 2018[951] and in March 2016, BKW communicated the date, when Mühleberg will be disconnected from the grid as of the 20 December 2019.[952]

Following the reactor pressure vessel problems identified at the Belgian Doel-3/Tihange-2 reactors (see Belgium Section), inspections have been carried out at the two Beznau units, both

947 - Ibidem.

948 - Schweizerische Bundeskanzlei, "Volksabstimmung vom 27.11.2016— Vorlage Nr. 608", Updated 3 August 2017, (in German), see https://www.admin.ch/ch/d/pore/va/20161127/det608.html, accessed 6 August 2017.

949 - *NIW*, "Switzerland—News Briefs", 1 November 2013.

950 - ENSI, "Forderungen des ENSI für den Weiterbetrieb des Kernkraftwerks Mühleberg bis zur endgültigen Ausserbetriebnahme (EABN) im Jahr 2019", 23 January 2015.

951 - Office Fédéral de l'Énergie (OFEN), "Calendrier et explications—1er Procédure de désaffectation de la centrale nucléaire de Mühleberg", 4 April 2016, (in German and in French), see http://www.bfe.admin.ch/themen/00511/06480/index.html?lang=fr&dossier_id=06572, accessed 10 August 2017.

952 - BKW, "Kernkraftwerk Mühleberg geht am 20. Dezember 2019 definitiv vom Netz— Endgültige Einstellung des Leistungsbetriebs", 2 March 2016, (in German), see http://www.bkw.ch/en/about-us/press-releases/detail/news/detail/News/kernkraftwerk-muehleberg-geht-am-20-dezember-2019-definitiv-vom-netz, accessed 15 June 2016.

365 MW Westinghouse PWRs. At the pressure vessel of Beznau-1, a total of 925 crack indications, up to 7.5 x 7.5 mm in size and 60 mm in depth have been identified. According to operator Axpo, the defaults, with a high degree of confidence, would not be hydrogen flakes, as in the Belgian cases, but aluminium oxide enclosures from the fabrication process. At the pressure vessel of Beznau-2, 77 indications have been found with a maximum size of 20 x 50 mm.[953] After evaluation of the identified defects in unit 2, in December 2015, ENSI grants restart permission for the reactor, while unit 1 remained offline.

In November 2016, Beznau operator Axpo transmitted its safety case to the regulator with the expectation to restart unit 1 in spring 2017. But the safety authorities requested "additional information" and the reactor is not expected to restart before 31 October 2017.[954]

The nuclear operators in Switzerland, like their colleagues in other countries, are struggling with increasing production costs at aging facilities, decreasing bulk power prices and stiff competition. Beznau operator Axpo filed a loss of CHF1.25 billion (US$1.23 billion) in 2016, after a loss of almost CHF1 billion (US$0.98 billion) in 2015 (financial years to October–September).

The leak of an internal strategy paper of Alpiq, besides Axpo the largest shareholder of the two reactors at Leibstadt and Gösgen, revealed the utilities' ambitions for a nationalization of the loss-making reactors.[955] Hans Wanner, Director of ENSI, started his presentation at the Swiss Energy Foundation's Nuclear Phaseout Congress in March 2016 with the following statement over a full slide: "We must not allow political and economic considerations to have a negative impact on the safety of the Swiss NPP."[956]

In 2016, Switzerland filed a negative electricity trade balance with net imports of 3.9 TWh, and, for the first time, the balance in monetary terms turned negative (–CHF145 million or –US$150 million).[957]

Central and Eastern Europe

In **Bulgaria**, nuclear power provided 15.01 TWh or 35 percent of the country's electricity in 2016, down from a maximum of 47.3 percent in 2002. At the country's only nuclear power plant, Kozloduy, there are just two reactors operating, where originally there were six; the other four reactors were closed as part of the agreement for Bulgaria to join the EU. The two remaining VVER1000 reactors are undergoing a relicensing program to extend their operating lifetimes for up to 60 years. In October 2014, a Franco-Russian consortium consisting of EDF, Rosenergoatom and Rosatom subsidiary Rusatom Service was awarded a lifetime-extension contract for Kozloduy-5. In January 2016, Rusatom Service and the Bulgarian company Risk Engineering signed an agreement for the assessment of the "technical condition and justifica-

953 - Christoph Pistner, "Beznau: Finding on the RPV", Presentation at INRAG, 27 February 2016.

954 - Axpo, "Sicherheitsnachweis KKB 1: AXPO muss zusätzliche Informationen liefern", 16 June 2017.

955 - Dominique Reber, "Public Affairs Konzept 2016—Alpiq", Hirzel.Neef.Schmid.Konsulenten, Alpiq, First Draft, 25 February 2015, (in German), see http://www.pdf-archive.com/2016/03/19/alpiq-konzept/preview/page/1/, accessed 21 June 2016.

956 - Hans Wanner, "Umgang mit älter werdenden Reaktoren", ENSI, presented at the Nuclear Phaseout Congress, 21 March 2016, (in German), see http://www.energiestiftung.ch/files/pdf/20160321_npc_hans_wanner.pdf, accessed 18 June 2016.

957 - BFE, "Schweizerische Elektrizitätsstatistik 2016", June 2017.

tion of the residual service life" of Kozloduy-6.[958] In May 2016, it was reported that the technical work on the completion of the life-extension on unit 5 has been completed.[959]

There have been ongoing attempts since the mid-1980s to build another nuclear power plant at Belene in Northern Bulgaria involving firms from Bulgaria, France, Germany, Russia, the United States, and now China. Due to cost and environmental concerns, these attempts ended in cancellations in 1990 and in 2012. Besides Belene, discussions are said to be ongoing for the construction of further reactors at the Kozloduy site.

After cancellation of the construction contract of the proposed nuclear power station at Belene, the International Court of Arbitration ruled in June 2016 in favor of the Russian nuclear technology exporter Atomstroyexport (ASE) over its claim for compensation for already manufactured parts. The press suggests that the Russian constructor was awarded about half of what it had asked for, receiving approximately US$600 million.[960] On receipt of payment, components for the reactors were shipped to Bulgaria, triggering further attempts to complete the units, including by Russian firms.[961] However, any such attempts will face the same financial challenges as the earlier ones.

In November 2015, the Bulgarian Prime Minister, Boyko Borisov, during a visit to China held talks on potential nuclear cooperation, which was followed by a Chinese delegation visiting Kozloduy in December 2015. It was suggested that Westinghouse, prior to its economic collapse, would team up with State Power Investment Corporation (SPIC) to construct further units at Kozludui.[962] Discussions were said to be ongoing with CNNC, with a delegation meeting with the Prime Minister in Sofia in December 2016.[963] The Bulgarian Government is reportedly also looking to Chinese sources, namely the Commercial Bank of China, to finance the completion of Belene.[964] However, with the then government excluding any electricity price guarantee—similar to the UK's Contract for Difference—international finance would appear unlikely.

The **Czech Republic** has six Russian-designed reactors in operation at two sites, Dukovany and Temelín. The former houses four VVER440-213 reactors, the latter two VVER1000-320 units. In 2016, nuclear plants generated 22.7 TWh or 29.4 percent of the electricity in the Czech Republic, that is over 6 percentage points down from record years 2013 and 2014. A fall in production in 2016 was caused by prolonged outages at the Dukovany power

958 - *NEI*, "Life extension for Bulgaria's Kozloduy 6", 1 February 2016, see http://www.neimagazine.com/news/newslife-extension-for-bulgarias-kozloduy-6-4798509, accessed 20 April 2017.

959 - Tsvetelia Tsolova, "Russia's Rosatom completes upgrade of Bulgarian nuclear reactor", *Reuters*, 31 May 2016, see http://uk.reuters.com/article/rosatom-bulgaria-idUKL8N18S28W, accessed 20 April 2017.

960 - *WNN*, "Russia wins 'half' of compensation claimed in Belene lawsuit", 16 June 2016, see http://www.world-nuclear-news.org/C-Russia-wins-half-of-compensation-claimed-in-Belene-lawsuit-16061601.html, accessed 20 April 2017.

961 - *Novinite*, "Russia Ready to Attract Investor for Bulgaria's Belene N-Plant – Ambassador", 5 March 2017, see http://www.novinite.com/articles/179113/Russia+Ready+to+Attract+Investor+for+Bulgaria%27s+Belene+N-Plant+-+Ambassador - sthash.1B4GvWmR.dpuf, accessed 3 April 2017.

962 - C.F. Yu "Will SPI Team Up with Westinghouse in Bulgaria?", *NIW*, 26 February 2016.

963 - Georgi Gotev, "China eyes nuclear project in Bulgaria", *Euractiv*, 9 December 2016, see http://www.euractiv.com/section/energy/news/china-eyes-nuclear-project-in-bulgaria/, accessed 3 April 2017.

964 - Gary Peach, "Can Bulgaria tempt the Chinese with Belene?", *NIW*, 16 December 2016.

plant due to faulty welds, which is reported to have cost the utility, CEZ, 'billions of crowns'.[965] In 2016, the country was a net exporter of 11.2 TWh of electricity, around half of the nuclear output.

The Dukovany units were started up during 1985–87 and have undergone a lifetime extension engineering program under the expectation they would operate until 2025, although it is now expected that operator CEZ will ask the regulator to extend the operating life for a further 10 years, until 2035–37.[966] In March 2016, the state regulator extended the operating license of Dukovany-1 indefinitely.[967] The Temelín reactors eventually started in 2000 and 2002 with financial assistance from the U.S. Export-Import Bank linked to the supply of instrumentation and control technology by Westinghouse.

The Czech Republic's National Report under the Convention on Nuclear Safety, draws attention to the ongoing problems with the nuclear regulator (SÚJB) as they stated that identified "significant weaknesses" in testing at both power plants and that this "raises the question whether the inspections carried out by the SÚJB in previous years were sufficient".[968]

In 2004, Government plans proposed the construction of at least two more reactors. By 2010, three consortia were being considered, led by Westinghouse, AREVA, and Skoda-Rosatom. However, it transpired that the tender was irrelevant, as a key issue for new-build was the level of state support, and in February 2014, then Prime Minister Bohuslav Sobotka stated: "The new government is not willing to provide guarantees for purchasing prices of electricity that could be a big financial burden for households and firms in the next decades."[969] In April 2014, CEZ simply cancelled its call for tenders for the two new units at Temelín, citing the low electricity market price and the lack of government guarantees.

Despite this, the Czech Industry and Finance Ministries continue to promote nuclear power, but there is little incentive or rationale for pushing for new construction in the short term. Rather, it is suggested that the government remains committed to building new capacity "sometime within the next 20 years".[970] In these plans, new capacity is foreseen for both locations, Dukovany and Temelín, to maintain employment after the closure of existing reactors. In the case of Dukovany this would require commissioning new nuclear capacity by 2037. According to CEZ, Czech PM Bohuslav Sobotka, stated: "It will be possible to launch a new nuclear unit in the nuclear power plant Dukovany in 2035." [971] CEZ is preparing preparatory work for the

965 - *WNN*, "CEZ aims to restore full nuclear potential", *World Nuclear News*, 30 March 2017, see http://www.world-nuclear-news.org/C-CEZ-aims-to-restore-full-nuclear-potential-30031702.html, accessed 3 April 2017. Note: 1 billion Czech Crowns are about US$53 million.

966 - CEZ Group, "The Dukovany Nuclear Power Station", see https://www.cez.cz/en/power-plants-and-environment/nuclear-power-plants/dukovany.html, accessed 3 April 2017.

967 - *NucNet*, "Dukovany-2 And -3 To Undergo Extended Checks On Pipe Welds", 13 May 2016, see http://www.nucnet.org/all-the-news/2016/05/13/dukovany-2-and-3-to-undergo-extended-checks-on-pipe-welds, accessed 3 April 2017.

968 - Státní úřad pro Jadernou Bezpečnost (SÚJB), "The Czech Republic National Report—Under the Convention on Nuclear Safety", State Office for Nuclear Safety, April 2016, see http://www-ns.iaea.org/downloads/ni/safety_convention/7th-review-meeting/czech-national-report-for-the-7th-rm.pdf, accessed 3 April 2017.

969 - *Ceskenoviny*, "Government won't guarantee electricity prices for Temelin—PM Sobotka", 6 February 2014.

970 - Phil Chaffee, "Prague's Vague NewBuild Plans", *NIW*, 23 January 2015.

971 - CEZ, "B. Sobotka: New nuclear unit could be launched in 2035", Press Release, 21 February 2017.

Environmental Impact Assessment,[972] but applications for construction are not expected until 2025.

In June 2016, the Government appointed former nuclear regulator Ján Štuller as Commissioner for Nuclear Energy to enable nuclear new-build. The Government has said that they are looking for a strategic partner for nuclear power in the Czech Republic, with interest in co-operation seen from Russia and South Korea.[973] In March 2016, CEZ signed an MoU with China General Nuclear Power Corporation (CGN) on the development of nuclear power and renewables, including on the assistance of CEZ in the licensing in Europe of the Hualong design.[974] In March 2017, it was reported that CEZ had held talks with Westinghouse, Rusatom Overseas, EDF, AREVA-Mitsubishi, CGN and Korea Hydro and Nuclear Power, with the companies expressing an interest in building reactors in the Czech Republic.[975]

Hungary has only one nuclear power plant, at Paks, where four VVER 440-213 reactors provided a record 15.2 TWh or 51.3 percent of the country's electricity in 2016. The reactors started operation in the early 1980s and have been the subject of engineering works to enable their operation for up to 50 years, until the 2030s. The first unit received permission to operate for another 20 years after a periodic safety review in 2012, the second unit in 2014, along with an uprating from 440 MWe (gross) to up to 510MWe (gross).[976] The extension of the operating life of Unit 3 was granted on 19 December 2016[977] and an application to extend the life of Unit 4 was filed the same month.

In March 2009, the Parliament approved a government decision-in-principle to build additional reactors at Paks.[978] Even then, Russian assistance seemed to be the preferred option, and the Foreign Minister indicated that expansion of the Paks plant would be part of a "package deal" on outstanding economic issues with Russia.[979] In February 2017, during a visit to Hungary, Russia's President Putin confirmed that it was willing to fund 100 percent of the €12 billion ($12.9 billion). Previously the Russian offer was limited to 80 percent of the financing.[980]

According to an early version of the loan contract leaked by the Russian side, the loan rate will be significantly below the market norm for such a project, with reports suggesting variable rates of 3.95-4.95 percent interest to cover 80 percent of the project's costs. The loan must be used by 2025 and be paid back within 21 years of the commissioning of the plant, starting in

972 - SÚJB, "The Czech Republic National Report—under the Convention on Nuclear Safety 2016", State Office for Nuclear Safety, see http://www-ns.iaea.org/downloads/ni/safety_convention/7th-review-meeting/czech-national-report-for-the-7th-rm.pdf, accessed 3 April 2017

973 - *NIW*, "Czech Republic", 29 January 2016.

974 - CGN, "CGN and CEZ Collaborate on Renewable and Nuclear Energy in the Czech Republic", 31 March 2016, see http://en.cgnpc.com.cn/n1017152/n1017227/c1295759/content.html, accessed 21 April 2016.

975 - *WNN*, "CEZ aims to restore full nuclear potential", 30 March 2017, see http://www.world-nuclear-news.org/C-CEZ-aims-to-restore-full-nuclear-potential-30031702.html, accessed 3 April 2017

976 - *WNN*, "Paks unit 2 gets 20-year life extension", 27 November 2014, see http://www.world-nuclear-news.org/RS-Paks-unit-2-gets-20-year-life-extension-27111401.html, accessed 3 April 2017.

977 - Orszagos Atomenergia Hivatal (OAH), "Hirdetmény közigazgatási hatósági engedélyezési eljárásban hozott döntésről", National Office for Atomic Energy, 22 December 2016, (in Hungarian), see http://www.oah.hu/web/v3/OAHPortal.nsf/web?OpenAgent&article=news&uid=6030935A5FE79DFDC125809100304792, accessed 10 May 2017.

978 - John Shepherd, "Hungary's Parliament Paves Way to Build New Reactor Unit", *NucNet*, 31 March 2009.

979 - *Realdeal.hu*, "Hungary, Russia Seek to Resolve All Outstanding Issues in One Package, Says FM", 21 January 2011.

980 - *NIW*, "Briefs—Hungary", 3 February 2017.

2026. However, penalty conditions are said to have the possibility to bankrupt the Hungarian State, and opposition parliamentarians at the time called for the Government to cancel the project. The Government is nonetheless determined to proceed and has even modified proposed legislation to increase the period for which contract terms would remain secret from 15 to 30 years. The scope of the confidentiality is that it "may deny publishing any data connected to the project, if their publication would engage either the national security interests of Hungary, or intellectual property rights."[981]

In September 2015, the European Commission notified the Hungarian authorities that the project meets the objectives of Article 41 of the EURATOM Treaty.[982] However, on 23 November 2015, the European Commission opened an investigation into the Paks II project, with particular focus on the non-tendering of the project and whether a private investor would have financed the project on similar terms, or if Hungary's investments constitutes State Aid.[983]

However the past twelve months have been an important year for the Paks II project, with four major milestones achieved. Firstly, the plant was granted an environmental license in September 2016, following the publication of a 2,000-page environmental impact assessment and consultations inside and outside of Hungary.[984] The environmental license is currently appealed by a coalition of NGOs, including Budapest-based Energia Klub and Greenpeace Hungary.

Then in November 2016, the European Commission cleared the award of the contract to Rosatom of any infringement on its procurement. The European Commission accepted the Hungarian justification for the decision that the "technical and safety requirements of the project can only be met by one company".[985] This is surprising given the range of reactors, such as the EPR, the AP1000 and ABWR that are under construction or under licensing review with in the European Union.

In March 2017, the European Commission approved the financial package for Paks II, acknowledging that it was State Aid, but they were satisfied that the impacts on the market would be kept to an acceptable level, if certain requirements were met, which included: any profits from the operation cannot be used to build or acquire additional generating capacity; Paks II, must be legally separated from Paks I; and that at least 30 percent of the power produced must be sold on the open market.[986] It is expected that the Austrian Government will challenge the decision and take the European Commission to the European Court of Justice, as it did with the Hinkley Point C case in 2015[987], which is ongoing.

981 - Phil Chaffee, "EU Hungary doubles down on Paks 2 secrecy", *NIW*, 27 February 2015.

982 - *WNN*, "Hungary meets Euratom Treaty objectives for Paks II", 15 September 2015, see http://www.world-nuclear-news.org/NN-Hungary-meets-Euratom-Treaty-objectives-for-Paks-II-15091501.html, accessed 20 April 2017.

983 - Official Journal of the European Union, "State Aid—Hungary—SA.38454 (2015/C) (ex 2015/N)— Possible aid to the Paks nuclear power station", 12 January 2016, letter dated 23 November 2015, see http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52016XC0112(01)&from=EN, accessed 30 July 2017.

984 - *WNN*, "Paks II projects gets environmental licence", 30 September 2016, see http://www.world-nuclear-news.org/NN-Paks-II-project-gets-environmental-licence-30091602.html, accessed 4 April 2017.

985 - *NEI*, "EC agrees to Hungary's Paks II, but funding decision still awaited", 23 November 2016, see http://www.neimagazine.com/news/newsec-agrees-to-hungarys-paks-ii-but-funding-decision-still-awaited-5677338, accessed 4 April 2017.

986 - European Commission, "State Aid: Commission clears investment in construction of Paks II nuclear power plant in Hungary", Press Release, 6 March 2017, see http://europa.eu/rapid/press-release_IP-17-464_en.htm, accessed 4 April 2017.

987 - *NIW*, "Vienna Poised to Challenge Paks II Decision", 10 March 2017.

Then at the end of March, the Hungarian Atomic Energy Authority approved the site license for the new construction.[988] Construction is planned to start in 2018 and commissioning in late 2023 or early 2024.[989]

However, there are still important economic consideration for the project. Most importantly, falling power prices across Europe have raised serious questions on the economic viability of the project and various studies have been undertaken to assess this. One report, undertaken by Rothschild & Cie for the Prime Minister's Office in September 2015, concluded that when making assumptions on the market price of power in the order of €65/MWh (US$74/MWh), described as in the "low end",

> the operational revenues generated from the sale of the power output envisaged on benchmarked load factor assumptions can be expected to generate sufficient cash flows to cover the operational costs of running the nuclear plant, as well as contributions towards returning the invested capital.[990]

This raises serious questions about the economics of the project as the operational costs are assumed relatively low for new nuclear power plants, and the Rothschild report states that investment costs can only be partially covered in their scenario, which make up a significant share of the cost of nuclear electricity. The report has been criticized for taking "outdated and overstated price expectations" and that under more realistic assumptions the project is "uneconomic in each tested scenario and would have to be significantly subsidized by Hungarian taxpayers".[991] The current market price for power (baseload future markets 2018) in Hungary is around €35-50/MWh (US$40-57/MWh).[992]

Romania has one nuclear power plant at Cernavoda, where two Canadian-designed CANDU reactors began operating in 1996 and 2007. In 2016, they provided 10.4 TWh or 17.1 percent of the country's electricity, compared to 20.6 percent in 2009.

Between 1982 and 1987, Romania started construction on five Canadian-designed reactors, but three of the projects (Cernavoda-3 to -5) were abandoned in 1990. Unit 1 was completed in 1996, and unit two started up in 2007, 34 years after construction started.

The first two units were partly funded by the Canadian Export Development Corporation, the second also partly by Euratom. Various foreign companies have been involved in the attempts to revive the construction of units 3, 4 and 5. The penultimate involved Enel, CEZ, GDF SUEZ, RWE, Iberdrola and ArcelorMittal, which established a company with the State nuclear corporation, called EnergoNuclear in 2008. However, one by one the foreign companies pulled out.[993]

988 - *NIW*, "Briefs—Hungary", 31 March 2017.

989 - *WNN*, "Hungary repeats 2018 target date for Paks II project", 18 November 2015, see http://www.world-nuclear-news.org/NN-Hungary-repeats-2018-target-date-for-Paks-II-project-18111501.html, accessed 4 April 2016.

990 - Rothschild& Cie, "Economic analysis for the Paks II nuclear power project, A rational investment case for Hungarian State resources", Prepared for the Office of the Hungarian Prime Minister, September 2015.

991 - Candole Partners, "NPP Paks II: Economic feasibility, impact on competition and subsidy costs", Prepared for Greenpeace, May 2016.

992 - PXE, "Price information from the Power Exchange Central Europe", see http://www.pxe.cz/, accessed 4 April 2017.

993 - WNA, "Nuclear Power in Romania", Updated July 2016, see http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/romania.aspx, accessed 4 April 2017.

The latest attempt was launched by China General Nuclear Power Group (CGN), which signed a letter of intent in November 2013 with Societatea Nationala Nuclearelectrica (SNN) to complete the projects in 2019 and 2020. In October 2014, SNN and CGN signed a binding agreement that made the latter the "selected investor". This was followed in November 2015, with the signing of a Memorandum of Understanding (MoU) between Nuclearelectrica and CGN for the construction, operation and decommissioning of units 3 and 4. The MoU, also included agreements on investments, the articles of incorporation of the new project company, the structuring of the project's financing and remarkably, CGN is to be the majority share owner of the project, with at least 51 percent of the shares.[994] In January 2016, the Romania Government formally expressed support for the project and outlined the policies and measures that it would introduce to support it, this included energy market reform, changes to the electricity tariff, commitments on state guarantees and financial incentive policies.[995]

During 2016 and 2017, negotiations between CGN and Nuclearelectrica were said to be ongoing, although deadlines for construction and financing agreements have continually been extended. In February 2017, the Government was reported as saying, it wanted to accelerate the process to enable a deal to be reached, which is likely to need the greater involvement of the Romanian government.[996] As with most other large power projects, especially nuclear, in Europe, the lower market price for electricity is likely to be a significant stumbling block for the deal. According to Nuclearelectrica, the break-even price for electricity from the project is about €82/MWh (US$94/MWh),[997] which is well above the current range of €35-45/MWh (US$40-51/MWh) in Romania.[998]

In **Slovakia**, the state utility Slovenské Elektrárne (SE) operates two nuclear sites, Jaslovské Bohunice, which houses two VVER440 units, and Mochovce, which has two similar reactors in operation. In 2016, these produced 13.7 TWh or 54.1 percent of the country's electricity—the second highest share in the world behind France (overtaking Ukraine in 2016). In October 2004, the Italian national utility ENEL acquired a 66 percent stake in SE and, as part of its bid, proposed to invest nearly €2 billion (US$2.7 billion) in new nuclear generating capacity, including completion of the third and fourth blocks of Mochovce, whose construction originally began in January 1985. Towards the end of 2014, ENEL announced that it was seeking to sell its share in SE and had received a number of nonbinding bids. In December 2015, it was announced that EPH was the winner of the bid, with a preliminary price of €750 million (US$812 million). Under the deal, ENEL will get €150 million (US$171 million) in the first stage, which will give EPH 33 percent in the company, the remaining share and final price will be agreed one year after Mochovce is completed.[999]

994 - *WNN*, "Romania and China seal Cernavoda agreement", 10 November 2015, see http://www.world-nuclear-news.org/NN-Romania-and-China-seal-Cernavoda-agreement-10111501.html, accessed 20 April 2017.

995 - *WNN*, "Romania expresses support for China's role at Cernavoda", 25 January 2016, see http://www.world-nuclear-news.org/NN-Romania-expresses-support-for-China-role-at-Cernavoda-25011601.html, accessed 20 April 2017.

996 - *NIW*, "Briefs—Romania", 24 February 2017.

997 - *NucNet*, "Negotiations On Construction Of Romania's Cernavoda-3 And -4 In 'Final Stage", as posted on *Neutron Bytes*, 29 October 2016, see https://neutronbytes.com/2016/10/29/romania-reports-progress-on-cernavoda-3-4/, accessed 4 April 2017.

998 - PXE, "Price information from the Power Exchange Central Europe", see http://www.pxe.cz/, accessed 4 April 2017.

999 - Tatiana Jancarikova and Jan Lopatka, "Enel sells stake in Slovak power group, including nuclear plant, to EPH", *Reuters*, 18 December 2015, see http://www.reuters.com/article/slovakia-enel-eph-idUSL8N14657L20151218, accessed 4 April 2017.

In February 2007, SE announced that it was proceeding with the construction of Mochovce-3 and -4 and that ENEL had agreed to invest €1.8 billion (US$_{2007}$2.6 billion). According to IAEA-PRIS, construction restarted in June 2009, and, at the time, the units were expected to generate power in 2012 and 2013 respectively.[1000] However, the project was beset with problems, and by May 2016, the estimate for the total costs of completion had risen to €5.1 billion (US5.7_{2016}$ billion), with completion at the end of 2016/early 2017.[1001] According to SE, as of the last quarter of 2016, unit 3 was over 94 percent complete and unit 4 over 80 percent.[1002] However, in March 2017, SE announced a considerable further delay in the project with operation now expected only at the end of 2018 and 2019 for each unit. This is an additional two years of construction, while the officially expected cost increase is only €300 million (US$333 million),[1003] so further cost overruns are highly likely. The new construction schedule means that the reactors are six years behind the planning issued when construction restarted in 2009.

In addition to the delays and cost overruns, concerns have been raised about the state of the power market, with power prices currently at €30/MWh (US$33/MWh) and electricity demand following the sluggish economy. It is expected that, if and when the Mochovce units are completed, their capacity will mainly be used for export, so given the low electricity prices in the European market, the chance that SE will recover their ever-increasing investment seems slim. Slovak Foreign Policy Association energy analyst Karel Hirman said: "The Mochovce expansion project is a liability. EPH is buying hundreds of tonnes of concrete that may either generate profit or loss in the future."[1004]

The Slovak state-owned utility JAVYS and the Czech utility CEZ in 2009 started a joint venture Jadrová energetická spoločnosť Slovenska, a.s. (JESS) to construct new nuclear capacity in Jaslovské Bohunice. JAVYS is currently responsible for the decommissioning at Jaslovské Bohunice of the A1 reactor and the two V1 reactors, as well as for Slovakia's radioactive waste management. The so-called Bohunice NJZ (nová jadrová zdroj) 1200 MW new-build project is proposed to be completed before 2025 at a cost of €4-6 billion (US$4.5-6.8 billion). JAVYS owns 51 percent of the shares and CEZ 49 percent. CEZ sought in 2013 to sell this stake to Russian Rosatom, but negotiations failed in March 2014.[1005] Also later negotiations with China were fruitless. The Slovak Environment Ministry approved the environmental impact assessment report in April 2016.[1006] In a next step, the project is expected to tender for technology. No timeline has been published.

1000 - ENEL, "ENEL Starts Site Works at Mochovce 3–4", Press Release, 3 November 2008, see https://servizi.enel.it/eWCM/salastampa/comunicati_eng/1594888-1_PDF-1.pdf, accessed 4 April 2017.

1001 - Spravy Pravda, "Ďalšie peniaze na Mochovce? Žiga nemá oficiálnu informáciu", "Additional money for Mochovce ? Ziza has no official information", 5 May 2016, (in Slovene), see http://spravy.pravda.sk/ekonomika/clanok/392783-dalsie-peniaze-na-mochovce-ziga-nema-oficialnu-informaciu/, accessed 4 April 2017.

1002 - SE, "Mochovce 3&4 Project Completion (01/03/2016)", 3 January 2016, see https://www.seas.sk/mochovce-3-4-npp, accessed 4 April 2017.

1003 - *WNN*, "Slovak utility increases Mochovce expansion budget", 31 March 2017, see http://www.world-nuclear-news.org/NN-Slovak-utility-increases-Mochovce-expansion-budget-31031701.html, accessed 4 April 2017.

1004 - Tatiana Jancarikova and Jan Lopatka, "Enel sells stake in Slovak power group, including nuclear plant, to EPH", *Reuters*, 18 December 2015, see http://www.reuters.com/article/slovakia-enel-eph-idUSL8N14657L20151218, accessed 20 April 2017.

1005 - Chris Johnstone, "ČEZ left with problematic Slovak nuclear joint venture after Rosatom talks die", *Radio Prague*, 7 March 2014, see http://www.radio.cz/en/section/business/cez-left-with-problematic-slovak-nuclear-joint-venture-after-rosatom-talks-die, accessed 20 April 2017.

1006 - *Energia*, "Nová atómka v Bohuniciach má zelenú od MŽP", 19 April 2016, (in Slovene), see http://energia.dennikn.sk/dolezite/jadrova-energia/nova-atomka-v-bohuniciach-ma-zelenu-od-mzp/19850/, accessed 20 April 2017.

Slovenia jointly owns the Krsko nuclear power plant with Croatia—a 696-MW Westinghouse PWR. In 2016, it provided 5.4 TWh or 35.2 percent of Slovenia's electricity (down from a maximum of 42.4 percent in 2005). The reactor was started in 1981 with an initial operational life of 40 years, but, the operator intends to seek a 20-year life extension. In July 2015, an Inter-State Commission agreed to extend the plants operational life to 60 years, so that would continue until 2043, as well as to construct a dry storage facility for the spent fuel.[1007] In March 2017 a contract, for an undisclosed amount, was given to the U.S. firm Holtec for the supply of a dry cask storage facility.[1008]

In January 2010, an application was made by the nuclear operator to the Ministry of Economy to build an additional unit, but no advancement of the project has been made since.

FORMER SOVIET UNION

Armenia has one remaining reactor at the Medzamor (also Metsamor or Armenian) nuclear power plant, situated within 30 kilometers of the capital Yerevan. Armenian-2 provided 2.2 TWh or 31.4 percent of the country's electricity in 2016, down from a maximum nuclear share of 45 percent in 2009.

The reactor started generating electricity in January 1980 and is a first generation, Soviet designed reactor, a VVER 440-230. In December 1988, Armenia suffered a major earthquake that killed some 25,000 people and led to the rapid closure of its two reactors in March 1989.

progress in Severe Accident Management (SAM) programme development and implementation is quite slow and delayed with respect to the original schedules. Various essential issues are unsolved

During the early 1990s and following the collapse of the former Soviet Union, a territorial dispute between Armenia and Azerbaijan resulted in an energy blockade against Armenia that led to significant power shortages, resulting in the government's decision in 1993 to re-open unit 2 at Medzamor. In October 2012, the Armenia Government announced that it would operate the Medzamor unit until 2026.

In June 2016, the European Nuclear Safety Regulators Group (ENSREG) issued the "EU Peer Review Report of the Armenian Stress Tests"[1009]. The report confirms numerous safety-related problems, and states, for example:

> Despite of various programmes of international aid and support, the progress in Severe Accident Management (SAM) programme development and implementation is quite slow and delayed with respect to the original schedules. Various essential issues are

1007 - *WNN*, "Partners agree on life extension for Krsko", 21 July 2015, see http://www.world-nuclear-news.org/C-Partners-agree-on-life-extension-for-Krsko-2107154.html, accessed 20 April 2017.

1008 - *NEI*, "Holtec to supply storage facility to Slovenia's Krsko", 3 March 2017, see http://www.neimagazine.com/news/news-holtec-to-supply-storage-facility-to-slovenias-krsko-5753449, accessed 20 April 2017.

1009 - ENSREG, "EU Peer Review Report of the Armenian Stress Tests", June 2016, see http://www.ensreg.eu/sites/default/files/attachments/2016-07-20_4259241_armenia_stress_tests_report-_ensreg_template_final.pdf, accessed 28 July 2017.

> unsolved. (...) With respect to hardware modifications especially enhancements of the Emergency Core Cooling System, containment tightness, hydrogen monitoring and control as well as containment spray system should be treated in priority.

The last sentence reads like a list of highest-level safety-related essentials.

In September 2016, at the IAEA general assembly, the Turkish Energy Minister, Berat Albakrak, called for the reactor to be shut down stating: "We again strongly underline that all necessary measures must be taken to eliminate the risks associated with this NPP".[1010]

Armenia-2's design lifetime—and with it its operating license—expired in September 2016. Since then, and at least until June 2018, when the operator is to submit an updated Safety Analysis Report (SAR), the reactor will be operated on the basis of "temporary permissions". A final decision on a license for lifetime extension is not expected before 2021.[1011]

In December 2014, Armenia and Russia signed an intergovernmental agreement that would see the Russian Government finance a program of upgrading to let the reactor operate until 2026.[1012] The contract was signed in July 2015 for work is to be funded by a Russian state loan of US$270 million and a grant of US$30 million.[1013]

For years, Armenia has been negotiating with Russia for the construction of a new 1000 MW unit, and signed an intergovernmental agreement in August 2010. In March 2014, the energy minister admitted that it was having difficulty in attracting funds to start construction.[1014] In September 2015, Deputy Energy Minister Areg Galstyan, was quoted as saying that Armenia was now considering the construction of two 600 MW units, rather than one 1,000 MW unit. The commissioning target would move from 2027 to 2036.[1015] Back to the one-unit option, in September 2016, Areg Galstyan, stated: "We have approximately 10 years to start the construction of the new energy unit on the same place, where the Metsamor NPP is located. We are 100 percent sure that the block will use pressurized water reactor. We have one, maximum two years to make the final decision on choosing the type of project."[1016]

In **Russia**, nuclear plants provided a historic maximum of 184.1 TWh of electricity. In 2016, nuclear energy contributed 17.1 percent to the country's electricity mix, a slight decline from

1010 - Herat Albakrak, "Statement of the Republic of Turkey", Minister of Energy and Natural Resources, 26 September 2016, statement made at the 60th General Conference of the International Atomic Energy Agency, 26-30 September, see https://www.iaea.org/sites/default/files/16/09/turkey2016.pdf, accessed 17 April 2017.

1011 - Leonti Chaloyan, "Armenian NPP—Stress Tests Action Plan", Presentation at the IAEA, Vienna, 27-29 March 2017, see https://www.iaea.org/NuclearPower/Downloadable/Meetings/2017/2017-03-27-03-29-NPES/15_Chaloyan.pdf, accessed 28 July 2017.

1012 - *Diario Armenia*, "Armenia and Russia signed an agreement to extend the life of Medzamor nuclear power plant", 27 December 2014, (in Spanish), see http://www.diarioarmenia.org.ar/armenia-y-rusia-firman-un-acuerdo-para-extender-la-vida-util-de-la-central-atomica-de-medzamor/, accessed 20 April 2017.

1013 - *NEI*, "Armenia NPP prepares for life extension", 12 February 2016, see http://www.neimagazine.com/news/newsarmenian-npp-prepares-for-life-extension-4811203, accessed 7 April 2017

1014 - *Business New Europe*, "Armenia denies plans to abandon nuclear power plant project", 28 March 2014.

1015 - *NIW*, "Briefs—Armenia", 25 September 2015.

1016 - *ARKA*, "Armenia has two years to decide on type of new NPP unit", 28 September 2016, see http://arka.am/en/news/technology/armenia_has_two_years_to_decide_on_type_of_new_npp_unit/, accessed 27 July 2017.

the record level in the previous two years (18.5 percent). However, Rosatom is hoping to further increase production in the coming years, with output in 2019 expected to reach 214 TWh.[1017]

Russia has seven reactors under construction, second only to China and equal to India. Two of these are "floating reactors" (Akademik Lomonosov-1 and -2), which are nominally 32 MWe each. These were ordered in February 2009 and were expected to be delivered to the customer at the end of 2012.[1018] During 2016, it has become clear that the project has become delayed again and Rosatom's director of innovation management, Vyacheslav Pershukov, said that they planned to start deployment of the plant in September 2019, followed by trials and operational launch.[1019] Critics of the project point out that the risk of accidents on a floating nuclear plant is greatly increased because they are even more susceptible to the elements, subject to threats of piracy, and if deployed widely would increase the risks of nuclear material proliferation.[1020]

Construction started at the Baltic-1 unit, a 1109 MW VVER-491 reactor, in February 2012. However, construction was suspended in June 2013 for a variety of reasons, including recognition of the limited market for the electricity. Accordingly, WNISR pulled the project off the construction listing. Despite no indication that construction has restarted, the project remains "under construction" in IAEA statistics.

Two VVER-1200 MW units are being built at the Leningrad nuclear power plant near St. Petersburg, where construction started in 2008 and 2010. At the time of ordering, the reactors were expected to start up in 2013 and 2016 respectively. However, repeated delays have occurred, with completion of unit 1 expected in 2018.[1021] Cold testing of the integrity of the system began in April 2017, although no new startup date was announced.[1022]

In 2016, a VVER1200 reactor at Novovoronezh (unit 6 at the site) was completed and reached full power by October,[1023] two years behind schedule. Soon after start-up, an electrical power failure caused the reactor to be taken offline and was only back to full power in January 2017.[1024] The VVER1200 is the first Gen III+ to be completed,[1025] given the delays in the EPR and AP1000 construction in Europe, US and China. A second unit is under construction at the site. Another reactor is being constructed at the Rostov nuclear power plant, expected to be put into operation in 2017.[1026]

1017 - *NEI*, "Russia plant to boost nuclear power generation", 18 April 2017, see http://www.neimagazine.com/news/newsrussia-plans-to-boost-nuclear-power-generation-5789303/, accessed 25 April 2017.

1018 - *NEI*, "KLT-40S nuclear barge project still afloat", 9 March 2010.

1019 - *WNN*, "Rosatom diversifies work in Arctic region", 3 April 2017, see http://www.world-nuclear-news.org/ON-Rosatom-diversifies-work-in-Arctic-region-03041701.html, accessed 17 April 2017.

1020 - Martin Matishak, "Floating nuclear reactors could fall prey to terrorist, experts say", *Global Security Newswire*, Nuclear Threat Initiative, 13 August 2010, see http://www.nti.org/gsn/article/floating-nuclear-reactors-could-fall-prey-to-terrorists-experts-say/, accessed 17 April 2017.

1021 - *NIW*, "Briefs—Russia", 7 August 2015.

1022 - *WNN*, "Russia starts pre-commissioning Leningrade II unit 1", 13 April 2017, see http://www.world-nuclear-news.org/NN-Russia-starts-pre-commissioning-Leningrad-II-unit-1-13041702.html, accessed 17 April 2017.

1023 - *WNN*, "Russia's Novovoronezh 6 operating at full power", 27 October 2016, see http://www.world-nuclear-news.org/NN-Russias-Novovoronezh-6-operating-at-full-power-27101601.html, accessed 17 April 2017.

1024 - *NEI*, "Russia's Novovoronezh 6 at full capacity again", 30 January 2017, see http://www.neimagazine.com/news/newsrussias-novovoronezh-6-at-full-capacity-again-5726083/, accessed 17 February 2017.

1025 - Gary Peach, "Russia Lauds Completion of World's First Gen3+ Reactor", *NIW*, 10 June 2016.

1026 - Energoatom, "Rostov NPP: power unit No 4 will be put into operation in 2017", 29 March 2017, see http://www.rosenergoatom.ru/en/for-journalists/highlights/12287/, accessed 11 August 2017.

In June 2016, the Russian regulator Rostechnadzor granted a construction license for the first unit of Kursk II. It is suggested that in 2017, 16.5 billion rubles (US$274 million) have been allocated for construction,[1027] with completion expected in 2022.[1028] This could be a particularly important project, as it would be the first of the latest Russian design, the VVER-TOI, which is said to be a 1200 MW, Generation III+ design and destined for export.

A January 2015 report by Russia's Audit Chamber found seven out of then nine units under construction 12 to 38 months behind schedule—probably an underestimate. The report also noted with concern the financial situation of Rosenergoatom's construction program with lower state budgets, which fell 18 percent during 2009–2015. Furthermore, Rosenergoatom, due to lower electricity prices, was forced to take out further loans to enable construction to proceed, and, as a result, had to use 68 percent of its reserves to cover interest costs.[1029] The report also refers to alarming environmental and safety implications of the current situation, with construction taking place in the absence of a passing review by Russia's Directorate-General for State Environmental Reviews. And the construction at the Leningrad-2 station lacks a synchronized schedule of equipment delivery and installation, so by the time some equipment comes online, it will be out of warranty.[1030]

In August 2016, a Government decree called for the construction of an additional 11 reactors by 2030, which includes two new fast breeder reactors, a VVER600 at Kola and seven new VVER-TOI units at Kola, Smolensk, Nizhny Novgorod, Kostrom and Tatar.[1031] With the anticipated closures of reactors this is likely to mean that the installed capacity would be around 30 GW by 2030. It is unclear how even this reduced development plan will be funded, as the draft Russian 2017 budget assumes a decreasing budget for nuclear power; in 2017 68.7 billion rubles ($1.1 billion) will be allocated, falling to 54.8 billion rubles (US$877 million).[1032] However, there are concerns over the likelihood that the fast-reactor construction program will even begin, and in January 2017, Rosatom pushed back its start to an unspecified date, due to its high cost.[1033]

In December 2016, unit 3 at the Novovoronezh station was closed definitely. A key issue for the industry is how to manage its aging reactors. There are mainly three classes of reactors in operation: the RBMK (a graphite-moderated reactor of the Chernobyl type), the VVER440, and the VVER1000. Both the RBMKs and VVER440 have been granted a 15-year life extension to enable them to operate for 45 years, although there are plans to extend this in some cases to 60 years[1034], while the VVER1000s are expected to work for up to 50 years. As of the middle

1027 - Tatiana Kanunnikova, "Rosenergoatom invests $274m in building Kursk NPP this year", *Russian Construction*, 12 January 2017, see http://russianconstruction.com/news-1/26133-rosenergoatom-invests-274m-in-building-kursk-npp-this-year.html, accessed 17 April 2017.

1028 - *NIW*, "Briefs—Russia", 10 July 2017.

1029 - Gary Peach, "Auditor Report Illuminates Rosatom's Financial Challenges", *NIW*, 23 January 2015.

1030 - Charles Digges, "Russian Audit Chamber cites ballooning budgets in domestic nuke projects", *Bellona*, 27 January 2015, see http://bellona.org/news/nuclear-issues/nuclear-russia/2015-01-russian-audit-chamber-cites-ballooning-budgets-domestic-nuke-projects, accessed 20 April 2017.

1031 - *WNN*, "Russia to build 11 new nuclear reactors by 2030", 10 August 2016, see http://www.world-nuclear-news.org/NP-Russia-to-build-11-new-nuclear-reactors-by-2030-10081602.html, accessed 17 April 2017.

1032 - *NIW*, "Moscow Plans Nuclear Power Spending Cuts", 14 October 2016.

1033 - *NEI*, "Breakthrough project continues as Brest reactor is postponed", 18 January 2017, see http://www.neimagazine.com/news/newsbreakthrough-project-continues-as-brest-reactor-is-postponed-5718901, accessed 20 April 2017.

1034 - *NEI*, "Russian permanently closes Novovoronezh 3", 4 January 2017, see http://www.neimagazine.com/news/newsrussia-permanently-closes-novovoronezh-3-5709099/, accessed 25 April 2017.

of 2017, 22 reactors have operated for over 30 years, of which eight have run for over 40 years. According to Belona, life extensions have been granted without the necessary environmental impact assessments, which has both lead to protests but also makes the life extensions "something of a legal grey area".[1035]

In February 2017, the new head of Rosatom, Aleksei Likhachev, announced that their order book at the end of 2016 was now worth US$133 billion, up from US$110 billion at the beginning of the year. This included two VVER reactors for Bangladesh, units 2 and 3 at Bushehr in Iran, units 5 and 6 at Kudankulam in India and the 4 units at Akkuyu in Turkey.[1036]

A large part of the funding for these projects comes from Russia's Wealth Funds. However, these are also being used for stabilizing the Russian economy as a result of the lower oil and gas prices, the falling value of the ruble, and ongoing sanctions. One of these funds, the Reserve Fund, has seen its stockpile fall from US$142 billion in 2008 to $32 billion in 2016.[1037] The credit-rating agencies reflect these developments in the Russian economy in general and the energy sector. In February 2017, Moody's downgraded, from stable to negative, Atomenergoprom, along with three other energy related firms, as a result of the overall decline in the country's economic climate. The Ba 1 rating was given despite recognition of its monopolistic position, strong degree of vertical integration and strong position in the international markets, because of the relative immaturity of the domestic regulatory environment, the execution and political risks of the overseas business.[1038]

Ukraine has 15 operating reactors, two of the VVER440 design and the rest VVER1000s. They provided 76.08 TWh or 52.3 percent of power in 2016, a decline from 82.4 TWh and 56.5 percent in the previous year. Despite this, operator Energoatom said that its revenues increased by 10 percent during the year to around UAH43 billion (US$1.6 billion).[1039]

Twelve out of the country's 15 reactors were completed in the 1980s and had an original design life of thirty years. The nuclear operator has proposed to extend lifetimes of the reactors for another 20 years. The proposal was accepted and now it is a core element of the nuclear strategy approved by the government. The safety upgrade program for the 15 reactors is estimated to cost €1.45 billion (US$1.62 billion) in total, of which the European Bank for Reconstruction and Development (EBRD) and EURATOM will contribute €600 million (US$670 million). To date, two nuclear reactors at Rivne have been granted a life extension of 20 years, two units at South Ukraine for 10 years, and also two units at Zaporizhzhya NPP for 10 years. Zaporizhzhya-3 is planning to implement measures necessary for the license extension with the expected decision of the nuclear regulator in November 2017.

1035 - Nils Bøhmer, Oskar Njaa, Charles Digges, "Russian nuclear power–2017—Updated as of 30.05.2017", *Bellona*, 2017, see http://network.bellona.org/content/uploads/sites/3/2017/05/2017-Russian-nuclear-power-NO-ISBN.pdf.

1036 - Gary Peach, "Rosatom Adjusts to Low-Growth Domestic Economy", *NIW*, 20 January 2017.

1037 - Vladimir Kuznetsov, "Russian Wealth Fund Has This Year's Biggest Drop as Buffers Wilt", *Bloomberg*, 6 September 2017, see https://www.bloomberg.com/news/articles/2016-09-06/russian-wealth-fund-has-this-year-s-biggest-drop-as-buffers-wilt, accessed 20 April 2017.

1038 - Moody's, "Rating Action: Moody's changes outlook to stable on 4 Russian utility companies and their affiliates following Russian outlook change to stable; affirms ratings", 21 February 2017.

1039 - *NEI*, "Ukraine's Energoatom sees revenue increase", 23 January 2017, see http://www.neimagazine.com/news/new-sukraines-energoatom-sees-revenue-increase-5722090/, accessed 25 April 2017.

The lifetime extension of Rivne-1 and -2 is part of an ongoing controversy within the Espoo Convention on transboundary Environmental Impact Assessment (EIA), which concluded that Ukraine was in non-compliance for not executing an EIA before its decision to prolong the lifetime of these VVER440 reactors after their technical lifetime of 30 years.[1040] Environmental groups in Ukraine have called upon European institutions to stop the support for "risk" life extension programs.[1041] In 2016, the Espoo Convention Implementation Committee (ECIC) has opened a new information-gathering case regarding lifetime extension of South Ukraine and at Zaporizhzhya based on information submitted by NGO CEE Bankwatch Network[1042].

Two reactors, Khmelnitsky-3 and -4, are officially under construction. WNISR pulled them from the list. Building work started in 1986 and 1987 but stopped in 1990. In February 2011, Russia and Ukraine signed an intergovernmental agreement to complete the reactors, and in 2012, the Ukrainian Parliament adopted legislation to create a framework to finance the project, with 80 percent of the funds to be coming from Russia. It is unclear how much work has been completed, with the documentation for the EIA stating the units were 35–40 percent and 5–10 percent complete respectively, while the operator NNEGC "Energoatom" stated on its website that construction of units 3 and 4 is reaching 75 percent and 28 percent completion respectively.[1043] However, in September 2015, the Ukrainian Parliament voted to cancel the project with Deputy Energy Minister Alexander Svetelik blaming Russia for "failing to fulfill the obligation under the deal", and saying that an "alternative partner" would be sought.[1044] In January 2017, the Russian Government confirmed that, on 12 May 2016, the 2011 agreement on the completion of the units had been cancelled.[1045]

Energoatom stated that it will double its investment budget in 2017 from UAH6.2 billion (US$243 million) in 2016 to 14 billion (US$540 million). However, with UAH 6.3 billion earmarked for safety improvements, UAH 4.3 billion (US$166 million) for infrastructure at existing sites, such as roads and training centers, and UAH 1.5 billion (US$57.9 million) for reactor extensions[1046], little is available for the construction of Khmelnitsky 3 and 4.

In March 2017, Energoatom, proposed that units 3 and 4 could be built and connected directly to the Polish grid, creating an "energy bridge" to the EU. The direct connection, which would

1040 - Committee Initiative on Ukraine, "EIA/IC/CI/4 Ukraine—Information on matters considered by the Committee", UNECE, see http://www.unece.org/environmental-policy/conventions/environmental-assessment/areas-of-work/review-of-compliance/committee-initiative/eiaicci4-ukraine.html, accessed 20 April 2017.

1041 - Iryna Holovko, "Time for Europe to stop supporting Ukraine's risky nuclear power sector", *Energy Post*, 18 May 2016, see http://www.energypost.eu/time-europe-stop-supporting-ukraines-risky-nuclear-power-sector/, accessed 20 April 2017.

1042 - Economic Commission for Europe, "Report of the Implementation Committee on its

thirty-eighth,session", meeting held 20-22 February 2017 (Geneva), Economic and Social Council, United Nations, report published 18 May 2017, see https://www.unece.org/fileadmin/DAM/env/documents/2017/EIA/MOP7/ece.mp.eia.ic.2017.2.final18.05.2017_typo_3.pdf , accessed 20 April 2017.

1043 - Oda Becker, et al., "Khmelnitsky NPP Construction of Units 3 and 4—Expert Statement to the Information and Analytical Survey (IAS) of the Feasibility Study (FS) and the EIA Report of the FS", Umweltbundesamt (Environment Agency Austria), Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2013, see http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0441.pdf, accessed 20 April 2017.

1044 - Ed Adamczyk, "Ukraine scraps nuclear reactor deal with Russia", *United Press International*, 16 September 2015, see http://www.upi.com/Top_News/World-News/2015/09/16/Ukraine-scraps-nuclear-reactor-deal-with-Russia/9811442413199/, accessed 20 April 2017.

1045 - *WNN*, "Russia announces cancellation of Khmelnitsky agreement", 16 January 2017, see http://www.world-nuclear-news.org/NP-Russia-announces-cancellation-of-Khmelnitsky-agreement-16011701.html, accessed 20 April 2017.

1046 - *NEI*, "Ukraine's Energoatom doubles investment for 2017", 30 November 2016, see http://www.neimagazine.com/news/newsukraines-energoatom-doubles-investment-for-2017-5684150/, accessed 25 April 2017.

enable electricity to be exported to the EU "by 2019", would be sufficient to finance the project. The cost of the interconnection would be relatively small at US$55 million, according to Energoatom. However, financing is not the only issue facing the completion plans. A primary concern is the availability of suitable reactor pressure vessels. Given the poor political relations between Russia and Ukraine, the usual supply is unlikely and the most likely alternative, the Czech firm Skoda JS, is partially owned, indirectly, by Gazprom bank, putting in doubt its availability.[1047]

1047 - Gary Peach, "Financing Khmelnitsky Via 'Energy Bridge' to Poland?", *NIW*, 24 March 2017.

ANNEX 2
REACTOR RESTART PROSPECTS IN JAPAN

NUCLEAR REGULATION AUTHORITY REVIEW AND REACTOR RESTART PROSPECTS

Compliance with the NRA guidelines, which came into force in July 2013[1048], is a requirement for utilities in their plans for reactor restart, along with "securing local public understanding" and approval from the local town mayors, Prefectural Assembly and Governor. The new guidelines cover a range of issues related to the safety risks of nuclear power plants, including seismic and tsunami assessments and protective measures undertaken by utilities;[1049] fire protection; the management of the reactor in the event of a loss of offsite electrical power, cooling function, and accident management,[1050] including prevention of hydrogen explosion; and the containment or filtered venting of radioactive materials into the environment. In the case of seismic assessments, reactors that are located above active faults are not be permitted to resume operations. Reactor owners are also required to assess their vulnerability to volcanic eruptions, which depending on scale of risk would not be permitted to operate or would be required to have specific countermeasures in place. Emergency evacuation plans are also required to be agreed with local communities within a 30-km radius of the nuclear plant. Upon completion of the preliminary approval of the safety case, the NRA holds a series of local public information meetings—an issue that has created controversy as to whether communities not immediately within the vicinity of a plant—but at risk in the event of a severe accident, would participate.

To date the NRA has only completed the review of PWRs, based on the regulator's analysis that it is easier to secure them against seismic events, than it is for BWRs. In addition, only one BWR review team of about 20 staff is in place at NRA, compared to three teams of about 60 people that are working on PWR inspections. There are 10 BWRs and 11 PWRs under review (13 for details).

In terms of reactors most advanced in the NRA review process, four reactors are expected to secure final approval before December 2017. The Genkai-3 and -4 PWRs, owned by Kyushu Electric in Saga prefecture on the island of Kyushu, were found to be compatible with the NRA's regulatory standards on 18 January 2017.[1051] The five NRA commissioners unanimously approved the upgrade plans for the reactors. It has taken Kyushu Electric three and a half years to obtain permission to make changes to the reactor installations (basic design approvals),

1048 - NRA, "New Regulatory Requirements for Light-Water Nuclear Power Plants—Outline", August 2013, see https://www.iaea.org/sites/default/files/requirements160913.pdf, accessed 18 June 2017.

1049 - NRA, "Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Earthquakes and Tsunamis)", 3 April 2013, see https://www.nsr.go.jp/data/000067118.pdf, accessed 18 June 2017.

1050 - NRA, "Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Severe Accident Measures)", 3 April 2013, see https://www.nsr.go.jp/data/000067119.pdf, accessed 18 June 2017.

1051 - JAIF, "Genkai-3 and -4 NPPs Clear Safety Examinations", 20 January 2017, see http://www.jaif.or.jp/en/genkai-3-and-4-npps-clear-safety-examinations/, accessed 14 June 2017.

Table 13 | Status of Japanese Nuclear Reactor Fleet (as of 1 July 2017)

Operator	Reactor	MW	Startup Year	Age Years	Shutdown Date [a] dd/mm/yy	Shutdown Duration	NRA Compliance		Status
							Application dd/mm/yy	Approval [b] dd/mm/yy	
CHUBU	Hamaoka-3 (BWR)	1056	1987	30.4	29/11/10	6.6	15/06/15		LTO
	Hamaoka-4 (BWR)	1092	1993	24.4	13/05/11	6.1	14/02/14		LTO
	Hamaoka-5 (ABWR)	1325	2004	13.2	14/05/11	6.1			LTO
CHUGOKU	Shimane-2 (BWR)	789	1988	29.0	27/01/12	5.4	25/12/13		LTO
HEPCO	Tomari-1 (PWR)	550	1988	28.6	22/04/11	6.2	08/07/13		LTO
	Tomari-2 (PWR)	550	1990	26.8	26/08/11	5.8	08/07/13		LTO
	Tomari-3 (PWR)	866	2009	7.6	05/05/12	5.2	08/07/13		LTO
HOKURIKU	Shika-1 (BWR)	505	1993	24.5	01/03/11	6.3			LTO
	Shika-2 (ABWR)	1108	2005	12.0	11/03/11	6.3	12/08/14		LTO
JAPCO	Tokai-2 (BWR)	1060	1978	39.3	21/05/11	6.1	20/05/14		LTO
	Tsuruga-2 (PWR)	1108	1986	31.0	29/08/11	5.8	05/11/15		LTO
KEPCO	Mihama-3 (PWR)	780	1976	41.4	14/05/11	6.1	17/03/15	16/11/16	LTO
	Ohi-1 (PWR)	1120	1977	39.5	10/12/10	6.6			LTO
	Ohi-2 (PWR)	1120	1978	38.7	16/12/11	5.5			LTO
	Ohi-3 (PWR)	1127	1991	26.1	02/09/13	3.8	08/07/13	24/05/17	LTO
	Ohi-4 (PWR)	1127	1992	25.0	15/09/13	3.8	08/07/13	24/05/17	LTO
	Takahama-1 (PWR)	780	1974	43.3	10/01/11	6.5	17/03/15	10/6/16 [c]	LTO
	Takahama-2 (PWR)	780	1975	42.5	25/11/11	5.6	17/03/15	10/06/16	LTO
	Takahama-3 (PWR)	830	1984		20/02/12	(3.9)	08/07/13	09/10/15	Restarted 9/6/17 [d]
	Takahama-4 (PWR)	830	1984		21/07/11	(5.8)	08/07/13	09/10/15	Restarted 22/05/17
KYUSHU	Genkai-2 (PWR)	529	1980	37.1	29/01/11	6.4			LTO
	Genkai-3 (PWR)	1127	1993	24.0	11/12/10	6.6	12/07/13	18/01/17	LTO
	Genkai-4 (PWR)	1127	1996	20.6	25/12/11	5.5	12/07/13	18/01/17	LTO
	Sendai-1 (PWR)	846	1983		10/05/11	(4.3)	08/07/13	27/05/15	Restarted 14/08/15
	Sendai-2 (PWR)	846	1985		01/09/11	(4.2)	08/07/13	27/05/15	Restarted 15/10/15
SHIKOKU	Ikata-2 (PWR)	538	1981	35.9	13/01/12	5.5			LTO
	Ikata-3 (PWR)	846	1994		29/04/11	(5.3)	08/07/13	19/04/16	Restarted 15/08/16
TEPCO	Kashiwazaki Kariwa-1 (BWR)	1067	1985	32.4	06/08/11	5.9			LTO
	Kashiwazaki Kariwa-2 (BWR)	1067	1990	27.4	19/02/07	10.4			LTO
	Kashiwazaki Kariwa-3 (BWR)	1067	1992	24.6	16/07/07	10.0			LTO
	Kashiwazaki Kariwa-4 (BWR)	1067	1993	23.5	16/07/07	10.0			LTO
	Kashiwazaki Kariwa-5 (BWR)	1067	1989	27.8	25/01/12	5.4			LTO
	Kashiwazaki Kariwa-6 (ABWR)	1315	1996	21.4	26/03/12	5.3	27/09/13 [e]		LTO
	Kashiwazaki Kariwa-7 (ABWR)	1315	1996	20.5	23/08/11	5.9	27/09/13		LTO

Operator	Reactor	MW	Startup Year	Age Years	Shutdown Date [a] dd/mm/yy	Shutdown Duration	NRA Compliance		Status
							Application dd/mm/yy	Approval [b] dd/mm/yy	
TOHOKU	Higashi Dori-1 (BWR)	1067	2005	11.8	06/02/11	6.4	20/06/14		LTO
	Onagawa-1 (BWR)	498	1983	33.6	10/09/11	5.8			LTO
	Onagawa-2 (BWR)	796	1994	22.5	06/11/10	6.7	27/12/13		LTO
	Onagawa-3 (BWR)	796	2001	16.1	10/09/11	5.8			LTO

a - The shutdown dates are from Japan Atomic Industrial Forum (JAIF), "Nuclear Power Plants in Japan - In operation and under construction", as of 10 June 2014, see http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1402531967P.pdf, accessed 13 June 2014.

b - Gray dates refer to the first step (Permission for change in reactor installation license). All others indicate final agreement of the 3-step conformity review.

c - For both Takahama-1 and -2, the first two steps of the conformity review were achieved on 10 April 2016. On 20 June 2016, the Nuclear Regulation Authority (NRA) granted KEPCO approval of extension of operation for 20 years and approval of Takahama's operational safety programs concerning aging management technical evaluation and long-term maintenance policy for those two units. For details: NRA, "The NRA approved the extension of operation period of Takahama Power Station Units 1 and 2", 21 June 2016, see https://www.nsr.go.jp/data/000154256.pdf, accessed 14 July 2017.

d - Takahama-3 had operated briefly between 29 January and 10 March 2016, before it was shut down by court order. The "Shutdown Duration" is calculated until this first restart.

e - On 16 June 2017 TEPCO re-filed its application with the NRA to confirm compliance with safety requirements for Kashiwazaki Kariwa-6 and -7. The NRA had requested resubmission in February 2017.

since it first applied to the NRA in September 2013.[1052] The NRA approval is the first of a three-stage process prior to restart with two further stages: pre-service inspections, and revisions to operational safety programs. The two Genkai 1180 MW units are the largest in terms of generating capacity to pass the NRA regulatory standards so far.

The utility was aiming to complete work on safety measures, including those related to severe accident mitigation and seismic reinforcements, by the end of March 2017. On 6 April 2017, Kyushu Electric submitted its 57 volume (containing 45,000 pages) engineering work program, which forms the basis of the NRA's review plan for pre-operational inspections.[1053] A revised document for Genkai-3 was submitted 13 June 2017.[1054] The NRA took on average 139 days to complete this phase for Sendai-1 and -2, and Ikata-3, indicating a possible August 2017 completion date for the Genkai reactors. As of 13 June 2017, Kyushu Electric had yet to submit a request for actual pre-operational inspections.

However, in April 2017 the NRA was challenged over its Genkai seismic safety assessments. In a complaint filed under the Administrative Appeal Act, which allows for the appeal and review of government decisions. NRA was expected to respond to the complaints in "several months," Yamato Sugita, a member of the PWR safety review staff, said on 24 April 2017.[1055] The complaint alleged that the assumed worst-case earthquake-caused ground motion of 620 gal at the Genkai plant was an "under-evaluation" by the NRA because the reviewers and company

1052 - Kyushu Electric Power Company, "Permission for Changes in Reactor Installation regarding Conformance to New Regulatory Requirements of Genkai Nuclear Power Station No3, 4", 18 January 2017, see http://www.kyuden.co.jp/var/revo/0065/9190/yy8k52ds.pdf, accessed 13 June 2017.

1053 - *Platts Nuclear News Flashes*, "Japan's Kyushu Electric files key Genkai-3 restart document", S&P, 6 April 2017.

1054 - *Platts Nuclear News Flashes*, "Japan's Kyushu Electric files revised Genkai-3 restart document", S&P, 13 June 2017.

1055 - *Platts Nuclear News Flashes*, "Complaint filed with NRA to revoke reactor upgrade approval", S&P, 24 April 2017.

officials had considered only 'risky' seismic faults.[1056] The submission to the NRA noted that the magnitude 6.6 Tottori earthquake on 21 October 2016, occurred despite the lack of 'risky' seismic faults in the area.[1057]

Genkai-3 is to operate with 20 plutonium mixed oxide (MOX) fuel assemblies manufactured by AREVA and delivered in June 2010. A series of citizen led legal challenges to prevent the use the fuel at Genkai over the safety risks of MOX have been defeated in the courts in the past two years.

The lack of consultation with communities within 30 km of the plant is a growing issue of controversy in Japan.

Saga Governor, Yoshinori Yamaguchi, on 24 April 2017 approved plans to restart the two Genkai units, stating that it would have been preferable to mainly use renewable energy, but that it unfortunately could not be provided with total stability and "considering the current situation, we have no choice (but to restart the nuclear plant)."[1058] Four city governments within a 30-kilometer radius of Genkai are opposed to the restart, however they have no say in the decision. The lack of consultation with communities within 30 km of the plant is a growing issue of controversy in Japan. The mayor of the city of Imari, with a population of 55,000, stated in summer 2016: "No matter how strongly we oppose (the utility's plan to restart the reactors), we are left out in the cold...But we are nevertheless forced to face the risk of a serious accident. That's too unfair."[1059]

Kyushu Electric secured a court victory on 13 June 2017 when the Saga District Court turned down a request filed by some 202 citizens from 17 prefectures, including Saga and Fukuoka, for a temporary injunction to stop the restart of the Genkai-3 and -4 reactors.[1060] The Saga court found that there was "no unacceptable flaw" in the NRA safety assessments.[1061] The Saga citizens have filed an appeal of the decision to the Fukuoka High Court.

The expectation is, barring any other major disruption, the two Genkai reactors will resume operation between the final quarter of 2017 and early 2018.

The two Ohi 1127 MW reactors owned by KEPCO, are the next two reactors most advanced in the NRA process. KEPCO submitted its applications to the NRA for safety examinations of Ohi-3 and -4 on 8 July 2013. The two reactors have not operated in Japan since September 2013

1056 - *Platts Nuclear News Flashes*, "Complaint filed with NRA to revoke reactor upgrade approval", S&P, 24 April 2017.

1057 - GeoSpatial Information Authority of Japan (GSI), "The 2016 Central Tottori Earthquake", 27 October 2016, see http://www.gsi.go.jp/cais/topic161027-index-e.html, accessed 14 June 2017.

1058 - *The Asahi Shimbun*, "Saga governor gives approval for nuclear plant to restart", 25 April 2017, see http://www.asahi.com/ajw/articles/AJ201704250035.html, accessed 14 June 2017.

1059 - *The Asahi Shimbun*, "Support of areas within 30-km zone vital for reactor restarts" 5 June 2017, see http://www.asahi.com/ajw/articles/AJ201706050017.html, accessed 14 June 2017.

1060 - JAIF, "Saga District Court Allows Two Genkai Reactors to Resume Operation", 14 June 2017, see http://www.jaif.or.jp/en/saga-district-court-allows-two-genkai-reactors-to-resume-operation/, accessed 16 June 2017.

1061 - *The Japan News*, "Demand to block restart of Genkai reactors nixed", *Yomiuri Shimbun*, 13 June 2017, see http://www.the-japan-news.com/news/article/0003758195, accessed 14 June 2017.

respectively. On 24 May 2017, the NRA approved safety examinations for the two reactors.[1062] KEPCO, as of 1 July 2017, has yet to submit construction work plans, which is the basis for regulatory detailed design approval. KEPCO estimates costs of ¥122 billion (US$1 billion) for retrofits at the Ohi-3 and -4.

A major issue at the Ohi site is the status of geologic faults within the site and the area around it. The seismic issue was a central element that led on 22 May 2014 to the Fukui District Court issuing a landmark ruling against operation of the Ohi reactors, the case was not an injunction as there was no immediate risk of restart.[1063] The Fukui Court ruled in favor of the 200 plaintiffs who contended that plant was not sufficiently robust against active seismic faults and that the acceleration at the site could exceed 1,260 gal.[1064] KEPCO appealed the Fukui court ruling which is ongoing at the Nagoya High Court's Kanazawa branch in Ishikawa Prefecture.

Kunihiko Shimazaki, the former NRA deputy chair and a professor emeritus of seismology at the University of Tokyo, in July 2016 voiced strong concerns related to the Ohi reactors and his "sense of crisis" over the approach to earthquake risk analysis by the NRA.**1065** Shimazaki had led the team of experts when the NRA examined the fitness of the Ohi reactors at the plant under the new regulations created in the aftermath of the 2011 Fukushima nuclear disaster. He was the only seismologist among the NRA's five members and in charge of checking utilities' preparedness for earthquakes and tsunami before he resigned in 2014. In evidence to the NRA, he called for a re-examination of the Ohi site, stating that he had realized that there were problems with the calculating equation adopted by KEPCO and accepted by the NRA, after analyzing the data on the seismic movement during the series of Kumamoto earthquakes that occurred from mid-April 2016. The NRA on 27 July 2016 announced that it would not be revising its seismic methodology, dismissing Shimazaki's assessment as "not up to a level that should be recommended by the NRA on the basis of scientific and technical sophistication."[1066] In summer 2016, Shimazaki submitted his analysis to the Kanazawa court, which is considering the KEPCO court appeal. On 23 April 2017, Shimazaki testified to the court that the formulas used by the NRA in computing the scale of earthquakes underestimates potential seismic impact by a factor of 3.5.[1067] The case is ongoing.

A nuclear plant that was expected to be further along the NRA review process is the Tomari PWR plant, owned by Hokkaido Electric, on the north island of Japan. Tomari-3 was the most advanced in the NRA review. Hokkaido Electric in September 2016 abandoned its plans for ear-

1062 - JAIF, "Ohi-3 & -4 NPPs Clear Safety Examinations toward Restarts this Autumn", 24 May 2017, see http://www.jaif.or.jp/en/ohi-3-4-npps-clear-safety-examinations-toward-restarts-this-autumn/, accessed 15 June 2017.

1063 - Fukui District Court, "Outline of Judgment on Claim for Injunction on Operation of No. 3 and No. 4 Units at Ohi Nuclear Power Plant Fukui District Court, May 21 2014", (Unofficial Translation), see http://www.greenpeace.org/international/Global/international/briefings/nuclear/2014/Ohi-ruling-translation.pdf, accessed 18 June 2017.

1064 - *Nikkei Asian Review*, "Court throws wrench into Japan's nuclear restart", 22 May 2014, see http://asia.nikkei.com/Politics-Economy/Policy-Politics/Court-throws-wrench-into-Japan-s-nuclear-restart, accessed 15 June 2017.

1065 - *Reuters*, "Former Japan nuclear regulator lashes out over earthquake standards" 15 July 2016, see http://www.reuters.com/article/us-japan-nuclear-regulation-idUSKCN0ZV11E accessed 15 June 2017.

1066 - *The Asahi Shimbun*, "NRA dismisses former expert member's Oi plant warning", 28 July 2016, see http://www.asahi.com/ajw/articles/AJ201607280058.html, accessed 15 June 2017.

1067 - Kunihiko Shimazaki, "'Maximum-class' Japan Sea tsunami scenarios are less than maximum-class — An error, left uncorrected, is a recipe for another 'unforeseeable' disaster", Kagaku , *Science Journal*, Vol.86, No.7, July 2016, see https://www.iwanami.co.jp/kagaku/eKagaku_201611_Shimazaki.pdf, accessed 15 June 2017.

ly restart.[1068] The utility applied to the NRA for review in July 2013. However, in July 2016, the NRA received evidence from Hokkaido Electric on the issue of an active fault line on the west coast of the Shakotan Peninsula, where the Tomari plant is located.[1069] This issue is still under deliberation with possible negative impacts on the current assessment of design basis ground motion and tsunami risks as the site. The prospects for a restart of Tomari-3 (or the other two reactors) is effectively zero in the coming few years. Citizen legal challenges are ongoing in the Sapporo district court, with seismic risks a central issue.

Shimazaki testified to the court that the formulas used by the NRA in computing the scale of earthquakes underestimates potential seismic impact by a factor of 3.5

The Japan Atomic Power Company (JAPCO) submitted an application to the NRA review for its Tsuruga-2 reactor on 5 November 2015, becoming the 26th reactor under review.[1070] However, there has been an ongoing dispute since 2012 between the NRA and JAPCO over the nature of a seismic fault line at the site. The definition of an active fault is one with having the "possibility of slipping in the future" and that has been active since the Late Pleistocene era, or some 120,000 and 130,000 years ago. An expert panel of the NRA indicated in December 2012 that the fault line was possibly active,[1071] and in in May 2013 the evaluation report of the NRA determined that the D-1 fracture zone lying directly under Tsuruga-2 was active.[1072] JAPCO, and a team of international experts have claimed ever since that the fault line is not active.[1073] Despite counter arguments from JAPCO, in March 2015, the NRA Commissioners agreed with the final evaluation that the fault was active.[1074] The decision is critical for JAPCO, with only two reactors in its fleet, the other being Tokai-2, where the prospects for restarting are close to zero. Thus, without the possibility of operating Tsuruga-2, it would mean the end of JAPCO as a nuclear plant operator, having to move the units from assets to liabilities in the balance sheet and triggering the weighty financial issue of decommissioning. JAPCO, a company established and owned by nine other nuclear power companies, has not accepted the NRA's judgement, hence the filing in November 2015 for review of Tsuruga-2 for compliance with the 2013 guidelines. Unless the NRA overturns its own decision, there is no prospect of Tsuruga-2 being approved for restart.

1068 - *The Japan Times*, "Hokkaido Electric abandons plan for reactor restart by March end", 24 September 2015, see http://www.japantimes.co.jp/news/2015/09/24/national/hokkaido-electric-abandons-plan-reactor-restart-march-end/#.WUi96RN95E4, accessed 18 June 2017.

1069 - Hokkaido Electric, "Topography and Geology and Geological Structure of the Shakotan Peninsula West Bank", 27 July 2017, see https://www.nsr.go.jp/data/000160416.pdf, accessed 19 June 2017.

1070 - JAIF, "JAPC Files Application for Compatibility Examination for Tsuruga-2", 9 November 2015, see http://www.jaif.or.jp/en/japc-files-application-for-compatibility-examination-for-tsuruga-2/, accessed 18 June 2017.

1071 - *The Japan Times*, "Detecting Active Faults Near Reactors", 14 December 2012, see http://www.japantimes.co.jp/opinion/2012/12/14/editorials/detecting-active-faults-near-reactors/, accessed 18 June 2017.

1072 - JAIF, "Thin Reasoning in NRA's Argument for Active Fault under Tsuruga-2", 25 November 2014, see http://www.jaif.or.jp/en/thin-reasoning-in-nras-argument-for-active-fault-under-tsuruga-2/, accessed 18 June 2017.

1073 - JAPCO, "Evaluation of shatter zones at Tsuruga NPP site Interim Report of the Joint International Experts' Meeting (TRM/IRG)", May 21, 2013, see http://www.japc.co.jp/english/shatter_zones/pdf/130521/250521_2.pdf, accessed 16 June 2017.

1074 - NRA, "NRA Accepts Finalization of Panel Report Recognizing the Fault Directly Under Tsuruga-2 as Active", 25 March 2015, see http://www.jaif.or.jp/en/nra-accepts-finalization-of-panel-report-recognizing-the-fault-directly-under-tsuruga-2-as-active/, accessed 16 June 2017.

Another nuclear power plant and utility that is in dispute with the NRA is Hokuriku Electric Power Company and its Shika-2 plant, which is under review. On 3 March 2016, a panel of experts of the NRA issued a report concluding that one of the fault zones running directly under the Shika-1 reactor building "could possibly become an active fault in the future." Hokuriku objected to the report.[1075] The older Shika unit is not under NRA review and its decommissioning is almost certain. However, the NRA also concluded that two fault lines running under the turbine building of both unit-1 and unit-2 could also be active.[1076] The NRA commissioners have yet to make a final determination on this issue, requesting more information from the utility in June 2016. Shika-2 is an 1100 MW Advanced Boiling Water Reactor (ABWR), which only began operation in 2005. A ruling by the NRA that the fault under Shika-2 is active, would leave Hokuriku, like JAPCO, with no operable reactors.

The Ohma ABWR reactor in Aomori prefecture remains officially 'under construction' and under NRA review.

FUTURE NUCLEAR OPERATIONS OF TEPCO

The future operation of TEPCO's nuclear plant at Kashiwazaki Kariwa, in Niigata prefecture on the Sea of Japan coast, became even more uncertain during the past 12 months.

In August 2015, the NRA had announced that it was putting the TEPCO reactors Kashiwazaki Kariwa-6 and -7 on a priority list for screening, suggesting that these will be the first BWRs out of a total of ten, to advance through the review process.[1077] The NRA review process for the reactors has been set back during the past months. In October 2016, TEPCO informed the NRA that it will be reviewing its plan for restart of units 6&7 due to the 'discovery' that ground liquefaction as a result of an earthquake could collapse the nuclear plant's tsunami seawalls.[1078] Liquefaction occurred at the site during the 2007 Chuetsu-Oki earthquake. TEPCO analysis presented to the NRA concluded that the tsunami walls protecting units 1 through 4 could be destroyed if the soil liquefied,[1079] with the serious potential to affect operations elsewhere on the site, including at units 6&7, in the event of an emergency. Large-scale construction is expected to take at least a year in an attempt to counter the risks from ground liquefaction, with doubts over the effectiveness of such measures. Consequently, TEPCO will be further delayed in applying to the NRA for review of any additional reactors at the site.

In February 2017, TEPCO confirmed to the NRA that a planned Emergency Response Center (ERC), does not meet the regulator's seismic requirements.[1080] The on-site ERC would

1075 - JAIF, "Hokuriku Electric Power Voices Objections to Report on Crushed Rock Fault Zones at Shika NPPs", 4 March 2016, see http://www.jaif.or.jp/en/hokuriku-electric-power-voices-objections-to-report-on-crushed-rock-fault-zones-at-shika-npps/, accessed 15 June 2017.

1076 - *The Japan Times*, "Shika Nuclear Power Plant Closer to Being Scrapped as NRA Upholds Faults Ruling", 27 April 2016, see http://www.japantimes.co.jp/news/2016/04/27/national/science-health/shika-nuclear-plant-closer-scrapped-nra-upholds-fault-ruling/#.Vz5HMiMrK2w, accessed 19 June 2017.

1077 - *Reuters*, "Japan puts Tepco reactors on priority list for restart screening", 6 August 2015, see http://www.reuters.com/article/japan-nuclear-restarts-idUSL3N10H32R20150806, accessed 15 June 2017.

1078 - *The Mainichi*, "TEPCO to review plan to reactivate nuclear reactors due to liquefaction fears" 14 October 2016, see http://mainichi.jp/english/articles/20161014/p2a/00m/0na/012000c, accessed 16 June 2017.

1079 - TEPCO, submission to NRA, 13 September 2016, see http://www.tepco.co.jp/about/power_station/disaster_prevention/pdf/nuclear_power_160913_02.pdf, accessed 16 June 2017.

1080 - *NW*, "Tepco safety review issues could raise local government concerns", S&P, *Platts*, Vol.58, No.9, 2 March 2017.

TEPCO had originally said the building could withstand an earthquake with a maximum intensity of seven on the Japanese seismic scale.

be essential in the event of a severe accident. TEPCO had originally said the building could withstand an earthquake with a maximum intensity of seven on the Japanese seismic scale. During the NRA screening process, however, it acknowledged that it may not be able to withstand even half of the assumed strongest seismic shaking. TEPCO said it learned about the inadequate level of earthquake resistance in 2014, but the information had not been shared within the company or communicated to the NRA. In response to the disclosures, NRA Chairman, Shunichi Tanaka, stated that it had, "left us with lingering suspicions."[1081]

In January 2017, TEPCO revised its projected costs for upgrades and retrofits at the site to ¥680 billion (US$6 billion).[1082] Investments so far have included construction of a 15-meter tsunami seawall, as well as the installation of filtered vents and catalytic hydrogen re-combiners (to prevent hydrogen explosions). One measure includes the installation of a so-called corium shield beneath unit 6&7 Reactor Pressure Vessels (RPV), and completed for unit 7 in May 2016, in an effort to prevent molten fuel in the event of a severe accident breaching the primary containment.[1083]

On 16 June 2017 re-filed its application with the NRA to confirm compliance with safety requirements for Kashiwazaki Kariwa-6 and -7. The NRA had requested resubmission in February 2017. TEPCO's submission included revised measures on how to mitigate more severe accidents, including station blackout (SBO). TEPCO now assumes SBO would be followed by unavailability of DC power sources and failure of a containment relief safety valve. TEPCO management described the submission as "the best that we can do," and that it was "not perfect."[1084]

TEPCO's political problems became far more complicated with the appointment in October 2016 of a new Governor of Niigata following an election, where operation of Kashiwazaki Kariwa was a central issue. One of the principal reasons Governor Yoneyama was elected was due to his stated opposition to early restart of the reactors, with an exit poll showing that 73 percent of voters opposed restarting the Niigata plant, while only 27 percent were in favor.[1085] The Governor's first term in office runs until mid-2020, beyond the earliest start up time proposed by TEPCO of 2019. In mid-June 2017, the Governor stated that a soon to be created advisory committee will review the 2011 Fukushima nuclear disaster and its health

1081 - Ibidem.

1082 - Yoichi Yoneya, "Kashiwazaki Kariwa Nuclear Power Plant Safety Cost, 1.4 times TEPCO's Forecast", *The Asahi Shimbun*, 27 January 2017, see http://www.asahi.com/articles/ASK1W6SG4K1WULFA03P.html, accessed 16 June 2017.

1083 - TEPCO, First Quarter, FY2016 Nuclear Safety Reform Plan Progress Report (Including Progress on Safety Measures at Power Stations)", see http://www.tepco.co.jp/en/press/corp-com/release/betu16_e/images/160802e0102.pdf, accessed 16 June 2017.

1084 - *Platts*, "Tepco re-files Kashiwazaki-Kariwa-6, -7 restart safety review application", *Nuclear News Flashes*, 19 June 2017.

1085 - Jeff Kingston, "Could nuclear advocacy be Abe's undoing?", *The Japan Times*, 29 October 2016, see http://www.japantimes.co.jp/opinion/2016/10/29/commentary/nuclear-advocacy-abes-undoing/#.WToKBBN95E4, accessed 16 June 2017.

impacts, as well as examine evacuation drills in Niigata.[1086] The review would take an estimated three years, during which time consent for restart by local communities, the prefectural assembly and Governor will not be possible.

A critical factor in TEPCO's new business plan released announced on 18 May 2017 is its intention to secure ¥500 billion (US$4.4 billion) in funds each year to cover Fukushima accident costs.[1087] A principal source of these funds would be the restart of Kashiwazaki Kariwa units 6&7. TEPCO is relying on these reactors to provide pretax profits of between ¥160 billion (US$1.4 billion) and ¥215 billion (US$1.9 billion) on average over the next 10 years.[1088] Units 6&7 have been offline since 2012 and 2011 and TEPCO has so far failed to overcome local and prefectural opposition to restart. Instead of generating income, these reactors cost TEPCO an estimated ¥240 billion (US$2.1 billion) each year they remain offline.[1089] When TEPCO submitted its second business plan to the Japanese government in 2014, it predicted that units 6&7 would be restarted in mid-2014 and units 1&5 in late 2014.[1090]

TEPCO's third new business plan delays further the restart at Kashiwazaki Kariwa, proposing that it will be 2019 at the earliest. In three scenarios included in TEPCO's business plant the company envisages restart of Units 6&7 from 2019, 2020 or 2021. Of the other Kashiwazaki Kariwa reactors, TEPCO has restart target-dates for units 1 and 5 between 2021 and 2023, and for Units 2, 3 and 4 between 2024 and 2026. In the worst-case scenario, TEPCO excludes a restart date for unit 2.

The prospect of decommissioning at the Kashiwazaki Kariwa site was made real, when on 1 January 2017, the mayor of Kashiwazaki City announced that as a condition for allowing restart of units 6&7, TEPCO must propose a decommissioning plan by 2019 for at least one reactor from units 1-5 (with no upward limit on the number of these reactors to be permanently shuttered).[1091] The mayor stated it is inevitable to scale down the plant, "considering the Fukushima nuclear accident, seven reactors are too many."[1092]

In an effort to overcome political obstacles to the restart of the Kashiwazaki Kariwa reactors, in October 2016, METI floated the idea of a creating a subsidiary for TEPCO's nuclear power operations, which could then be merged with another nuclear operator.[1093] "This would make

1086 - Kentaro Hamada and Osamu Tsukimori, "Niigata governor's plans may upend TEPCO's nuclear restarts, restructuring", *Reuters*, 9 June 2017, see http://www.euronews.com/2017/06/09/niigata-governors-plans-may-upend-tepcos-nuclear-restarts-restructuring, accessed 16 June 2017.

1087 - TEPCO, "Outline of the 'Revised Comprehensive Special Business Plan (The Third Plan)' 18 May 2017, see https://www4.tepco.co.jp/en/press/corp-com/release/betu17_e/images/170518e0101.pdf, accessed 16 June 2017.

1088 - *Nikkei Asian Review*, "Tepco's turnaround prospects hang on retooled nuclear ops", 12 May 2017, see http://asia.nikkei.com/Business/Companies/Tepco-s-turnaround-prospects-hang-on-retooled-nuclear-ops, accessed 16 June 2017.

1089 - *NW*, "Tepco faces questions about potential nuclear alliance, analysts say", S&P, *Platts*, Vol.57, No.44, 3 November 2016.

1090 - *The Japan Times*, "Tepco business plan, including July reactor restart, gets official OK", 15 January 2017, see http://www.japantimes.co.jp/news/2014/01/15/national/tepco-business-plan-including-july-reactor-restarts-gets-official-ok/#.WTTopROGNE4, accessed 16 June 2017.

1091 - Niigata-Nippo, "Mayor Kashiwazaki asks TEPCO for decommissioning one of Units 1 to 5", 6 January 2017, (in Japanese), see http://www.niigata-nippo.co.jp/news/national/20170601327254.html, accessed 16 June 2017.

1092 - *The Mainichi*, "Mayor to link reactor decommissioning to restarting 2 others at same TEPCO plant", 2 June 2017, see https://mainichi.jp/english/articles/20170602/p2a/00m/0na/002000c, accessed 16 June 2017.

1093 - METI's position on this is central to the future of TEPCO, the utility is now owned 50.1% by Nuclear Damage Compensation and Decommissioning Facilitation Corp., or NDF, which is a government body in combination with Japan's other nuclear utilities.

it easier to make an alliance," said a Nuclear Decommissioning Fund official.[1094] TEPCO at the time declined to comment. Apart from the possible economic benefits of such a merger, it was thought that operating Kashiwazaki Kariwa with another utility could contribute to overcoming local opposition in Niigata to restart, and that METI "may ask Tohoku Electric Power Co. to join TEPCO to take over operation of Kashiwazaki-Kariwa-6 and -7 (...). Niigata residents are familiar with Tohoku Electric, not TEPCO, as Niigata is an area, where Tohoku Electric sells its electricity."[1095]

The Japanese government has been a strong advocate of this approach, describing it as "essential", and thinking it would be a positive step towards 'detoxifying' TEPCO.[1096]

There was no enthusiasm from Japan's nuclear utilities for this proposal. In addition to the multiple practical, legal, liability and other financial risk issues, the utilities have other priorities in overcoming the multiple obstacles to restart of their own reactors. In May 2017, the Hokuriku Electric president made clear that, "We're not interested in a nuclear merger with them...Changing a plant operator would make it harder to get local trust on plant operations", views mirrored by Chubu Electric.[1097]

Despite the lack of utility enthusiasm for merger with TEPCO, the proposal made it into their new business plan in May 2017, however, the target date was pushed back ten years to 2026.[1098]

The decision of the NRA to focus on the ABWRs at Kashiwazaki has also meant that the review of three other BWRs—Chugoku Electric Power Company's Shimane-2, Tohoku Electric Power Company's Onagawa-2 and Chubu Electric Power Company's Hamaoka-4—were moving further back in the process.[1099] However, given the push back in restart dates for TEPCO's Kashiwazaki Kariwa 6&7 to at least 2019, there is a remote possibility that one or more of these reactors will become operational in the coming few years. For these BWRs—Hamaoka-4, Tokai-2, Shimane-2 and Onagawa-2—all are at various stages of review, including seismic assessments, but each is confronted with a range of technical, political and in some cases, legal issues, which will set back any operation during the next few years.

1094 - S&P, *Platts*, "Tepco may seek partner for nuclear operations", quoting Shigehiro Yoshino, managing director at Nuclear Damage Compensation and Decommissioning Facilitation Corp., or NDF, cited in *Nucleonics Week*, Vol.57, No.43, 27 October 2016. The NDF is Japanese government body that holds a 50.1% ownership stake in Tepco to oversees decommissioning work at Fukushima Daiichi.

1095 - *Nucleonics Week*, "Tepco may seek partner for nuclear operations", S&P, *Platts*, Vol.57, No.43, 27 October 2016.

1096 - *Reuters*, "Japan's Tepco to seek partners for nuclear business", 11 May 2017, see http://www.businessinsider.com/r-japans-tepco-to-seek-partners-for-nuclear-business-2017-5, accessed 15 June 107.

1097 - Yutaka Kanai at a press conference 19 May 2017, *Nucleonics Week*, "Tepco's revised offer for nuclear venture unlikely to lure partner: analysts", S&P, *Platts*, Vol.58, No.21, 25 May 2017.

1098 - TEPCO, "Outline of the 'Revised Comprehensive Special Business Plan (The Third Plan)", 18 May 2017, see https://www4.tepco.co.jp/en/press/corp-com/release/betu17_e/images/170518e0101.pdf, accessed 16 June 2017.

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ANNEX 3
DEFINITION OF CREDIT RATING BY THE MAIN AGENCIES

Moody's		S&P		Fitch		
Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	
Aaa	P-1	AAA	A-1+	AAA	F1+	Prime
Aa1		AA+		AA+		High grade
Aa2		AA		AA		
Aa3		AA-		AA-		
A1		A+	A-1	A+	F1	Upper medium grade
A2		A		A		
A3	P-2	A-	A-2	A-	F2	
Baa1		BBB+		BBB+		Lower medium grade
Baa2	P-3	BBB	A-3	BBB	F3	
Baa3		BBB-		BBB-		
Ba1	Not prime	BB+	B	BB+	B	Non-investment grade speculative
Ba2		BB		BB		
Ba3		BB-		BB-		
B1		B+		B+		Highly speculative
B2		B		B		
B3		B-		B-		
Caa1		CCC+	C	CCC	C	Substantial risks
Caa2		CCC				Extremely speculative
Caa3		CCC-				In default with little prospect for recovery
Ca		CC				
		C				
C			/	DDD	/	In default
/		D		DD		
/				D		

Source : Wikipedia, "Credit Rating", Last Update 12 July 2017.

ANNEX 4
ABOUT THE AUTHORS

Mycle Schneider is an independent international consultant on energy and nuclear policy based in Paris. He is a founding board member of the International Energy Advisory Council (IEAC) and serves as the Coordinator of the Seoul International Energy Advisory Council (SIEAC). Mycle is a member of the International Panel on Fissile Materials (IPFM), based at Princeton University, U.S. He has provided information and consulting services, amongst others, to the Belgian Energy Minister, the French and German Environment Ministries, the U.S. Agency for International Development, the International Atomic Energy Agency, the European Commission, the European Parliament's Scientific and Technological Option Assessment Panel, and the French Institute for Radiation Protection and Nuclear Safety. Mycle has given evidence and held briefings at national Parliaments in fourteen countries and at the European Parliament. Between 2004 and 2009, he was in charge of the Environment and Energy Strategies lecture of an International MSc at the French Ecole des Mines in Nantes. He has given lectures at 20 universities and engineering schools around the globe. He founded the Energy Information Agency WISE-Paris in 1983 and directed it until 2003. In 1997, along with Japan's Jinzaburo Takagi, he received the Right Livelihood Award, also known as the "Alternative Nobel Prize".

Antony Froggatt works as independent European energy consultant based in London. Since 1997, he has worked as a freelance researcher and writer on energy and nuclear policy issues in the EU and neighboring states. He has worked extensively on EU energy issues for European governments, the European Commission and Parliament, environmental NGOs, commercial bodies, and media. He has given evidence to inquiries and hearings in the parliaments of Austria, Germany, UK and the EU. He is a part time Senior Research Fellow at the Royal Institute of International Affairs—Chatham House in London. He is also an Associate Member of the Energy Policy Group at Exeter University. Prior to working freelance, Antony served for nine years as a nuclear campaigner and coordinator for Greenpeace International.

S. David Freeman has more than four decades of experience directing federal, regional and local energy policies. He was appointed Chairman of the Tennessee Valley Authority (TVA) by President Jimmy Carter in 1977, where he pioneered a massive energy-efficiency program. Subsequently, Mr. Freeman served for two decades as general manager of several large public power agencies including the Los Angeles Department of Water and Power, the New York Power Authority, the Lower Colorado River Authority and the Sacramento Municipal Utility District. He holds a B.S. in Civil Engineering from Georgia Tech, and an L.L.B. from the University of Tennessee. He wrote *Energy: The New Era* in 1974, *Winning Our Energy Independence: An Energy Insider Shows How* in 2007, and more recently, *All-Electric America* and an auto-biography entitled *The Green Cowboy*.

Julie Hazemann, based in Paris, France, is the director of EnerWebWatch, an international documentation monitoring service, specializing in energy and climate issues, launched in 2004. As an information engineer and researcher, she has maintained, since 1992, a world nuclear reactor database and undertakes data-modelling and data-visualization work for the World Nuclear Industry Status Report. Active in information and documentation project-management, she has a strong tropism for information structuration, dataviz and development of electronic information products. She also undertakes specialized translation and research activities for specific projects. She is a member of négaWatt (France) and develops EnerWebWatch in the framework of the Coopaname Coop.

Tadahiro Katsuta holds a PhD in plasma physics from Hiroshima University (1997). He is currently an Associate Professor at Meiji University, Tokyo, Japan. During 2014–15 he is a Visiting Fellow in the Program on Science and Global Security (PSGS) at Princeton University, U.S. He is researching Japan's spent fuel management issues. He is also studying the Fukushima Daiichi nuclear power plant accident and following the new regulation standards with a focus on technical and political aspects. He has been appointed by Japan's Nuclear Regulation Authority (NRA) as a member of the study teams on the New Regulatory Requirements for Commercial Nuclear Power Reactors, for Nuclear Fuel Facilities, Research Reactors, and for Nuclear Waste Storage/Disposal Facilities. During 2008–09, he conducted research on multilateral nuclear fuel cycle systems as a Visiting Fellow at PSGS. During 2006–08, he carried out research at the University of Tokyo on separated plutonium issues linked to the Rokkasho reprocessing plant. During 1999–2005, he worked as a researcher at the Citizens Nuclear Information Center (CNIC) in Tokyo.

M.V. Ramana is the Simons Chair in Disarmament, Global and Human Security with the Liu Institute for Global Issues at the University of British Columbia, Vancouver, Canada. He received his Ph.D. in theoretical physics from Boston University. Ramana is the author of The Power of Promise: Examining Nuclear Energy in India (Penguin Books, 2012) and co-editor of Prisoners of the Nuclear Dream (Orient Longman, 2003). He is a member of the International Panel on Fissile Materials (IPFM) and the recipient of a Guggenheim Fellowship and a Leo Szilard Award from the American Physical Society. He has been selected as a Distinguished Lecturer by Sigma Xi for 2016-17.

Juan Camilo Rodriguez works as an equity analyst on the energy sector for AlphaValue, an independent equity research provider for financial institutions. He has worked for AlphaValue since 2014 coordinating research and valuation studies for the major European energy companies traded on the stock market. In 2013, he worked in Paris for the Economic Laboratory for Nuclear Risks (LERN: Laboratoire Economique des Risques Nucléaires), an economic focus group of the IRSN (Institut de Radioprotection et Sûreté Nucléaire) to measure the economic impact of nuclear risks. Juan holds a double Master degree in Empirical & Theoretical Economics (ETE) and Mathematical Models in Economics and Finance (MMEF) from the Sorbonne University and Paris School of Economics. He holds as well a double Bachelor's degree in Economics and Finance from Florida International University (FIU). His expertise in financial markets and the financial analysis over the spectrum of European power utilities

takes into account both public and private decisions around energy policy and the financial impact of those, with the expected variation on valuation metrics and stock market performance. In 2016, he has given invited expert evidence to the French National Assembly mission on nuclear decommissioning.

Andreas Rüdinger works as independent consultant on energy and climate policies, working with NGOs, research institutes and public authorities. He is an associate research fellow at the Institute for Sustainable Development and International Relations (IDDRI) in Paris, France. He has worked for IDDRI's Energy and Climate Program since 2011, coordinating various research projects on energy transition policies in France and Europe. In 2013, he participated in the French national Energy Transition Debate as a member of the Expert Committee and advisor to the Chair, Laurence Tubiana. His expertise covers the multiple aspects of energy transition strategies and policies at the local, national and European level: energy efficiency policies, support mechanisms and market integration of renewable energies, financing instruments, as well as governance and public participation issues. He has published various studies and research papers on energy topics. Andreas holds a double Master degree in Political Sciences and International Relations from Sciences Po Bordeaux and the University of Stuttgart. He has worked as a guest lecturer at Sciences Po Paris (PSIA), HEC Business School, AgroParisTech and ISAE-SupAéro Toulouse.

Agnès Stienne is an artist, cartographer, and independent graphic designer. She has contributed for over a decade to the French journal *Le Monde Diplomatique*, and the *Visionscarto.net* website dedicated to cartographical experimentation. She has created numerous "narrative cartographics" to illustrate a wide range of complex subjects and issues, including international treatises on armed conflicts, and the damages of wars. She currently leads a research project focusing on agricultural practices, 'land grabbing' and other fundamental agriculture and food issues. The results of her research are featured on the *Visionscarto.net* website, as "geo-poetic" briefs, in which she uses aquarelle-paint to translate her findings into maps and data-vizualisations. Over the Summer 2017, the exhibition "Géopoétique des champs", in the framework of the #Ensemble Festival, presented her work at the Musée de la Mode et du Design in Paris. Her assignments include the design of the United Nations "*Unosat Global Report on Maritime Piracy: a geospacial analysis 1995-2003*", published in 2014.

ANNEX 5
ABBREVIATIONS

ABB	Asea Brown Boveri
ABWR	Advanced Boiling Water Reactors
ACRO	Association pour le Contrôle de la Radioactivité dans l'Ouest Association for the Control of Radioactivity in the West (France)
AEC	Atomic Energy Council (Taiwan)
AECL	Atomic Energy of Canada Limited
AES	[Rosatom Reactor Design]
AFP	*Agence France Presse* — French News Agency
AGEB	Arbeitsgruppe Energiebilanzen — Working Group on Energy Balances (Germany)
AGEE-Stat	Arbeitsgruppe Erneuerbare Energien-Statistik Working Group in charge of Renewable Energy Statistics (Germany)
AGR	Advanced Gas-cooled Reactors
AHWR	Advanced Heavy Water Reactor
ANS	American Nuclear Society (U.S.)
AP	*Associated Press*
APR	Advanced Power Reactor or Advanced Pressurized Reactor
ASE	Atomstroyexport — "Atom-Building-Export" Foreign Trade Engineering Company from Rosatom Corp. (Russia)
ASLB	Atomic Safety Licensing Board (from the Nuclear Regulatory Commission, U.S.)
ASN	Autorité de Sûreté Nucléaire — Nuclear Safety Authority (France)
ASTRID	Advanced Sodium Technological Reactor for Industrial Demonstration
ATMEA	[AREVA Reactor Design]
B&W	Babcock & Wilcox
BBC	British Broadcasting Corporation
BFE	Bundesamt für Energie — Federal Office of Energy (Switzerland)
BKW	Bernische Kraftwerke Bernese Power Production & Distribution Utility (Switzerland)
BMWi	Bundesministerium für Wirtschaft und Energie Federal Ministry for Economic Affairs and Energy (Germany)
BNDES	Brazilian National Development Bank
BN-350	[Rosatom Reactor Design]
BNEF	Bloomberg New Energy Finance
BOO	Build-Own-Operate

BP	Beyond Petroleum
BUND	Bund für Umwelt und Naturschutz Deutschland e.V. — Friends of the Earth, Germany
BWR	Boiling Water Reactor
CANDU	CANadian Deuterium Uranium
CAREM25	Central Argentina de Elementos Modulares
CB&I	Chicago Bridge and Iron (U.S.)
CCS	Carbon Capture and Storage
CEA	Central Electric Authority (India) **or** Atomic Energy Commission (France)
	Commissariat à l'énergie atomique et aux énergies alternatives
CEO	Chief Executive Officer
CfD	Contract for Difference
CFSI	Counterfeit, Fraudulent, Suspect Item
CGN	China General Nuclear Power Corporation
CNAAA	Central Nuclear Almirante Alvaro Alberto (Brazil)
CNEA	Comisión Nacional de Energía Atómica
	National Atomic Energy Commission (Spain)
CNEC	China Nuclear Engineering Corp.
CNIC	Citizens Nuclear Information Center (Japan)
CNNC	China National Nuclear Corporation
CNNPC	China National Nuclear Power Corporation (subsidiary of CNNC)
CNP	Commission for Nuclear Provisions (Belgium)
COD	Commercial Operation Dates
COL	Construction and Operating License
ComEd	Commonwealth Edison Company
CRE	Commission de Régulation de l'Energie — Regulatory Commission of Energy (France)
CSN	El Consejo de Seguridad Nuclear — Nuclear Safety Council (Spain)
CWE	Central West Europe
CWIP	Combined Works In Progress
DEC	Dongfang Electric Corporation (China)
DECC	Department of Energy & Climate Change (U.K.)
DIB	debtor-in-possession
DOE	Department of Energy (U.S. or South Africa)
DPP	Democratic Progressive Party (China)
DSSA	Development and Sale of Structured Assets
E.ON	[German Energy Corporation]
E&P	Exploration and Production

EBITDA	Earnings Before Interest, Tax, Depreciation and Amortization
EBRD	European Bank for Reconstruction and Development
EC6	Enhanced CANDU-6 (CANadian Deuterium Uranium)
ECIC	Espoo Convention Implementation Committee
EDF	Electricité de France — French Electric Utility Company
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment (Ukraine)
	or Energy Information Administration (U.S.)
EnBW	Energie Baden-Württemberg — Power Utility Baden-Wurttemberg (Germany)
ENEC	Emirates Nuclear Energy Corp (U.A.E.)
ENEL	Ente Nazionale per l'energia elettrica — Italian National Entity for Electricity
ENSI	Eidgenössisches Nuklearsicherheitsinspektorat
	Nuclear Safety Inspectorate (Switzerland)
ENSREG	European Nuclear Safety Regulators Group
EPDC	Electric Power Development Company, or J-Power (Japan)
EPH	Energeticky a Prumyslovy Holding
	Energy and Industry Holding — privately-held Czech-Slovak company
EPR	European Pressurized Water Reactor
	or Evolutionary Pressurized Water Reactor (U.S.)
EPSA	Electric Power Supply Association
EPZ	Elektriciteits Produktiemaatschappij Zuid-Nederland
	Electricity Production Company South-Netherlands
ERCOT	Electric Reliability Council of Texas (U.S.)
ERD	Economic Relations Division (Bangladesh)
ETE	Empirical & Theoretical Economics
ETS	Emission Trading System
EU	European Union
EU28	European Union 28 Member States
EÜAS	State-owned electricity generating company (Turkey)
Euratom	European Treaty
EVN	Electricity of Vietnam
EWEA	European Wind Energy Association
FANC	Federal Agency for Nuclear Control (Belgium)
FEPC	Federation of Electric Power Companies (Japan)
FERC	Federal Energy Regulatory Commission (U.S.)
FIU	Florida International University (U.S.)

FL3	Flamanville-3 (France)
FOA	Funding Opportunity Announcement
FS	Frankfurt School (Germany)
FY	Financial Year
GDA	Generic Design Assessment
GDF-Suez	Gaz de France - now known as Engie
GDOS	General Directorate for the Environment (Poland)
GDP	Gross Domestic Product
GE	General Electric
GP ESPN	Advisory Committee of Experts for Nuclear Pressure Equipment
GWEC	Global Wind Energy Council
HM	Her Majesty's
HPC	Hinkley Point C (U.K.)
HSBC	The Hongkong and Shanghai Banking Corporation Limited
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency
IANS	*Indo-Asian News Service*
IDDRI	Institut du Développement Durable et des Relations Internationales Institute for Sustainable Development and International Relations (France)
IEA	International Energy Agency
IESO	Independent Electricity System Operator
INDAG	*International Journal of Nuclear Desalination*
INDCs	Intended National Determined Contributions
INRAG	International Nuclear Risk Assessment Group
IPCC	International Panel on Climate Change
IPFM	International Panel on Fissile Materials, Princeton University (U.S.)
IPO	initial public offering
IPS	Integrated Project Schedule
IRENA	International Renewable Energy Agency
IRID	International Research Institute for Nuclear Decommissioning
IRP	Integrated Resource Plan (South Africa)
IRRS	Integrated Regulatory Review Service (IAEA)
IRSN	Institut de Radioprotection et Sûreté Nucléaire — Institute for Radiation Protection and Nuclear Safety (from the French Nuclear Safety Authority)
ISO	International Organization for Standardization
ITC	Investment Tax Credit

J-Power	Electric Power Development Company (Japan)
JAEA	Japan Atomic Energy Agency
JAEC	Jordan Atomic Energy Commission
	or Japan Atomic Energy Commission
JAIF	Japan Atomic Industrial Forum, Inc.
JAPCO	Japan Atomic Power Company
JAPEIC	Japan Power Engineering And Inspection Corporation
JAVYS	Jadrova A VYradovacia Spolocnost — State owned Energy utility (Slovakia)
JCER	Japan Center for Economic Research
JCFC	Japan Casting and Forging Corporation
JESS	Jadrová energetická spoločnosť Slovenska — Nuclear Power Company (Slovakia)
JMA	Japan Meteorological Agency
JNFL	Japan Nuclear Fuel Limited
JPY	Japanese Yen
JSFR	Japan Sodium Fast Reactor
JSW	Japan Steel Works
KA-CARE	King Abdullah City for Atomic and Renewable Energy (U.A.E.)
KAERI	Korea Atomic Energy Research Institute
KAPP	Kakrapar (India)
KEPCO	Korea Electric Power Corporation
KFK	Kommission zur Überprüfung der Finanzierung des Kernenergieausstiegs
	Commission to Review the Financing for the Phase-out of Nuclear Energy (Germany)
KGHM	Copper Mining and Smelting Industrial Complex (Poland)
KHNP	Korea Hydro and Nuclear Power Co
KINS	Korea Institute of Nuclear Safety
KMT	Chinese Nationalist Party
KRW	Korean Republic Won—Currency (South Korea)
LCOE	Levelized Cost of Electricity
LEU	low enriched uranium
LNG	liquefied natural gas
LTO	Long-Term Outage
LTS	Long-Term Shutdown
METI	Ministry of Economy, Trade and Industry (Japan)
MHI	Mitsubishi Heavy Industries
MHLW	Ministry of Health, Labor and Welfare (Japan)
MISO	Midcontinent Independent System Operator (U.S.)

MMEF Mathematical Models in Economics and Finance
MOEA Ministry of Economic Affairs (China)
MoSPI Ministry of Statistics and Programme Implementation (India)
MoU Memorandum of Understanding
MOX Mixed Oxide
MSC Mycle Schneider Consulting
NAO National Audit Office — Department for Business, Energy & Industrial Strategy, U.K. Government (U.K.)
NEA National Energy Administration (China)
NEB National Energy Board, Canada
NEI Nuclear Energy Institute (U.S.) **or** *Nuclear Engineering International*
NGO Non-Governmental Organization
NIA Nuclear Industry Association (U.K.)
NISA Nuclear And Industrial Safety Agency (Japan)
NIW Nuclear Intelligence Weekly
NJZ nová jadrová zdroj
NNEGC National Nuclear Energy Generating Company (Ukraine)
NP Nuclear Power
NPAD New Politics Alliance for Democracy (Japan)
NPCIL Nuclear Power Corporation of India Ltd
NPP Nuclear Power Plant
NPS National Policy Statement (U.K.) **or** Nuclear Power Station (Japan)
NRA Nuclear Regulation Authority (Japan)
NRC Nuclear Regulatory Commission (U.S.)
NSG Nuclear Suppliers Group
NSSC Nuclear Safety and Security Commission (Korea)
NW Nucleonics Week
NYPSC New York Public Services Commission (U.S.)
OAH Orszagos Atomenergia Hivatal — National Office for Atomic Energy (Hungary)
OECD Organization for Economic Development and Co-operation-Nuclear Energy Agency
OFEN Office Fédérale de l'Énergie — Federal Office of Energy (Switzerland)
OKG Oskarshamns Kraftgrupp AB (Sweden)
OL Olkiluoto Unit 3 or 4 (Finland)
ONR Office for Nuclear Regulation (U.K.)
OPG Ontario Power Generation (Canada)
OPPD Omaha Public Power District (U.S.)
OPR [Korean Reactor Design]

ORS	South Carolina Office of Regulatory Staff (U.S.)
PFBR	Prototype Fast Breeder Reactor
PG&E	Pacific Gas & Electric Co (U.S.)
PGE	Polska Grupa Energetyczna — Polish Energy Group
PHWR	Pressurized Heavy-Water Reactor
PIE	Power in Europe
PJM	Pennsylvania-New Jersey-Maryland Interconnection LLC (U.S.)
PLEC	Japan Nuclear Power Plant Life Engineering Center
PLEX	Plant Life Extension
PPA	Power Purchase Agreement
PRIS	International Atomic Energy Agency's Power Reactor Information System
PSC	Georgia Public Service Commission (U.S.)
PSGS	Program on Science and Global Security (Princeton University, U.S.)
PTC	Production Tax Credits
PV	photovoltaic
PWR	Pressurized Water Reactor
PXE	Power Exchange Central Europe — Prague Stock Exchange
PZEM	Provinciale Zeeuwse Energie Maatschappij N.V.
RAB	Regulated Asset Base
RAPP	Rajasthan (India)
RAV	Regulated Asset Value
RBMK	Reaktor Bolshoy Moshchnosty Kanalny — high-power channel reactor
REN21	Renewable Energy Policy Network for the 21st Century
ROCE	Return on Capital Employed
ROE	Return on Equity
RPV	Reactor Pressure Vessel
RTE	Réseau de Transport d'Électricité — high voltage network (France)
RTO	Regional Transmission Organization
RWE	Rheinisch-Westfälisches Elektrizitätswerk — Rhine-Westphalia Power Utility
S&P	Standard & Poor's
SAFCEI	Southern African Faith Communities Environment Institute
SAM	Severe Accident Management
SAR	Safety Analysis Report
SCE&G	South California Electric & Gas (U.S.)
SE	Slovenské Elektrárne — Slovak Power Plants; state utility (Slovakia)
SIEAC	Seoul International Energy Advisory Council

SL	Severity Level
SMART	System-Integrated Modular Advanced Reactor
SMR	Small Modular Reactor
SNN	Societatea Nationala Nuclearelectrica
	National Nuclear Electricity Company (Romania)
SNPTC	State Nuclear Power Technology Corporation (China)
SPIC	State Power Investment Corporation (China)
SPP	Southwest Power Pool (U.S.)
SSE	Safe Shutdown Earthquake
STUK	Säteilyturvakeskus — Radiation and Nuclear Safety Authority (Finland)
SÚJB	Státní úřad pro Jadernou Bezpečnost — State Office for Nuclear Safety (Czech Rep.)
TASS	*Telegraph Agency of the Soviet Union*
TEPCO	Tokyo Electric Power Company (Japan)
TMI	Three Mile Island (U.S.)
TVA	Tennessee Valley Authority (U.S.)
TVO	Teollisuuden Voima Oyj — Nuclear Power Company (Finland)
UNECE	United Nations Economic Commission for Europe
U.A.E.	United Arab Emirates
U.K.	United Kingdom
U.S.	United States of America
UAE	United Arab Emirates
UAMPS	Utah Associated Municipal Power Systems (U.S.)
UCLA	University of California Los Angeles (U.S.)
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
U.S.DOE	United States Department of Energy
VVER	Vodo-Vodianoï Energuetitcheski Reaktor — Russian Pressurized Water Reactor Design
WACC	Weighted Average Cost of Capital
WNA	World Nuclear Association
WNISR	World Nuclear Industry Status Report
WNN	*World Nuclear News*
WSJ	*Wall Street Journal*
WWS	Wind, Water, and Sunlight
ZEC	Zero Emissions Credits
WWTP	Waste Water Treatment Plant

Electrical and Other Units

kW	kilowatt (unit of installed electric power capacity)
kWh	kilowatt-hour (unit of electricity production or consumption)
MW	megawatt (10^6 watts)
MWe	megawatt electric (as distinguished from megawatt thermal, MWt)
GW	gigawatt (10^9 watts)
GWe	gigawatt electric
TWh	terawatt hour (10^{12} watt-hours)
Bq	Becquerel
Bq/l	Becquerel per litre
Bq/km²	Becquerel per square kilometer
Bq/m²	Becquerel per square meter
PBq	Petabecquerel (10^{15} Becquerel)
Gy	gray (derived unit of ionizing radiation dose; defined as the absorption of one joule of radiation energy per kilogram of matter)
Person-gray	unit of collective dose for specific organ exposures
mSv	millisievert
mSv/h	millisievert per hour
person-Sv	unit of collective dose for whole body exposures
Sv	Sievert
Sv/h	Sievert per hour
Sv/y	Sievert per year

ANNEX 6
STATUS OF NUCLEAR POWER IN THE WORLD

Table 14 | Status of Nuclear Power in the World (as of 1 July 2017)

Country	Nuclear Fleet					Power	Energy
	Operating			LTO	Under Construction	Share of Electricity [a]	Share of Commercial Primary Energy [b]
	Units	Capacity (MW)	Mean Age (Years)	Units	Units		
Argentina	2	1 032	23.2	1	1	5.6% (=)	2.1 (=)
Armenia	1	375	37.5			31.4% (–)	
Belarus					2		
Belgium	7	5 913	37.3			51.7% (+)	16 (+)
Brazil	2	1 884	26.1			2.9% (=)	1.2 (=)
Bulgaria	2	1 926	27.8			35% (+)	19.7 (+)
Canada	19	13 554	34			15.6% (=)	7 (=)
China	37	32 384	7		20	3.6% (=)	1.6 (=)
Czech Republic	6	3 930	26			29.4% (–)	13.7 (–)
Finland	4	2 764	38.3		1	33.7% (=)	19.6 (=)
France	56	60 920	32.3	2	1	72.3% (–)	38.7 (–)
Germany	8	10 799	31.1			13.1% (=)	5.9 (=)
Hungary	4	1 889	32			51.3% (–)	16.6 (=)
India	20	5 948	20.2	1	6	3.4% (=)	1.2 (=)
Iran	1	915	5.8			2.1% (=)	0.5 (=)
Japan	5	4 198	31	33	1	2.2% (+)	0.9 (=)
South Korea	24	22 501	19.6		3	30.3% (–)	12.8 (=)
Mexico	2	1 552	25.4			6.2% (=)	1.3 (=)
Netherlands	1	482	44			3.4% (=)	1.1 (=)
Pakistan	5	1 320	13.9		2	4.4% (=)	1.5 (=)
Romania	2	1 300	15.5			17.1% (=)	7.7 (=)
Russia	35	26 111	30.4		6	17.1% (–)	6.6 (=)
Slovakia	4	1 814	25.3		2	54.1% (–)	21 (=)
Slovenia	1	688	35.7			35.2% (–)	?
South Africa	2	1 860	32.6			6.6% (+)	2.9 (=)
Spain	7	7 121	32.4			21.4% (+)	9.8 (=)
Sweden	8	8 629	36.9			40% (+)	27.2 (+)
Switzerland	4	2 968	40.8	1		34.4% (=)	18.3 (=)
Taiwan	5	4 448	35	1		13.7% (–)	6.4 (=)
UAE	0				4		
UK	15	8 883	33.4			20.4% (=)	8.6 (=)
Ukraine	15	13 107	28.4			52.3% (–)	21.1 (–)
USA	99	99 868	37.1		4	19.7% (=)	8.4 (=)
EU	125	117 058	32.4	2	4	25.9% (=) (2)	11.6 (=)
WORLD	403	351 083	29.30	39	53	10.5% (=) (2)	4.5 (=)

Sources: WNISR, IAEA-PRIS, BP, 2017

a - From IAEA-PRIS, as of 11 August 2017

b - From BP, 2017

The +/-/= in brackets refer to changes in 2016 versus 2015; a change of less than one percentage point is considered =.

ANNEX 7
NUCLEAR REACTORS IN THE WORLD "UNDER CONSTRUCTION"

Table 15 | Nuclear Reactors in the World "Under Construction" (as of 1 July 2017)

Country	Units	Capacity MW net	Model	Construction Start (dd/mm/yyyy)	Expected Grid Connection	Behind Schedule
Argentina	1	25				
Carem25		25	CAREM (PWR)	08/02/2014	2019[1]	yes
Belarus	2	2 218				
Belarusian-1		1 109	VVER V-491	06/11/2013	End 2019[2] (commercial operation)	yes
Belarusian-2		1 109	VVER V-491	03/06/2014	Late 2020[3] (commercial operation)	
China[4]	20	20 500				
Fangchenggang-3		1 000	HPR-1000 (Hualong One)	24/12/2015	2019[5]	
Fangchenggang-4		1 000	HPR-1000 (Hualong One)	23/12/2016	2020[6]	
Fuqing-4		1 000	CPR-1000	01/10/2012	7/2017[7]	
Fuqing-5		1 000	HPR-1000 (Hualong One)	07/05/2015	6/2020 (Completion)[8]	yes
Fuqing-6		1 000	HPR-1000 (Hualong One)	22/12/2015	2020[9]	
Haiyang-1		1 000	AP-1000	24/09/2009	2018[10] (commercial operation)	yes
Haiyang-2		1 000	AP-1000	21/06/2010	2018[11]	yes
Hongyanhe-5		1 000	ACPR-1000	29/03/2015	2019[12]	
Hongyanhe-6		1 000	ACPR-1000	24/07/2015	2020[13]	
Sanmen-1		1 000	AP-1000	19/04/2009	2018[14]	yes
Sanmen-2		1 000	AP-1000	17/12/2009	2018[15]	yes
Shidao Bay-1		200	HTR-PM	01/12/2012	2018[16]	yes
Taishan-1		1 660	EPR-1750	28/10/2009	S2/2017[17]	yes
Taishan-2		1 660	EPR-1750	15/04/2010	S1/2018[18]	yes
Tianwan-3		990	VVER V-428M	22/12/2012	2/2018[19]	yes
Tianwan-4		990	VVER V-428M	27/09/2013	3/2019[20]	yes
Tianwan-5		1 000	ACPR-1000	27/12/2015	12/2020[21] (commercial operation)	
Tianwan-6		1 000	ACPR-1000	07/09/2016	10/2021[22] (commercial operation)	
Yangjiang-5		1 000	ACPR-1000	18/09/2013	11/2017[23]	
Yangjiang-6		1 000	ACPR-1000	31/12/2013	7/2019[24]	yes
Finland	1	1 600				
Olkiluoto-3		1 600	EPR	12/08/2005	2018[25]	yes
France	1	1 600				
Flamanville-3		1 600	EPR	03/12/2007	Second Quarter 2019[26]	yes

Country	Units	Capacity MW net	Model	Construction Start (dd/mm/yyyy)	Expected Grid Connection	Behind Schedule
India	6	3907				
Kakrapar-3		630	PHWR-700	22/11/2010	2018[27] (commercial operation)	yes
Kakrapar-4		630	PHWR-700	22/11/2010	2018[28] (commercial operation)	yes
Kudankulam-3		917	VVER1000	29/06/2017	mid-2023[29] (completion)	
PFBR		470	FBR	23/10/2004	2018[30]	yes
Rajasthan-7		630	PHWR	18/07/2011	2018[31] (completion)	yes
Rajasthan-8		630	PHWR	30/09/2011	2019[32]	yes
Japan[33]	1	1325				
Shimane-3		1325	ABWR	12/10/2007	?[34]	yes
Pakistan	2	2028				
Kanupp-2		1014	ACP-1000 (Hualong One)	20/08/2015	2021	
Kanupp-3		1014	ACP-1000 (Hualong One)	31/05/2016[35]	Late 2022[36]	
Russia	6	4359				
Leningrad 2-1		1085	VVER V-491	25/10/2008	5/2018[37]	yes
Leningrad 2-2		1085	VVER V-491	15/04/2010	11/2019[38]	yes
Novovoronezh 2-2		1114	VVER V-392M	12/07/2009	10/2018[39]	yes
Rostov-4		1011	VVER V-320	01/01/1983[40]	12/2017[41]	yes
Akademik Lomonosov-1		32	KLT-40S 'Floating'	15/04/2007	2019	yes
Akademik Lomonosov-2		32	KLT-40S 'Floating'	15/04/2007	2019	yes
Slovakia	2	880				
Mochovce-3		440	VVER V-213	01/01/1985	End 2018[42] (operation)	yes
Mochovce-4		440	VVER V-213	01/01/1985	End 2019[43] (operation)	yes
South-Korea	3	4020				
Shin-Hanul-1		1340	APR-1400	10/07/2012	4/2018[44] (commercial operation)	yes
Shin-Hanul-2		1340	APR-1400	19/06/2013	2/2019[45] (commercial operation)	yes
Shin-Kori-4		1340	APR-1400	19/09/2009	9/2018[46] (commercial operation)	yes
UAE	4	5380				
Barakah-1		1345	APR-1400	19/07/2012	2018[47]	yes
Barakah-2		1345	APR-1400	30/05/2013	2018	?
Barakah-3		1345	APR-1400	24/09/2014	2019	?
Barakah-4		1345	APR-1400	30/07/2015	2020	?
USA	4	4468				
Summer-2[48]		1117	AP-1000	09/03/2013	2020	yes
Summer-3		1117	AP-1000	02/11/2013	2020	yes
Vogtle-3		1117	AP-1000	12/03/2013	mid-2019[49]	yes
Vogtle-4		1117	AP-1000	19/11/2013	mid-2020[50]	yes
WORLD	**53**	**52310**			**2017-2023**	**37**

1 - Delayed. According to CNEA, first criticality is now expected for the first semester of 2019.
See CNEA, "Proyecto CAREM—Cronograma", Undated, see http://www.cnea.gov.ar/carem-cronograma, accessed 18 April 2017.
WNA mentions a "trial period" ending in July 2019.
See WNA, "Nuclear Power in Argentina", 22 May 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/argentina, accessed 6 August 2017.
WNISR2017 uses second quarter 2019 for grid connection—at least six months delay compared to original startup date of 2018, in WNISR2016.

2 - A delay of at least six months compared to scheduled date of operation (2018) in WNISR2016. According to Rosatom, 2019 is the most feasible date for the startup of Belarusian-1. See BelTa, "Rosatom describes 2019 as feasible term for launching Belarusian nuclear power plant first reactor", 18 November 2016, see http://eng.belta.by/economics/view/rosatom-describes-2019-as-feasible-term-for-launching-belarusian-nuclear-power-plant-first-reactor-96465-2016/, accessed 19 November 2016. WNA's date for commercial operation was pushed back from "early 2019" to "end 2019". See WNA, "Nuclear Power in Belarus", July 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/belarus.aspx, accessed 5 August 2017.

3 - Commercial operation date from WNA, "Nuclear Power in Belarus", July 2017.

4 - WNA's dates for China refer to WNA's Table "Nuclear reactors under construction and planned". See WNA, "China Nuclear Power", Updated August 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx, accessed 6 August 2017.

5 - No information concerning expected startup date in CGN's announcement of construction start. As of August 2017, WNA's table "Nuclear reactors under construction and planned" indicates 2019-20 for operation/grid connection for Fangchenggang-3. See reference in previous Note (4).

6 - No information concerning original expected startup date in CGN's announcement of construction start. As of August 2017, WNA's table "Nuclear reactors under construction and planned" indicates 2020 for operation/grid connection for Fangchenggang-4. See reference in Note (4).

7 - Fuqing-4 was connected to the grid on 29 July 2017. See CNNC, "Fuqing Unit 4 joins power grid", Press Release, 2 August 2017, see http://en.cnnc.com.cn/2017-08/02/c_89010.htm, accessed 6 August 2017.

8 - In March 2016, CNNC stated that construction of first Hualong reactor was expected to be completed by June 2020. See *Reuters*, "China's debut Westinghouse reactor delayed until June 2017", 9 March 2016, see http://www.reuters.com/article/us-china-parliament-nuclear-idUSKCN0WB09F, accessed 24 June 2016. No change since WNISR2016, already delayed from original startup date of 2019.

9 - See previous note. No change since WNISR2016.

10 - Delayed. Haiyang-1 was supposed to start up in 2014. In February 2017, it was listed amongst reactors to be completed in 2017 in NEA's "Energy Work Guidance Opinion". See *WNN*, "China sets out nuclear plans for 2017", 2 March 2017, see http://www.world-nuclear-news.org/NP-China-sets-out-nuclear-plans-for-2017-0203174.html, accessed 3 March 2017. However, in July 2017 WNA has moved the expected startup to 2018, and commercial operation is expected in 2018 according to NEI. See NEI, "Milestones—Chinese AP1000s Approach Operation", 27 July 2017, see https://www.nei.org/News-Media/News/Milestones, accessed 6 August 2017. The reactor is delayed by at least several months, compared to WNISR2016. WNISR2017 uses 2018 for Commercial Operation.

11 - *NEI*, "Milestones—Chinese AP1000s Approach Operation", 27 July 2017. See previous note.

12 - At construction start of Hongyanhe-5 and then Hongyanhe-6, it was announced that they would be completed by 2021, date previously used in WNISR2016. However, operation of Hongyanhe-5 is now reported to start in November 2019, change introduced in WNISR2017. See *NEI*, "Dome installed at China's Hongyanhe-5", 17 April 2017, see http://www.neimagazine.com/news/newsdome-installed-at-chinas-hongyanhe-5-5787690, accessed 6 August 2017.

13 - At construction start of Hongyanhe-5 and then Hongyanhe-6, it was announced that they would be completed by 2021, date previously used in WNISR2016. However, operation of Hongyanhe-6 is now reported to start in August 2020—change introduced in WNISR2017. See NEI, "Dome installed at China's Hongyanhe-5", 17 April 2017, see previous note.

14 - Delayed. Original startup date: 2013. According to an announcement from Westinghouse in May 2017, the first of the Sanmen units is to be "completed in the first quarter of 2018". See David Stanway, "Westinghouse says first AP1000 reactor to be completed in China in early 2018", *Reuters*, 17 May 2017. Delayed at least a few months since WNISR2016.

15 - Delayed. Original startup date: 2014. See previous note. 2018 for grid connection from WNA.

16 - Delayed. Original startup date: 2017. According to interview of Wang Yiren, deputy director general of the State Administration of Science, Technology and Industry for National Defence by *CCTV+ television*, Shidao Bay is to go online in 2018. See *CCTV*, "China's 4th generation nuclear power plant to go online in 2018 - CCTV News", 14 February 2017, see http://english.cctv.com/2017/02/14/VIDEOS4JarzcwUsx01sg28jZ170214.shtml, accessed 26 May 2017. WNISR2017 uses 2018 for grid connection, a delay of about one year compared to WNISR2016 (commercial operation in 2017).

17 - Delayed several times. Taishan-1 is amongst reactors to be completed in 2017, according to NEA. See NEA, "Energy Work Guidance Opinion", February 2017. According to CGN, commercial operation of Taishan-1 has been "adjusted" from the original first half of 2017 to the second half of 2017. See CGN, "Inside Information—Construction Progress of Taishan Nuclear Power Generating Units", 20 February 2017, see http://www.hkexnews.hk/listedco/listconews/SEHK/2017/0220/LTN20170220443.pdf; and *WNN*, "China sets out nuclear plans for 2017", 2 March 2017, see http://www.world-nuclear-news.org/NP-China-sets-out-nuclear-plans-for-2017-0203174.html; both accessed 17 August 2017. WNISR2017 uses end 2017 for grid connection, a delay of about six months compared to WNISR2016 (already delayed by almost two years since WNISR2015). Total delay is over three years (2013).

18 - Delayed several times. According to CGN, commercial operation of Taishan-2 has been "adjusted" from the original second half of 2017 to the first half of 2018. See CGN, "Inside Information—Construction Progress of Taishan Nuclear Power Generating Units", 20 February 2017. WNISR2017 uses WNA's date of 2018 for grid connection, a further delay of about six months compared to WNISR2016 (already delayed two years since WNISR2015).

19 - Delayed. Table from the China's National Energy Administration (2014), shows targeted completion for Tianwan-3 as February 2018. See Shan Sun, "Challenges during construction of new NPPS", Huaneng Shandong Shidao Bay Nuclear Power Company, 4 February 2014,

see http://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2014-02-04-02-07-TM-INIG/Presentations/37_S7_China_Sun.pdf, accessed 31 May 2014; table translated in *NIW*, "China—Sanmen—Two Year Delay Pushes Costs Higher", 14 March 2014.
No change since WNISR2016.

20 - Delayed. Table from the China's National Energy Administration (2014), indicated a targeted completion for Tianwan-4 as November 2018 (see previous reference). As of August 2017, WNA had changed grid connection date to 3/2019. WNISR2017 uses 3/2019 for startup. A delay of at least several months compared to WNISR2016 (11/2018).

21 - *WNISR*, "China: Grid Connection for Fuqing-3 and Construction Start on Tianwan-6", 9 September 2016, see https://www.worldnuclearreport.org/China-Grid-Connection-for-Fuqing-3-and-Construction-Start-on-Tianwan-6.html. Commercial operation date has been changed from 2021 in WNISR2016 to 12/2020.

22 - *WNISR*, "China: Grid Connection for Fuqing-3 and Construction Start on Tianwan-6", 9 September 2016. See previous note.

23 - Shan Sun, "Challenges during construction of new NPPS", Huaneng Shandong Shidao Bay Nuclear Power Company, 4 February 2014.
See Note 19.

24 - Delayed. According to presentation by Shan Sun, (see Note 19), completion of Yangjiang-6 was to last 56 months, and operation was scheduled "by 2018". See *WNN*, "China celebrates construction milestones", 31 December 2013, see http://www.world-nuclear-news.org/NN-China-celebrates-construction-milestones-3112134.html, accessed 3 January 2014. No date change since WNISR2016.

25 - Delayed numerous times from its original planned commissioning in 2009. In 2016, TVO confirmed the 2018 deadline: "According to the schedule submitted by the OL3 supplier, regular electricity generation at OL3 will start at the end of 2018". See TVO, "TVO Submits OL3 Operating License Application to the Ministry of Employment and the Economy", 14 April 2016, see http://www.tvo.fi/news/1711, accessed17 August 2017.
No changes compared to WNISR2016.

26 - Delayed numerous times from the original planned startup date in 2012. According to EDF, actual grid connection expected in 2019: "The coupling of the Flamanville 3 EPR to the grid is scheduled for the second quarter of 2019 and generation at full capacity of rated power, after a gradual ramping-up phase, for the fourth quarter of 2019". See EDF, "Reference Document—2016 Annual Financial Report", March 2017,
see https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-finance-fr/informations-financieres/informations-reglementees/document-de-reference/edf-ddr_2016-en.pdf, accessed 14 April 2017. A further delay of about six months compared to WNISR2016 (4th quarter 2018), when EDF did not provide precisions on the expected grid-connection date.

27 - Delayed several times. No new date on NPCIL's dedicated page, which indicates "Under Review", since expected commercial operation date of June 2015 was removed. See NPCIL, "Plants Under Construction—Kakrapar Atomic Power Project", Undated, see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=91, accessed 24 January 2016. In December 2016, according to officials, quoted by IANS, fuel loading was expected in October 2017, first criticality in November, and Commercial Operation in early 2018. See IANS, "Trial run of India's first 700 MW reactor in 2017", *The Economic Times*, 31 December 2016, see http://economictimes.indiatimes.com/industry/energy/power/trial-run-of-indias-first-700-mw-reactor-in-2017/articleshow/56270382.cms, accessed 5 August 2017. WNIRS2017 uses early 2018 for Commercial Operation instead of completion in 2017 (WNISR2016), no indication on additional delay.

28 - Delayed. No new startup date on NPCIL's dedicated page, which indicates "Under Review", since expected commercial operation date of December 2015 was removed. According to IANS, Kakrapar-4 to start six to seven months after Kakrapar-3 (see previous note).
WNIRS2017 uses 2018 for commercial operation, instead of completion in WNISR2016.

29 - According to an article published in *Daily News & Analysis*: "The project, being built with Russian collaboration, is expected to be completed in 73 months". See *Daily News & Analysis*, "Work begins for unit 3 of Kudankulam Nuclear Power Plant", 29 June 2017, see http://www.dnaindia.com/business/report-work-begins-for-unit-3-of-kudankulam-nuclear-power-plant-2487774, accessed 6 August 2017.

30 - Delayed many times. Since late 2016, DAE says that PFBR is expected to go operational by October 2017. However, according to "sources in the Department of Atomic Energy", quoted by the *Deccan Herald*, DAE has a new target of mid-2018.
See Kalyan Ray, "Fast breeder nuclear reactor delayed by 8 yrs", *Deccan Herald*, 15 April 2017, see http://www.deccanherald.com/content/606431/fast-breeder-nuclear-reactor-delayed.html, accessed 18 May 2017.
WNISR2017 uses 2018, a delay of over a year compared to WNISR2016 (criticality 3/2017).

31 - Delayed. No new date on NPCIL's dedicated page, which indicates "Under Review" after it removed the June 2016 startup date in January 2017. See NPCIL, "Plants Under Construction—Rajasthan Atomic Power Station", Undated, see http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=87, accessed 27 January 2017. According to recent answers to parliamentary questions, RAPP-7&8 are expected to be completed by 2019, but with no specific date for RAPP-7, and no other indication of further delay. See for example Lok Sabha, "Unstarred Question No. 1300—To be answered on 23.11.2016—Construction of Nuclear Power Plants", Department of Atomic Energy, Government of India, with official Answer by Dr. Jitendra Singh, The Minister Of State For Personnel, Public Grievances & Pensions And Prime Minister's Office, see http://www.dae.nic.in/writereaddata/parl/winter2016/lsus1300.pdf, accessed 29 December 2016. WNISR2017 keeps 2018 for completion, no delay compared to WNISR2016.

32 - Delayed. No new date on NPCIL's dedicated page, which indicates "Under Review" after it removed the December 2016 startup date in January 2017. See previous note. No change since WNISR2016.

33 - After the 3/11 events, Japan halted work at two ABWR units, Shimane-3 and Ohma, which had been under construction since 2007 and 2010 respectively. In September 2012, METI approved the restart of construction at both sites. In 2015, despite lack of detailed information, WNISR reintegrated both reactors in the list of reactors under construction. The Ohma reactor is again removed from the list in WNISR2017, since construction at the site has effectively been suspended, according to J-Power.

34 - No planned grid connection date.

35 - Construction of Kanupp-3 was only introduced on IAEA-PRIS in November 2016, with a construction-start date of 31 May 2016.
See PRIS, "Reactor Details—Kanupp 3", IAEA, 6 November 2016, see https://www.iaea.org/pris/CountryStatistics/ReactorDetails.aspx?current=1068, accessed 17 August 2017. In December 2016, *NIW* provided a different date, 31 July 2016, for concrete pouring.
See *NIW*, "China's Nuclear Drive in Pakistan", 2 December 2016. WNISR2017 uses the date of 31 May 2016.

36 - No official startup date. Commercial operation from WNA, "Nuclear Power in Pakistan", July 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/pakistan.aspx, accessed 6 August 2017.

37 - Delayed several times. Original startup date: 2013. Grid connection date from WNA, "Nuclear Power in Russia", 27 July 2017, see http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx, accessed 6 August 2017.
Delayed about one year since WNISR2016.

38 - Delayed several times. Original startup date: 2016. Grid connection date from WNA, "Nuclear Power in Russia", Updated 27 July 2017.
No further delay since WNISR2016.

39 - Delayed. Commercial operation scheduled for January 2019. Grid connection date from WNA, "Nuclear Power in Russia", Updated 27 July 2017.
WNISR2017 uses 10/2018 as grid connection date, instead of 2019 for commercial operation in WNISR2016.

40 - IAEA-PRIS considers construction start date to be 16 June 2010, but the Rostov-4 reactor was already listed as under construction by the IAEA in April 1986, with a construction start of 1983. See IAEA, "Nuclear Power Reactors in the World", April 1986.

41 - Delayed numerous times. Latest announcement by Rosatom: "The Rostov-4 first power is scheduled for December 2017".
See Rosatom: "Rostov-4 has started pressure tests and circulation flushing", Press Release, 11 July 2017, see http://www.rosatom.ru/en/press-centre/news/rostov-4-has-started-pressure-tests-and-circulation-flushing/, accessed 17 August 2017.

42 - Delayed several times. Construction was suspended between March 1993 and June 2009. In the Framework of the Strategic Plan, approved by the extraordinary General Assembly of Slovenské Elektrárne, a.s. (SE) on 28 March 2017, operation of Mochovce-3 is expected by the end of 2018.
See Slovenské Elektrárne, "Shareholders approved the 2017 – 2021 Strategic Plan", 29 March 2017, see https://www.seas.sk/article/shareholders-approved-the-2017-2021-strategic-plan/305, accessed 30 March 2017. A further delay of at least one year compared to WNISR2016.

43 - Delayed several times. Construction was suspended between March 1993 and June 2009. In the Framework of the Strategic Plan, approved by the extraordinary General Assembly of Slovenské Elektrárne, a.s. (SE) on 28 March 2017, operation of Mochovce-4 is expected by the end of 2019.
See previous reference. A further delay of at least one year compared to WNISR2016.

44 - Delayed. No indications of further delay since WNISR2016. See section on **South Korea** in the "Focus Countries" Chapter.

45 - Delayed. See previous note.

46 - Delayed numerous times, from original startup date of September 2014.
As of June 2017, KHNP's dedicated webpage indicates Fuel Loading in January 2018 and Commercial Operation in September 2018.
See KHNP, "Nuclear Power Construction—Shin Kori #3,4", 30 June 2017, see http://cms.khnp.co.kr/eng/content/546/main.do?mnCd=EN03020302, accessed 10 July 2017. A delay of 1.5 years compared to WNISR2016. See section on **South Korea** in the "Focus Countries" Chapter.

47 - Delayed. In May 2017, ENEC announced a new timeline, including "an extension for the start-up of nuclear operations for Unit 1, from 2017 to 2018". See ENEC, "ENEC Announces Completion of Initial Construction Work for Unit 1 of Barakah Nuclear Energy Plant & Progress Update Towards Safety-led Operations", 5 May 2017, see https://www.enec.gov.ae/enec-announces-completion-of-initial-construction-work-barakah-unit-1-progress-update/, accessed 5 May 2017. WNISR2017 uses 2018 as startup year, without any indication of a specific month, compared to 2017 in WNISR2016.

48 - Summer-1&2 were still considered as under construction as of 1 July 2017. The abandonment of construction was announced on 31 July 2017 (see **Focus United States**).

49 - Delayed numerous times. A new delay was announced in February 2017, affecting the commercial operation date, pushed back from June 2019 to December 2019 (an additional delay of six months). No grid connection dates are provided.
See *Nikkei Asian Review*, "Westinghouse delays Georgia reactor construction", 23 February 2017, see http://asia.nikkei.com/Business/Companies/Westinghouse-delays-Georgia-reactor-construction, accessed 24 February 2017. WNISR2017 keeps the grid connection date of mid-2019 already announced in WNISR2016.

50 - Delayed numerous times. A new three-month delay was announced in February 2017, affecting the commercial operation date, pushed back from June 2010 to September 2020. No grid connection dates are provided. See *Nikkei Asian Review*, "Westinghouse delays Georgia reactor construction", 23 February 2017. WNISR2017 keeps the grid connection date of mid-2020 already announced in WNISR2016.