



A MYCLE SCHNEIDER CONSULTING PROJECT
Paris, London, Tokyo, July 2016

THE WORLD NUCLEAR INDUSTRY

STATUS REPORT 2016

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ACKNOWLEDGMENTS

The project coordinator wishes to thank Antony Froggatt, all-time key contributor to this project. Many thanks also to contributing authors Tadahiro Katsuta and M.V. Ramana for their renewed professional contributions. Pleasure to work with you.

Ian Fairlie and Fulcieri Maltini provided exceptional contributions this year. Thank you very much.

A special thanks goes out to Tomas Kåberger, who contributed a thoughtful foreword under hardly acceptable time constraints.

A big chunk of the success of this project is due to its visibility through the graphic illustrations based on the project database designed and maintained by data engineer Julie Hazemann. And there is more to come in the near future. Nina Schneider put her excellent proof-reading and formatting skills to work and contributed fundamental research for one of the chapters. Thank you both. We were lucky to have Max Schneider assist with Japanese language issues. Thank you.

Many other people have contributed pieces of work to make this project possible and bring it to the current standard. These include in particular Shaun Burnie, who contributed more than invaluable research and Benoît Rozel, who provided terrific support on data management.

The report has greatly benefitted from partial or full proof-reading, editing suggestions and comments by Shaun Burnie, Nils Epprecht, Eloi Glorieux, Jan Haverkamp, Yuri Hiranuma, Iriyna Holovko, Amory B. Lovins, Jean-Marc Nollet, Olexi Pasyuk, Walt Patterson, Nina Schneider, Shawn-Patrick Stensil, Yury Urbansky and several anonymous reviewers. Thank you all.

The authors wish to thank in particular Rebecca Bertram, Rebecca Harms, Amory B. Lovins, Matthew McKinzie and Sabine von Stockar, for their durable and enthusiastic support of this project.

And everybody involved is grateful to the MacArthur Foundation, Natural Resources Defense Council, Heinrich Böll Foundation North America, the Greens-EFA Group in the European Parliament, and the Swiss Renewable Energy Foundation for their generous support for this project.

A big thank-you to Philippe Rivière for his solid, reliable work on the website and his generous assistance at any time of the day as well as to Noëlle Papay who created the special cover page and the new layout (again) for this report.

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 Tomas Kåberger¹

The *World Nuclear Industry Status Report (WNISR)* is the best compilation of data, trends and facts about the nuclear industry available. This is all the more impressive considering the competition from resource-rich commercial or intergovernmental institutions. It is free from the political constraints, e. g. those leading the International Atomic Energy Agency (IAEA) to the false claim there are more than 40 reactors operating in Japan. Nor does it suffer from the anti-nuclear exaggerations or pro-nuclear enthusiasm so often tainting descriptions of this industry's status.

This year, special chapters on Chernobyl and Fukushima confirm that nuclear accidents bear not only significant human and environmental but also economic risks. These, however, are risks the nuclear industry has been sheltered from by political decisions limiting their liability.

The WNISR this year is more about a risk the industry will not easily be protected from: The economic and financial risks from nuclear power being irreversibly out-competed by renewable power.

The year 2015 seems to be the best year for the nuclear industry in the last quarter of a century. A record 10 new reactors with a total capacity of over 9 GW were put into operation. This was less than new solar and less than wind capacity, which increased five and six times as much respectively. In actual electricity produced, nuclear increased by 31 TWh, while fossil fuels based electricity generation decreased. The main reason why fossil fuels decreased was the expansion in renewable power generation, an increase of more than 250 TWh compared to 2014, seven times more than the modest nuclear increase.

The development of installations and generation is a result of renewable energy cost reductions. As we may also read in this report, nuclear construction is not only costly, it is often more costly, and requires more time, than envisioned when investment decisions were taken. Solar and wind, on the other hand, have come down in price to an extent that new wind and solar are often providing new generation that is clearly cheaper than new nuclear power.

Even more challenging to the nuclear industry is the way renewables are bringing down electricity prices in mature industrial countries to the extent that an increasing number of reactors operate with economic losses despite producing electricity as planned.

But a foreword is not meant to be another summary. My appreciation of the report is already clearly stated. Let me use the final paragraphs on what implications may follow from the facts laid out in this report:

First: A nuclear industry under economic stress may become an even more dangerous industry. Owners do what they can to reduce operating costs to avoid making economic loss. Reduce staff, reduce maintenance, and reduce any monitoring and inspection that may be avoided. While a stated ambition of "safety first" and demands of safety authorities will be heard, the conflict is always there and reduced margins of safety may prove to be mistakes.

¹ Tomas Kåberger is Professor of Industrial Energy Policy at Chalmers University of Technology in Sweden and Executive Board Chairman of the Renewable Energy Institute in Japan.

Secondly: The economic losses of nuclear come as fossil fuel based electricity generation is also suffering under climate protection policies and competition from less costly renewable power. The incumbent power companies are often loosing net cash-flow as well as asset values. As a result, many power companies are downgraded by credit-rating agencies and their very existence threatened. Electric power companies' ability to actually manage the back-end cost of the nuclear industry is increasingly uncertain. As the estimates of these costs become more important, and receive attention they tend to grow.

Reading the WNISR2016, a premonition appears of what may lay ahead of this industry and the 31 governments hosting it.

Let us hope WNISR will help many people understand the situation and contribute to responsible regulation and management of the industry in the critical period ahead of us.

Executive Summary and Conclusions

Key Insights in Brief

The China Effect

- Nuclear power generation in the world increased by 1.3%, entirely due to a 31% increase in China.
- Ten reactors started up in 2015—more than in any other year since 1990—of which eight were in China. Construction on all of them started prior to the Fukushima disaster.
- Eight construction starts in the world in 2015—to which China contributed six—down from 15 in 2010 of which 10 were in China. No construction starts in the world in the first half of 2016.
- The number of units under construction is declining for the third year in a row, from 67 reactors at the end of 2013 to 58 by mid-2016, of which 21 are in China.
- China spent over US\$100 billion on renewables in 2015, while investment decisions for six nuclear reactors amounted to US\$18 billion.

Early Closures, Phase-outs and Construction Delays

- Eight early closure decisions taken in Japan, Sweden, Switzerland, Taiwan and the U.S.
- Nuclear phase-out announcements in the U.S. (California) and Taiwan.
- In nine of the 14 building countries *all* projects are delayed, mostly by several years. Six projects have been listed for over a decade, of which three for over 30 years. China is no exception here, at least 10 of 21 units under construction are delayed.
- With the exception of United Arab Emirates and Belarus, *all* potential newcomer countries delayed construction decisions. Chile suspended and Indonesia abandoned nuclear plans.

Nuclear Giants in Crisis – Renewables Take Over

- AREVA has accumulated US\$11 billion in losses over the past five years. French government decides €5.6 billion bailout and breaks up the company. Share value 95 percent below 2007 peak value. State utility EDF struggles with US\$41.5 billion debt, downgraded by S&P. Chinese utility CGN, EDF partner for Hinkley Point C, loses 60% of its share value since June 2015.
- Globally, wind power output grew by 17%, solar by 33%, nuclear by 1.3%.
- Brazil, China, India, Japan and the Netherlands now all generate more electricity from wind turbines alone than from nuclear power plants.

Chernobyl+30/Fukushima+5

- Three decades after the Chernobyl accident shocked the European continent, 6 million people continue to live in severely contaminated areas. Radioactive fallout from Chernobyl contaminated 40% of Europe's landmass. A total of 40,000 additional fatal cancer cases are expected over the coming 50 years.
- Five years after the Fukushima disaster began on the east coast of Japan, over 100,000 people remain dislocated. Only two reactors are generating power in Japan, but final closure decisions were taken on an additional six reactors that had been offline since 2010-11.

The *World Nuclear Industry Status Report 2016 (WNISR)* 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 WNISR2016 edition includes again an assessment of the financial status of many of the biggest industrial players in the sector. This edition also provides a Chernobyl Status Report, 30 years after the accident that led to the contamination of a large part of Europe. The Fukushima Status Report gives an overview of the standing of onsite and offsite issues five years after the beginning of the catastrophe.

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 31 countries operating nuclear power plants, with extended Focus sections on Belgium, China, France, Japan, and the United States.

Reactor Status and Nuclear Programs

Startups and Shutdowns. In 2015, 10 reactors started up (eight in China, one in Russia, and one in South Korea) and two were shut down (Grafenrheinfeld in Germany and Wylfa-1 in the U.K.). Doel-1 was shut down in January when its operational license ran out, but was restarted in December after a lifetime extension was approved. Final closure decisions were taken on five reactors in Japan that had not generated power since 2010-11, and on one Swedish reactor that had been offline since 2013.

In the first half of 2016, five reactors started up, three in China, one in South Korea and one in the U.S. (Watts Bar 2, 43 years after construction start), while none were shut down. However, the permanent closure of one additional reactor has been announced in Japan. Ikata-1, that had not generated any power since 2011.

Operation and Construction Data²

Reactor Operation. There are 31 countries operating nuclear power plants, one more than a year ago, with Japan restarting two units.³ These countries operate a total of 402 reactors—excluding Long Term Outages (LTOs)—a significant increase, 11 units, compared to the situation mid-2015, but four less than in 1987 and 36 fewer than the 2002 peak of 438. The total installed capacity increased over the past year by 3.3 percent to reach 348 GW⁴, which is comparable to levels in 2000. Installed capacity peaked in 2006 at 368 GW. Annual nuclear electricity generation reached 2,441 TWh in 2015—a 1.3 percent increase over the previous year, but 8.2 percent below the historic peak in 2006. The 2015 global increase of 31 TWh is entirely due to production in China where nuclear generation increased by 30 percent or 37 TWh.

² See Annex 1 for a country-by-country overview of reactors in operation and under construction as well as the nuclear share in electricity generation.

³ Unless otherwise noted, the figures indicated are as of 1 July 2016.

⁴ All figures are given for nominal net electricity generating capacity. GW stands for gigawatt or thousand megawatt.

WNISR classifies 36 Japanese reactors⁵ as being in LTO.⁶ Besides the Japanese reactors, one Swedish reactor (Ringhals-2) and one Taiwanese reactor (Chinshan-1) meet the LTO criteria. All ten reactors at Fukushima Daiichi and Daini are considered permanently closed and are therefore excluded in the count of operating nuclear power plants.

Share in Energy Mix. The nuclear share of the world's power generation remained stable⁷ over the past four years, with 10.7 percent in 2015 after declining steadily from a historic peak of 17.6 percent in 1996. Nuclear power's share of global commercial primary energy consumption also remained stable at 4.4 percent—prior to 2014, the lowest level since 1984.⁸

The “big five” nuclear generating countries—by rank, the U.S., France, Russia, China, and South Korea—generated about two-thirds (69 percent in 2014) of the world's nuclear electricity in 2015. China moved up one rank. The U.S. and France accounted for half of global nuclear generation, and France produced half of the European Union's nuclear output.

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-2016 stood at 29 years. Over half of the total, or 215 units, have operated for more than 30 years, including 59 that have run for over 40 years, of which 37 in the U.S.

Lifetime Extension. The extension of operating periods beyond the original design is licensed differently from country to country. While in the U.S. 81 of the 100 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. In Belgium, 10-year extensions for three reactors were approved but do not jeopardize the legal nuclear phase-out goal for 2025.

Lifetime Projections. If all currently operating reactors were shut down at the end of a 40-year lifetime—with the exception of the 59 that are already operating for more than 40 years—by 2020 the number of operating units would be 22 below the total at the end of 2015, even if all reactors currently under active construction were completed, with the installed capacity declining by 1.7 GW. In the following decade to 2030, 187 units (175 GW) would have to be replaced—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 only increase by two, and adding 17 GW in 2020 and until 2030, an additional 144.5 GW would have to start up to replace 163 reactor shutdowns.

Construction. As in previous years, fourteen countries are currently building nuclear power plants. As of July 2016, 58 reactors were under construction—9 fewer than in 2013—of which 21 are in China. Total capacity under construction is 56.6 GW.

- The current average time since work started at the 58 units under construction is 6.2 years, a considerable improvement from the average of 7.6 years one year ago. This is mainly because four units with 30+ construction years were taken off the list (two started up, two were suspended) and work started on six new reactors.

⁵ Including the Monju reactor, shut down since 1995, listed under “Long Term Shutdown” in the International Atomic Energy Agency (IAEA), Power Reactor Information System (PRIS), database.

⁶ 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.

⁷ Less than 0.2 percentage points difference between the four years, a level that is certainly within statistical uncertainties.

⁸ According to BP, “Statistical Review of World Energy”, June 2016.

- All of the reactors under construction in 9 out of 14 countries have experienced delays, mostly year-long. At least two thirds (38) of all construction projects are delayed. Most of the 21 remaining units under construction, of which eleven 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.
- Three reactors have been listed as “under construction” for more than 30 years: Rostov-4 in Russia and Mochovce-3 and -4 in Slovakia. As no active construction has been ongoing and with the construction contract cancelled, Khmelnitski-3 and -4 in Ukraine have been taken off the list.
- Two units in India, Kudankulam-2 and the Prototype Fast Breeder Reactor (PFBR), have been listed as “under construction” for 14 and 12 years respectively. The Olkiluoto-3 building site in Finland reached its tenth anniversary in August 2015.
- The average construction time of the latest 46 units in ten countries that started up since 2006 was 10.4 years with a very large range from 4 to 43.6 years. The average construction time increased by one year compared to the WNISR2015 decennial assessment.

Construction Starts & New Build Issues

Construction Starts. In 2015, construction began on 8 reactors, of which 6 were in China and one each were in Pakistan and the United Arab Emirates (UAE). This compares to 15 construction starts—of which 10 were in China alone—in 2010 and 10 in 2013. Historic analysis shows that construction starts in the world peaked in 1976 at 44. Between 1 January 2012 and 1 July 2016, first concrete was poured for 28 new plants worldwide—fewer than in a single year in the 1970s.

Construction Cancellations. Between 1977 and 2016, a total of 92 (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. Public information on the status of these construction projects is scarce. 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, Turkey, and Vietnam. Chile and Lithuania shelved their new-build projects, whereas Indonesia abandoned plans for a nuclear program altogether for the foreseeable future.

Nuclear Economics: Corporate Meltdown?

Nuclear Utilities in Trouble. Many of the traditional nuclear and fossil fuel based utilities are struggling with a dramatic plunge in 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 giants EDF, Engie (France), E.ON, RWE (Germany) and Vattenfall (Sweden), as well as utilities TVO (Finland) and CEZ (Czech Republic) have all been downgraded by credit-rating agencies over the past year. All of the utilities registered severe losses on the stock market. EDF shares lost over half of their value in less than a year and 87 percent compared to their peak value in 2007. RWE shares went down by 54 percent in 2015.
- In **Asia**, the share value of the largest Japanese utilities TEPCO and Kansai was wiped out in the aftermath of the Fukushima disaster and never recovered. Chinese utility CGN, listed on the Hong Kong stock exchange since December 2014, has lost 60 percent of its share value since June 2015. The only exception to this trend is the Korean utility KEPCO that still operates as a virtual monopoly in a regulated market, controlling production, transport and distribution. Its share value has gone up by 80 percent since 2013.
- In the **U.S.**, the largest nuclear operator Exelon lost about 60 percent of its share value compared to its peak value in 2008.

AREVA Debacle (new episode). The French state-controlled integrated nuclear company AREVA is technically bankrupt after a cumulative five-year loss of €10 billion (US\$10.9 billion). Debt reached €6.3 billion (US\$6.9 billion) for an annual turnover of €4.2 billion (US\$4.6 billion) and a capitalization of just €1.3 billion (US\$1.5 billion) as of early July 2016, after AREVA's share value plunged to a new historic low, 96 percent below its 2007 peak. The company is to be broken up, with French-state-controlled utility EDF taking a majority stake in the reactor building and maintenance subsidiary AREVA NP that will then be opened up to foreign investment. The rescue scheme has not been approved by the European Commission and could turn out to be highly problematic for EDF as its risk profile expands.

Operating Cost Increase–Wholesale Price Plunge. In an increasing number of countries, including Belgium, France, Germany, the Netherlands, Sweden, Switzerland and parts of the U.S., historically low operating costs of rapidly aging reactors have escalated so rapidly that the average unit's operating cost is barely below, and increasingly exceeds, the normal band of wholesale power prices. Indeed, the past five years saw a dramatic drop of wholesale prices in European markets, for example, about 40% in Germany and close to 30% in the Scandinavian Nord Pool in 2015 alone.

Utility Response. This has led to a number of responses from nuclear operators. The largest nuclear operator in the world, the French-state-controlled utility EDF, has requested significant tariff increases to cover its operating costs. In the U.S., Exelon, the largest nuclear operator in the country, has been accused of “blackmailing” the Illinois state over the “risk” of early retirements of several of its reactors that are no longer competitive under current market conditions. In spite of “custom-designed” tools, like the introduction of modified rules in capacity markets that favor nuclear power, an increasing number of nuclear power plants cannot compete and fail to clear auctions. In Germany, operator E.ON closed one of its reactors six months earlier than required by law. In Sweden, early shutdown of at least four units has been confirmed because of lower than expected income from electricity sales and higher investment needs. Even in developing markets like India, at least two units are candidates for early closure as they are losing money.

Chernobyl+30 Status Report

Thirty years after the explosion and subsequent fire at unit 4 of the Chernobyl nuclear power plant on 26 April 1986, then in the USSR, now in independent Ukraine, the consequences are still felt throughout the region.

Accident Sequence. A power excursion—output increased about 100-fold in 4 seconds—a hydrogen explosion and a subsequent graphite fire that lasted 10-days released about one third of the radioactive inventory of the core into the air.

Environmental Consequences. The chimney effect triggered by the fire led to the ejection of radioactive fission products several kilometers up into the atmosphere. An estimated 40 percent of Europe's land area was contaminated ($>4,000$ Bq/m²). Over six million people still live in contaminated areas in Belarus, Russia and Ukraine. A 2,800 km² exclusion zone with the highest contamination levels in a 30-km radius has been established in the immediate aftermath of the disaster and upheld ever since.

Human Consequences. About 130,000 people were evacuated immediately after the initial event, and in total about 400,000 people were eventually dislocated. Around 550,000 poorly trained workers called “liquidators”, engaged by the Soviet army in disaster management, received amongst the highest doses.

Health Consequences. A recent independent assessment expects a total of 40,000 fatal cancers over the coming 50 years caused by Chernobyl fallout. Over 6,000 thyroid cancer cases have been identified so far, another 16,000 are expected in the future. Similarly, 500 percent increases were observed in leukemia risk in both Belarus and Ukraine. Some new evidence indicates increased incidences of cardiovascular effects, stroke, mental health effects, birth

defects and various other radiogenic effects in the most affected countries. Strong evidence has been published on Chernobyl related effect on children, including impaired lung function and increased breathing difficulties, lowered blood counts, high levels of anemias and colds and raised levels of immunoglobulins.

Remediation Measures. In 1986, under extremely difficult conditions, the liquidators had built a cover over the destroyed reactor called the “sarcophagus” that quickly deteriorated. Under the Shelter Implementation Plan financed by 44 countries and the EU, a US\$ 2 billion New Safe Confinement (NSC) has been built. The NSC is a gigantic mobile cover that will be pushed over the old sarcophagus and serve as protection during the dismantling of the ruined nuclear plant.

Waste Management. The largest single risk potential at the Chernobyl site remains the spent fuel from all four units that is to be transferred to a recently completed dry storage site between end of 2017 and April 2019. Constructions of liquid and solid waste treatment facilities were completed in 2015.

Fukushima+5 Status Report

Over five years have passed since the Fukushima Daiichi nuclear power plant accident (Fukushima accident) began, triggered by the East Japan Great Earthquake on 11 March 2011 (also referred to as 3/11 throughout the report) and subsequent events. This assessment includes analyses of onsite and offsite challenges that have arisen since and remain significant today.

Onsite Challenges. In June 2015, the Japanese government revised the medium- and long-term roadmap for the decommissioning of the Fukushima Daiichi site. Key components include spent fuel removal, fuel debris evacuation and limitation of contaminated water generation.

- **Spent Fuel Removal.** Spent fuel is to be removed from unit 3 between Financial Years (FY) 2017 and 2019, from unit 2 between 2020 and 2021 and from unit 1 between 2020 and 2022.
- **Molten Fuel Removal.** Radiation levels remain very high inside the reactor buildings (about 4-10 Sievert per hour) and make human intervention impossible. No conclusive video footage is available and it remains unknown where the molten fuel is actually located. Commencement of work on fuel debris removal is planned for 2021. However, no methodology has been selected yet.
- **Contaminated Water Management.** Large quantities of water (about 300 cubic meters per day) are still continuously injected to cool the fuel debris. 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. The commissioning of a dedicated bypass system and the pumping of groundwater has reduced the influx of water from around 400 m³/day to about 150 to 200 m³/day. An equivalent amount of water is decontaminated to some degree—it contains still very high levels of tritium (over 500,000 Bq/l) and stored in large tanks. The storage capacity onsite is 800,000 m³. A frozen soil wall that was designed to further reduce the influx of water was commissioned at end of March 2016. Its effectiveness is under review.

Workers. Between 3,000 and 7,500 workers per day are involved in decommissioning work. Several fatal accidents have occurred at the site. In September 2015, the Ministry of Health recognized, for the first time, the leukemia developed by a worker who had carried out decommissioning tasks as an occupational disease.

Offsite Challenges. Amongst the main offsite issues are 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.

Evacuees. According to government figures, the number of evacuees from Fukushima Prefecture as of May 2016 was about 92,600 (vs. 164,000 at the peak in June 2013). About 3,400 people have died for reasons related to the evacuation, such as decreased physical condition or suicide (all classified as “earthquake-related deaths”). The government plans to lift restriction orders for up to 47,000 people by March 2017. However, according to a survey by

Fukushima Prefecture, 70 percent of the evacuated people do not wish to return to their homes (or what is left of them) even if the restrictions are lifted, while 10 percent wish to return and 20 percent remain undecided.

Health Issues. Conflicting information has been published concerning the evolution of thyroid cancer incidence. While a Fukushima Prefectural committee concluded that “it is unlikely that the thyroid cancers discovered until now were caused by the effects of radiation”, but it did not rule out a causal relationship. In contrast, an independent study from Okayama University concluded that the incidence of childhood thyroid cancer in Fukushima was up to 50 times higher than the Japanese average.

Decontamination. Decontamination activities inside and outside the evacuation area in locations, “where daily activities occur” throughout Fukushima Prefecture, have been carried out on 80 percent of the houses, 5 percent of the roads and 70 percent of the forests, according to government estimates. However, the efficiency of these measures remain highly questionable.

Cost of the Accidents. The Japanese Government has not provided a comprehensive total accident cost estimate. However, based on information provided by TEPCO, the current cost estimate stands at US\$133 billion, over half of which is for compensation, without taking into account such indirect effects as impacts on food exports and tourism.

Fukushima vs. Chernobyl

Every industrial accident has its own very specific characteristics and it is often difficult to compare their nature and effects. The large explosions and subsequent 10-day fire at inland Chernobyl led to a very different release pattern than the meltdowns of three reactor cores at coastal Fukushima. The dispersion of radioactivity from Chernobyl led to wide-spread contamination throughout Europe, whereas about four fifths of the radioactivity released from Fukushima Daiichi came down over the Pacific Ocean. Radioactivity in the soil mainly disappears with the physical half-lives of the radioactive isotopes (30 years for the dominant cesium-137). Radioactive particles are greatly diluted in the sea and many isotopes, including cesium-137, are water soluble. This does not mean that radioactivity released to the ocean does not have effects, particularly in fish species near the coast, but further away any effects are difficult to identify.

Some parameters can be compared, and some are model estimates based on calculations and assumptions: care needs to be taken in interpreting their conclusions. Under practically all criteria, the Chernobyl accident appears to be more severe than the Fukushima disaster: 7 times more cesium-137 and 12 times more iodine-131 released, 50 times larger land surface significantly contaminated, 7–10 times higher collective doses and 12 times more clean-up workers. More people were evacuated in the first year at Fukushima than at Chernobyl. However, the number has tripled over time to about 400,000 at Chernobyl because more and more people were displaced as more hotspots were identified.

Nuclear Power vs. Renewable Energy Deployment

The transformation of the power sector has accelerated over the past year. New technology and policy developments favor decentralized systems and renewable energies. The Paris Agreement on climate change gave a powerful additional boost to renewable energies. For the Paris Agreement 162 national pledges called Intended National Determined Contributions (INDCs) were submitted of which only 11 mention nuclear power in their plans and only six actually state that they were proposing to expand its use (Belarus, China, India, Japan, Turkey and UAE). This compares with 144

countries that mention the use of renewable energies and 111 that explicitly mention targets or plans for expanding their use.

Investment. Global investment in renewable energy reached an all-time record of US\$286 billion in 2015, exceeding the 2011 previous peak by 2.7 percent. China alone invested over US\$100 billion, almost twice as much as in 2013. Chile and Mexico enter the Top-Ten investors for the first time, both countries having doubled their expenditure over the previous year. A significant boost to renewables investment was also given in India (+44 percent), in the U.K. (+60 percent) and in the U.S. (+21.5 percent). Global investment decisions on new nuclear power plants remained an order of magnitude below investments in renewables.

Installed Capacity. In 2015, the 147 GW of renewables accounted for more than 60 percent of net additions to global power generating capacity. Wind and solar photovoltaics both saw record additions for the second consecutive year, making up about 77 percent of all renewable power capacity added, with 63 GW in wind power and 50 GW of solar, compared to an 11 GW increase for nuclear power. China continued the acceleration of its wind power deployment with 31 GW added—almost twice the amount added in 2013—and with a total of 146 GW wind capacity installed significantly exceeding its 2015 goal of 100 GW. China added 14 GW of solar and overtook Germany as the largest solar operator. China started up 7.6 GW of new nuclear capacity, over 68 percent of the global increase.

Since 2000, countries have added 417 GW of wind energy and 229 GW of solar energy to power grids around the world. Taking into account the fact that 37 GW are currently in LTO, operational nuclear capacity meanwhile fell by 8 GW.

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—now all generate more electricity from non-hydro renewables than from nuclear power.

In 2015, annual growth for global generation from solar was over 33 percent, for wind power over 17 percent, and for nuclear power 1.3 percent, exclusively due to China.

Compared to 1997, when the Kyoto Protocol on climate change was signed, in 2015 an additional 829 TWh of wind power was produced globally and 252 TWh of solar photovoltaics electricity, compared to nuclear's additional 178 TWh.

In China, as in the previous three years, in 2015, electricity production from wind alone (185 TWh), exceeded that from nuclear (161 TWh). The same phenomenon is seen in India, where wind power (41 TWh) outpaced nuclear (35 TWh) for the fourth year in a row. Of all U.S. electricity, 8 percent was generated by non-hydro renewables in 2015, up from 2.7 percent in 2007.

The figures for the European Union illustrate the rapid decline of the role of nuclear: during 1997–2014, wind produced an additional 303 TWh and solar 109 TWh, while nuclear power generation *declined* by 65 TWh.

In short, the 2015 data shows that renewable energy based power generation is enjoying continuous rapid growth, while nuclear power production, excluding China, is shrinking globally. Small unit size and lower capacity factors of renewable power plants continue to be more than compensated for by their short lead times, easy manufacturability and installation, and rapidly scalable mass production. Their high acceptance level and rapidly falling system costs will further accelerate their development.

Introduction

A major accident, like those of Chernobyl and Fukushima, cannot be excluded anywhere in the world, including in Europe

Pierre-Franck Chevet, President
French Nuclear Safety Authority
April 2016⁹

We must not allow political and economical considerations to have a negative impact on the safety of the Swiss nuclear power plants

Hans Wanner, Director
Swiss Nuclear Safety Inspectorate
March 2016¹⁰

The year 2016, marking the 30th anniversary of the Chernobyl catastrophe (see the Chernobyl+30 Status Report Chapter) and the 5th year since the Fukushima disaster started unfolding (see the Fukushima+5 Status Report Chapter), strangely might go down in history as the period when the notion of risk of nuclear power plants turned into the perception of nuclear power plants at risk. Indeed, an increasing number of reactors is threatened by premature closure due to the unfavorable economic environment. Increasing operating and backfitting costs of aging power plants, decreasing bulk market prices and aggressive competitors. The development started out in the U.S., when in May 2013 Kewaunee was shut down although its operator, Dominion, had upgraded the plant and in February 2011 had obtained an operating license renewal valid until 2033. Two reactors at San Onofre followed, when replacement steam generators turned out faulty. Then Vermont Yankee shut down at the end of 2014. Early shutdown decisions have also hit Pilgrim and Fitzpatrick, likely to close before the end of 2017 and 2019. Utility Exelon, largest nuclear operator in the U.S., has announced on 2 June 2016 that it was retiring its Clinton (1065 MW) and Quad Cities (2 x 940 MW) nuclear facilities in 2017 as they have been losing money for several years. Only days later, Pacific Gas & Electric Co. (PG&E) in California announced that they would close the two Diablo Canyon units by 2025, replacing the capacity by energy efficiency and renewables, making the sixth largest economy in the world (having overtaken France in 2016) nuclear-free. Still in the same month of June 2016, the Omaha Public Power District (OPPD) Board voted unanimously to shut down the Fort Calhoun reactor by the end of the year—in the words on one board member, “simply an economic decision”.¹¹ Nuclear Energy Institute President Marv Fertel stated in May 2016 that “if things don’t change, we have somewhere between 10 and 20 plants at risk”.¹²

⁹ *Le Monde*, “Trente ans après Tchernobyl, ‘un accident nucléaire majeur ne peut être exclu nulle part’”, (in French), Updated 26 April 2016, see http://www.lemonde.fr/energies/article/2016/04/22/un-accident-nucleaire-majeur-ne-peut-etre-exclu-nulle-part-dans-le-monde_4907303_1653054.html?xtmc=pierre_franck_chevet&xtcr=9, accessed 30 June 2016.

¹⁰ Hans Wanner, “Umgang mit älter werdenden Reaktoren”, Swiss Energy Foundation, as presented at the Nuclear Phaseout Congress, Zürich, 21 March 2016, see www.energiestiftung.ch/files/pdf/20160321_npc_hans_wanner.pdf, accessed 30 June 2016.

¹¹ Cole Epley, “‘Simply an Economic Decision’: OPPD to Close Fort Calhoun Nuclear Plant by End of 2016,” *Omaha.com*, 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 1 July 2016.

¹² *EE News*, “NEI’s Fertel says imminent state, federal policy changes could keep existing plants open”, 17 May 2016, see <http://www.eenews.net/tv/videos/2131/transcript>, accessed 10 July 2016.

“Nuclear plants at risk”; the expression has become a common phrase in the news world, not only in the U.S. In Germany, the Grafenrheinfeld reactor was taken off the grid in 2015, six months earlier than required by law, because refueling was not worthwhile anymore. In Sweden, after two years of work and spending of several hundred million euros, upgrading was halted on Oskarshamn-2 in 2015 and the reactor was permanently closed. Oskarshamn-1 will follow in 2017 and Ringhals-1 and -2 will close in 2020 and 2019 respectively. Ringhals operator Vattenfall stated: “Sweden’s nuclear power industry is going through what is probably the most serious financial crisis since the first commercial reactors were brought into operation in the 1970s.”¹³ Even in Asia, nuclear plants are coming under economic pressure. The two Indian units Tarapur-1 and -2 are likely to be closed in the short term because they are not competitive under current market prices. “We are pouring in money into the reactors rather than making income from them”, Sekhar Basu, secretary at the Department of Atomic Energy stated.¹⁴

In addition to the usual, global overview of status and trends in reactor building and operating, as well as the traditional comparison between deployment trend in the nuclear power and renewable energy sectors, the 2016 edition of the *World Nuclear Industry Status Report (WNISR)* provides an assessment of the trends of the economic health of some of the major players in the industry. Special chapters are devoted to the aftermath of the Chernobyl and Fukushima disasters.

General Overview Worldwide

The Role of Nuclear Power

As of the middle of 2016, 31 countries were operating nuclear reactors for energy purposes. Nuclear power plants generated 2,441 net terawatt-hours (TWh or billion kilowatt-hours) of electricity in 2015¹⁵, a 1.3 percent increase, but still less than in 2000 and 8.2 percent below the historic peak nuclear generation in 2006 (see Figure 1). Without China—which increased nuclear output by 37.4 TWh (just over 30 percent), more than the worldwide increase of 31 TWh—global nuclear power generation would have decreased in 2015.

Nuclear energy’s share of global commercial gross electricity generation remained stable over the past four years¹⁶, but declined from a peak of 17.6 percent in 1996 to 10.7 percent in 2015.¹⁷ Over

¹³ Vattenfall, “Wahlborg: ‘Things are tough at the moment’”, 21 December 2015, see <http://news.vattenfall.com/en/article/wahlborg-things-are-tough-nuclear-power-moment>, accessed 1 July 2016.

¹⁴ *Bloomberg*, “Oldest Indian Nuclear Reactors Near Mumbai May Be Shut Down”, 15 March 2016, see <http://www.bloomberg.com/news/articles/2016-03-15/india-mulls-shutting-oldest-nuclear-plants-amid-mounting-costs>, accessed 4 July 2016.

¹⁵ 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 www.iaea.org/programmes/a2/index.html. Production figures are net of the plant’s own consumption unless otherwise noted.

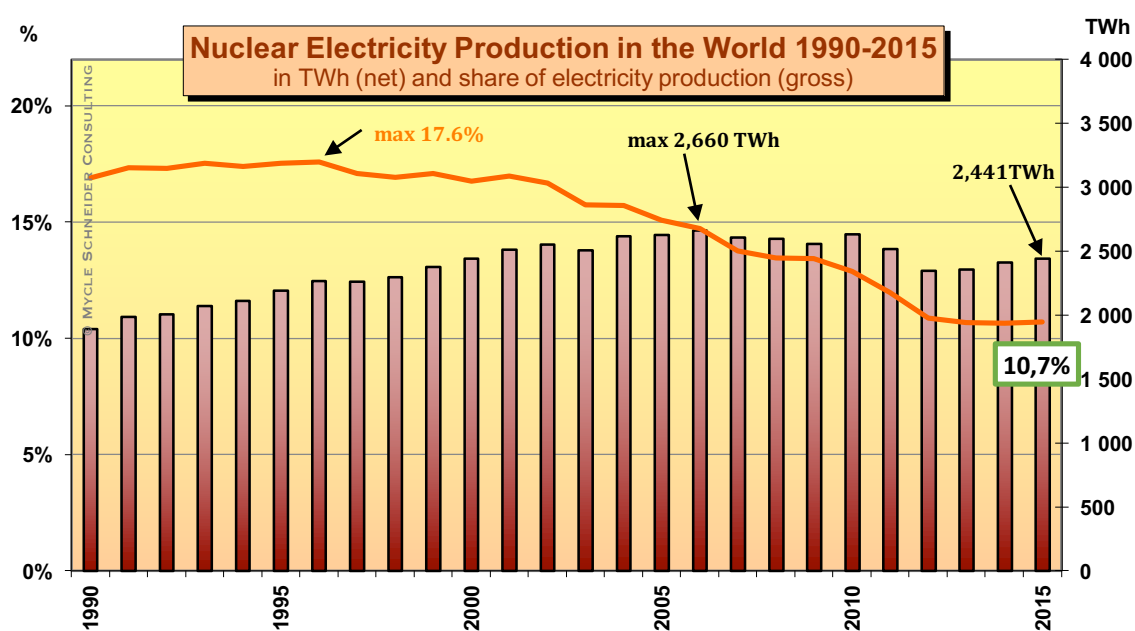
¹⁶ +0.05 percentage points in 2015 compared to 2014 and +0.01 percentage points compared to 2013. In 2015, as in previous years, BP applied minor corrections to the 2014 figure, from 10.78 to 10.64 percent. These differences are no doubt within statistical uncertainties.

¹⁷ BP, “Statistical Review of World Energy”, June 2016, 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.

the past two decades, nuclear power lost a small part of its share in every single year, except for the years 1999 and 2001, and probably in year 2015 (+0.05 percentage points), should the figure be confirmed in the coming years. The main reason for this is the stagnation in the world's power consumption (+0.9 percent, slightly below the modest increase in nuclear generation of 1.3 percent).

In 2015, nuclear generation increased in 11 countries (down from 19 in 2014), declined in 15 (up from 9), and remained stable in five.¹⁸ Five countries (China, Hungary, India, Russia, South Korea) achieved their greatest nuclear production in 2015, of these, China, Russia and South Korea connected new reactors to the grid. China started up a record eight units (see Figure 2). Only the two leading nuclear countries in the world, the U.S. and France have ever started up that many reactors in a single year, the U.S. in 1976, 1985 and 1987, and France in 1981. Besides China, two other countries increased their output by more than 20 percent in 2015—Argentina as it started up a third reactor in 2014, and Mexico that brought the second unit back on line after uprating. Two countries saw their nuclear generation drop by over 20 percent—Belgium that is struggling with reactor pressure vessel issues, and South Africa that has steam generator issues.

Figure 1: Nuclear Electricity Generation in the World



Sources: IAEA-PRIS, BP, MSC, 2016¹⁹

The “big five” nuclear generating countries—by rank, the United States, France, Russia, China and South Korea—generated over 70 percent of all nuclear electricity in the world and two countries alone, the U.S. and France accounted for half of global nuclear production.

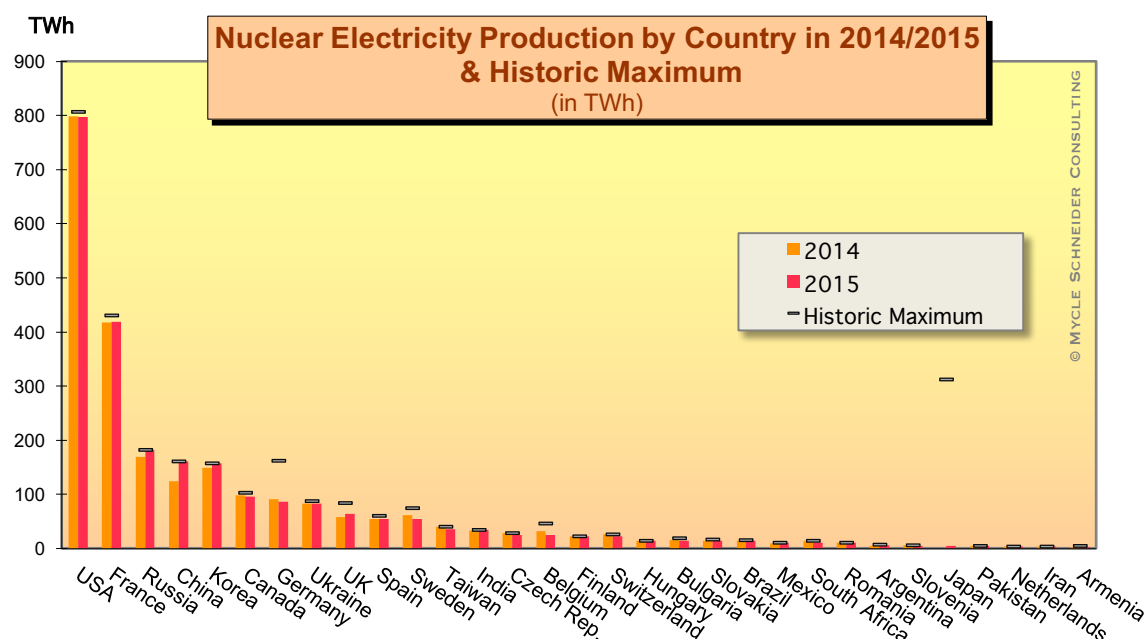
Seven countries’ nuclear power generation peaked in the 1990s, among them Belgium, Canada, Japan, and the U.K. A further eleven countries’ nuclear generation peaked between 2001 and 2010 including France, Germany, Spain, and Sweden. A remarkable 14 countries generated their maximum amount of nuclear power in the past five years, these obviously include nuclear growth

¹⁸ Less than 1 percent variation from the previous year.

¹⁹ BP stands for BP plc; MSC for Mycle Schneider Consulting.

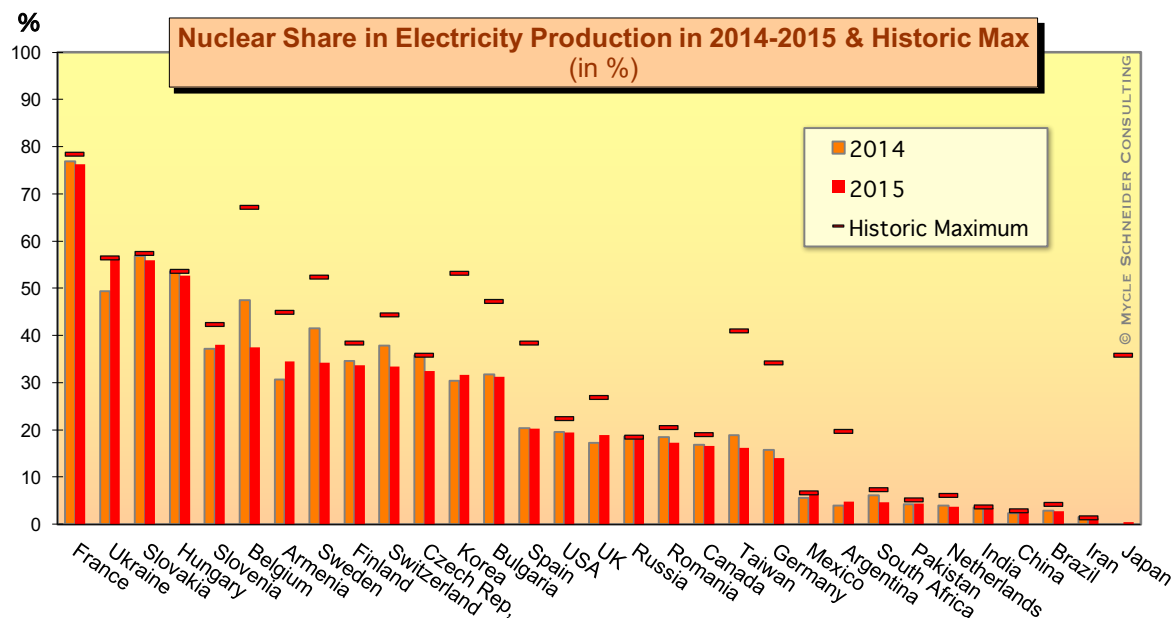
countries China, India, Russia and South Korea, but also the U.S. and smaller programs like the Czech Republic, Hungary and Taiwan.

Figure 2: Annual Nuclear Power Generation by Country and Historic Maximum



Sources: IAEA-PRIS, MSC, 2016

Figure 3: Annual Nuclear Share in Electricity Mix by Country and Historic Maximum



Sources: IAEA-PRIS, MSC, 2016

In many cases, even where nuclear power generation increased, the development is not keeping pace with overall increases in electricity production, leading to a nuclear share below the historic maximum (see Figure 3).

There were three exceptions in 2015 that peaked their respective nuclear share in power generation:

- China exceeded 2014 maximum of 2.4 percent, to reach 3.0 percent. The 0.6 percentage-point increase was achieved with a 30 percent higher nuclear power output in 2015.
- Mexico increased its nuclear share by 1.2 percentage points to reach 6.8 percent, after completing extensive uprating of its two nuclear reactors.
- Ukraine increased its 2004 record by 5.4 percentage points to 56.5 percent. However, overall national power generation fell by 13.6 percent. So the higher share was achieved with an even slightly lower (-0.9 percent) nuclear power output.

In addition, Russia repeated its historic maximum of the previous year of 18.6 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 (52/29), 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 2015, the startup of 29 reactors—of which 18, or close to two thirds, in China—did not make up for the shutdown of 34 units over the same period, largely as a result of the events in Fukushima. (See Figure 4).

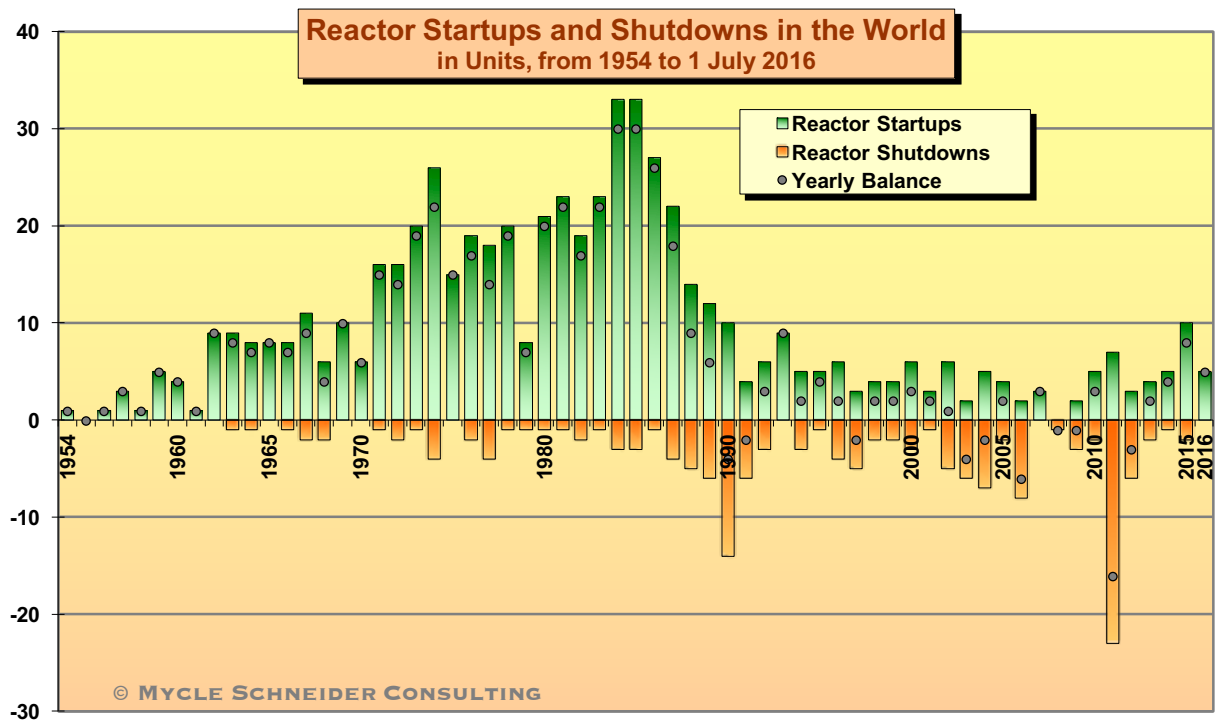
In 2015, ten reactors started up, more than in any year since 1990. However, this is again the result of the “China Effect”, as the country contributed eight out of the ten reactor startups (see Figure 5), while one each was commissioned in Russia (Beloyarsk-4 after 31 years of construction) and South Korea (Shin-Wolsong-2 after 6.5 years of construction). In 1990, five countries shared the startups: Canada (2), France (3), Japan (2), Russia (1) and U.S. (2).

Two reactors were closed in 2015, Grafenrheinfeld in Germany and Wylfa-1 in the United Kingdom. Doel-1 in Belgium was shut down in February 2015, after its license had expired, but in June 2015, the Belgian Parliament voted a 10-year lifetime extension and the reactor was restarted on 30 December 2015.²⁰

The IAEA in its online database Power Reactor Information System (PRIS), in addition to the closures in Germany and the U.K., accounts for five shutdowns in Japan. As WNISR considers shutdowns from the moment of grid disconnection—and not from the moment of the industrial, political or economic decision—and the units have not generated power for several years, in WNISR statistics, they are closed in the year of the latest power generation. Two units have not produced any electricity since 2010, the other three were taken off the grid following the 3/11 disaster.

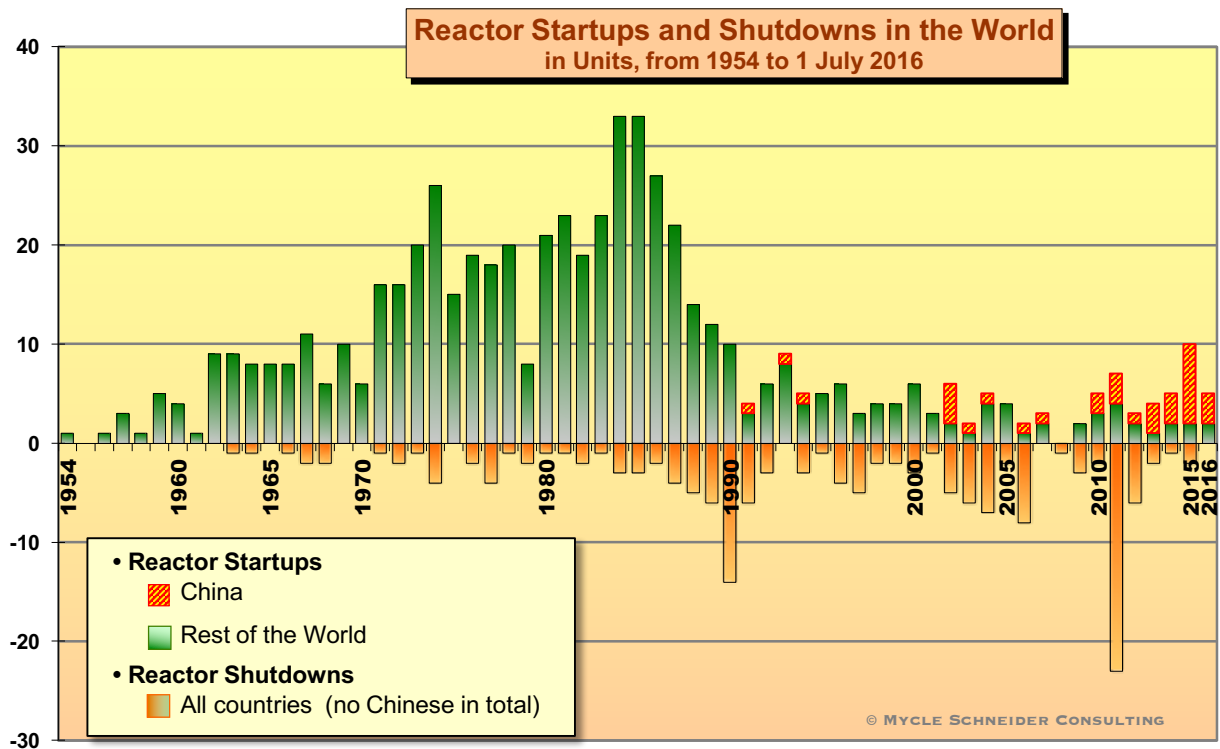
²⁰ On 18 June 2015, the Belgian Parliament voted legislation to extend the lifetime of Doel-1 and -2 by ten years. As the Doel-2 license had not yet expired, its operation was not interrupted. See also section on Belgium in Annex 1.

Figure 4: Nuclear Power Reactor Grid Connections and Shutdowns, 1954-2016



Sources: IAEA-PRIS, MSC, 2016

Figure 5: Nuclear Power Reactor Grid Connections and Shutdowns, 1954-2016
The China Effect



Sources: IAEA-PRIS, MSC, 2016

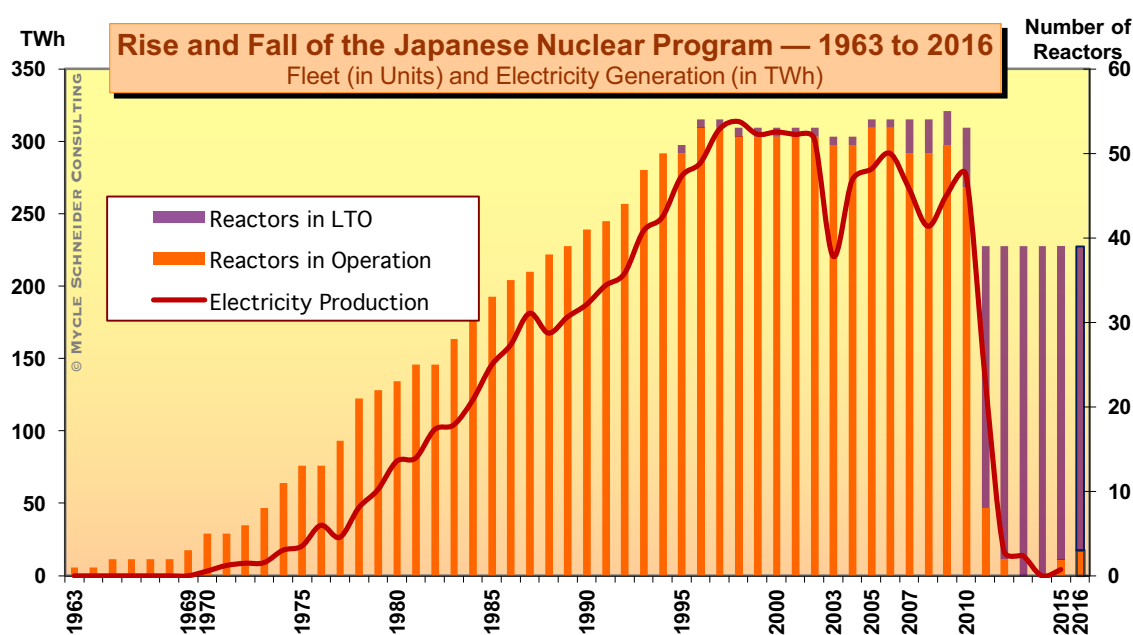
In the first half of 2016, three reactors started up in China and one each in South Korea and the U.S., while none were shut down. The final closure of one additional reactor has been announced in Japan. That unit, Ikata-1, had not generated any power since 2011.

All 46 reactors, except for two—Atucha-2 in Argentina and Watts Bar 2 in the U.S., respectively 33 and 43 years after construction start—that were commissioned over the past decade (2006/June 2016) are in Asia (China, India, Iran, Japan, Pakistan, South Korea), or Eastern Europe (Romania, Russia).²¹ With 25 units, China started up by far the largest fleet, over half of the world's total, followed by India (6) and South Korea (5).

The IAEA continues to count 43 units in Japan in its total number of 446 reactors “in operation” in the world²²; yet no nuclear electricity has been generated in Japan between September 2013 and August 2015, and as of the end of June 2016, only two reactors, Sendai-1 and -2, are operating. A third unit, Takahama-3, was restarted in October 2015, while Takahama-4 failed grid connection late February 2016 due to technical problems. In March 2016, both Takahama units were ordered by court to shut down for safety reasons (see Figure 6 and Japan Focus section for details).

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 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.

Figure 6: Rise and Fall of the Japanese Nuclear Program 1963–2016



Sources: IAEA-PRIS, MSC, 2016

²¹ The last units to start up in the Western world were Argentina’s Atucha-2 in 2014 after 33 years of construction, Brazil’s Angra-2 in 2000 after 24 years, and Civaux-2 in France in 1999 after 8.5 years.
²² IAEA, “Power Reactor Information System”, see <http://www.iaea.org/pris/>, accessed 26 June 2016.

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”. As illustrated in WNISR2013, one could argue that all but two Japanese reactors fit the category that year.²⁴

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 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”.²⁵

Applying this definition to the world nuclear reactor fleet leads to considering 36 Japanese units in LTO, as 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 classifies as LTS the fast breeder reactor Monju,²⁶ because it was shut down after a sodium fire in 1995 and has never generated power since. It also meets WNISR’s LTO criterion.

Besides the Japanese reactors, the Swedish reactor Ringhals-2 and the Taiwanese unit Chinshan-1 fall into the LTO category. The total number of nuclear reactors in LTO as of 1 July 2016 is therefore 38; yet all but one (Monju) are considered by the IAEA as “in operation”.

As of 1 July 2016, a total of 402 nuclear reactors are operating in 31 countries, up 11 units (+2.8 percent) from the situation in July 2015. This is a considerable increase compared to previous years due to construction starts launched prior to the 3/11 disaster and reactor restarts in Japan. Since 2012, when the world’s reactor fleet had dropped to its lowest level in the past 30 years, this is a cumulated net increase of 19 units.

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

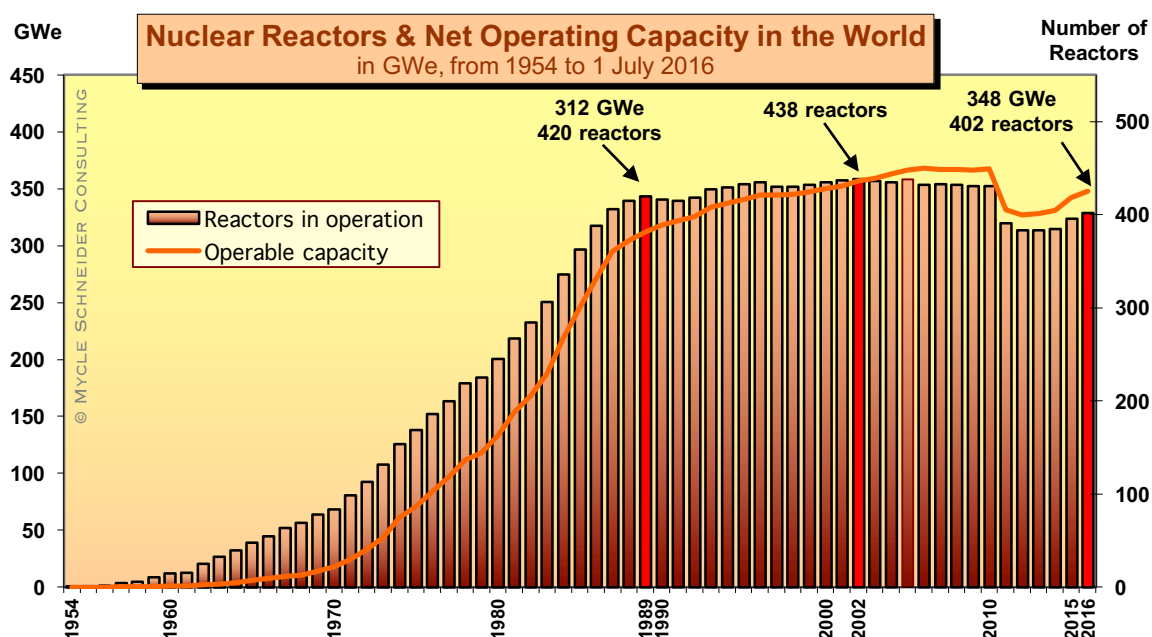
²⁴ For two days in January 2013, the IAEA moved 47 units to the LTS category on the IAEA-PRIS website, before that action was abruptly reversed and ascribed to clerical error. See detailed accounts on the WNISR website, www.WorldNuclearReport.org.

²⁵ Tatsujiro Suzuki, “Foreword”, WNISR2014, 18 August 2014, see http://www.worldnuclearreport.org/WNISR2014.html#_Toc268768687, accessed 1 July 2016.

²⁶ The IAEA also considers the Spanish reactor Garoña in LTS, while WNISR considers it shut down permanently.

The current world fleet has a total nominal electric net capacity of 348 gigawatts (GW or thousand megawatts), up from 337 GW (+3.3 percent) one year earlier (see Figure 7).

Figure 7: World Nuclear Reactor Fleet, 1954–2016



Sources: IAEA-PRIS, MSC, 2016

For many years, the net installed capacity has continued to increase more than the net increase of numbers of operating reactors. This was a result of the combined effects of larger units replacing smaller ones and, mainly, technical alterations at existing plants, a process known as uprating.²⁷ In the United States, the Nuclear Regulatory Commission (NRC) has approved 156 uprates since 1977. The cumulative approved uprates in the United States total 7.3 GW.²⁸ Only for one site, the three units at Browns Ferry, uprate approval request (for 14.3 percent) has been issued in 2015. Completion is expected in 2017.²⁹

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.

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 as of July 2016 (see Figure 2). Close to half of the world's nuclear countries are located in the European

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

²⁸ Nuclear Regulatory Commission (NRC), "Approved Applications for Power Uprates", Updated 26 August 2014, see www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications.html, accessed 10 June 2015.

²⁹ NRC, "Pending Applications for Power Uprates", Updated 24 May 2016, see <http://www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/pending-applications.html>, accessed 1 June 2016.

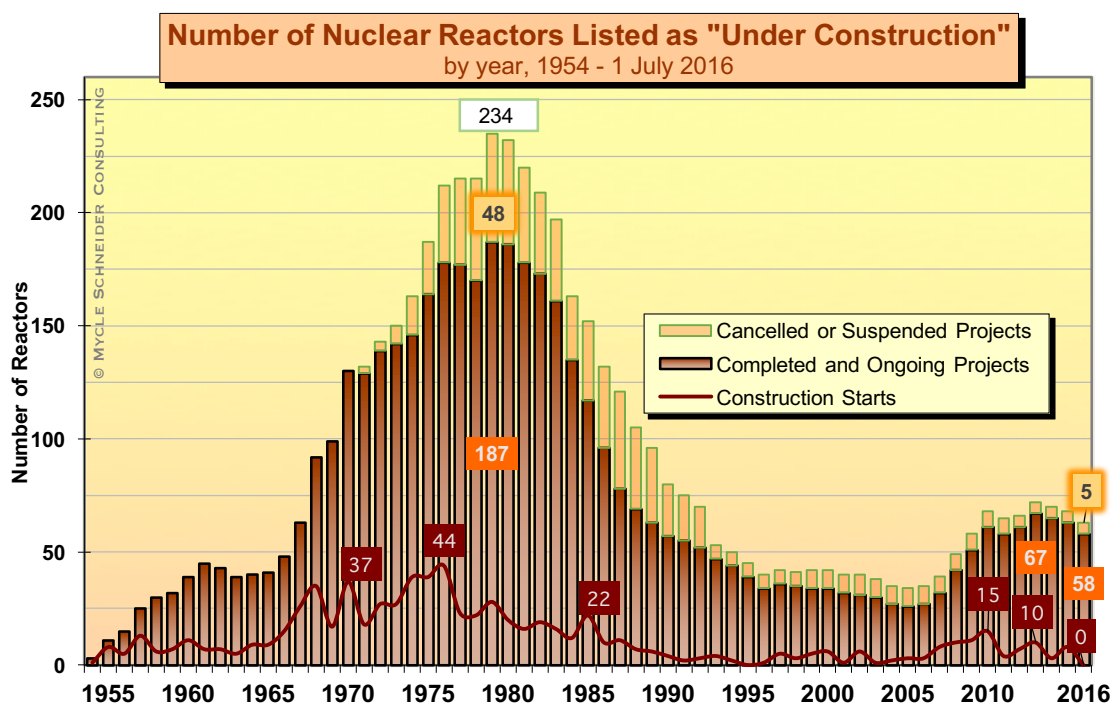
Union (EU), and in 2015 they accounted for exactly one third (down 1.2 percentage points) of the world's gross nuclear production,³⁰ with half that EU generation in France.

Overview of Current New Build

As of the middle of July 2016, 58 reactors are considered here as under construction, four fewer than WNISR reported a year ago, and nine less than in mid-2014. Almost 80 percent of all new-build units (46) are in Asia and Eastern Europe, of which 21 in China alone.

Eight building sites were launched in 2015, six in China, as well as one each in Pakistan, and United Arab Emirates (UAE).

Figure 8: Nuclear Reactors Under Construction



Sources: IAEA-PRIS, MSC 2016

WNISR2016 applies two changes over previous editions. First, two reactors—Ohma and Shimane-3—are reintegrated as “under construction” in Japan, as reportedly there is “some” construction activity ongoing, even though there is no planned official startup date (for a detailed discussion see Annex 1, Japan Focus, New-build). Second, the two projects in Ukraine—Khmelnitsky-3 and -4—are taken off the list, as apparently no construction has been ongoing for many years and the prospects for completion have been further delayed with the cancellation of the Russian construction contract (see Annex 1, Ukraine).

The number of active building sites has been shrinking from 67 in 2013 to 58 in mid-2016. And it is relatively small compared to a peak of 234 units—totaling more than 200 GW—in 1979.

³⁰ BP, “Statistical Review of World Energy”, June 2015. BP corrected the 2013 value from 35.7 percent to 35.2 percent.

However, many of those projects (48) were never finished (see Figure 8). 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 slightly, by 0.6 GW to 56.6 GW, with an average unit size of 976 MW (see Annex 9 for details).

Table 1: Nuclear Reactors “Under Construction” (as of 1 July 2016)³¹

Country	Units	MW (nets)	Construction Starts	Grid Connections	Delayed Units
China	21	21 500	2009 - 2015	2016 - 2021	11
Russia	7	5 473	1983 - 2010	2016 - 2019	7
India	6	3 907	2002 - 2011	2016 - 2019	6
USA	4	4 468	2013	2019 - 2020	4
UAE	4	5 380	2012 - 2015	2017 - 2020	
Pakistan	3	1 644	2011 - 2015	2016 - 2021	
Korea	3	4 020	2009 - 2013	2017 - 2019	3
Slovakia	2	880	1985	2017 - 2018	2
Japan	2	2 650	2007 - 2010	?	2
Belarus	2	2 218	2013 - 2014	2018 - 2020	
France	1	1 600	2007	2018	1
Argentina	1	25	2014	2018	
Finland	1	1 600	2005	2018	1
Brazil	1	1 245	2010	2019	1
Total	58	56 610	1983 - 2015	2016 - 2021	38

Sources: IAEA-PRIS, MSC, 2016

³¹ For further details see Annex 9.

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 2016, the 58 reactors currently being built have been under construction for an average of 6.2 years. With four reactors that had construction of over 30 years taken off the list—two started up, two have no active construction—and six new construction starts over the year, the average construction time has come down significantly from 7.7 years as of mid-2015.
- All reactors under construction in 9 out of 14 countries have experienced mostly year-long delays. At least about two thirds (38) of all building sites are delayed. Most of the 20 remaining units under construction in the world, of which eleven 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. Uncertainty remains over two Pakistani reactors.
- Three reactors have been listed as “under construction” for more than 30 years, Mochovce-3 and -4 in Slovakia, and Rostov-4 in Russia. The U.S. unit Watts Bar-2, 43 years after construction start, was finally connected to the grid on 3 June 2016, but automatically shut down twice in the first three weeks. Considering increasing uncertainty over the restart of construction works at the Russian projects Khmel'nitski-3 and -4 in Ukraine, WNISR has pulled the units off the list, three decades after construction start.
- Three reactors have been listed as “under construction” for more than a decade, two units in India, Kudankulam-2 and the Prototype Fast Breeder Reactor (PFBR), have been listed as “under construction” for 14 and 12 years respectively, and the Olkiluoto-3 reactor project in Finland reached its tenth anniversary in August 2015.

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, and site preparation.

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 9 illustrates, construction times of reactors completed in the 1970s and 1980s were quite homogenous, while in the past two decades they have varied widely.

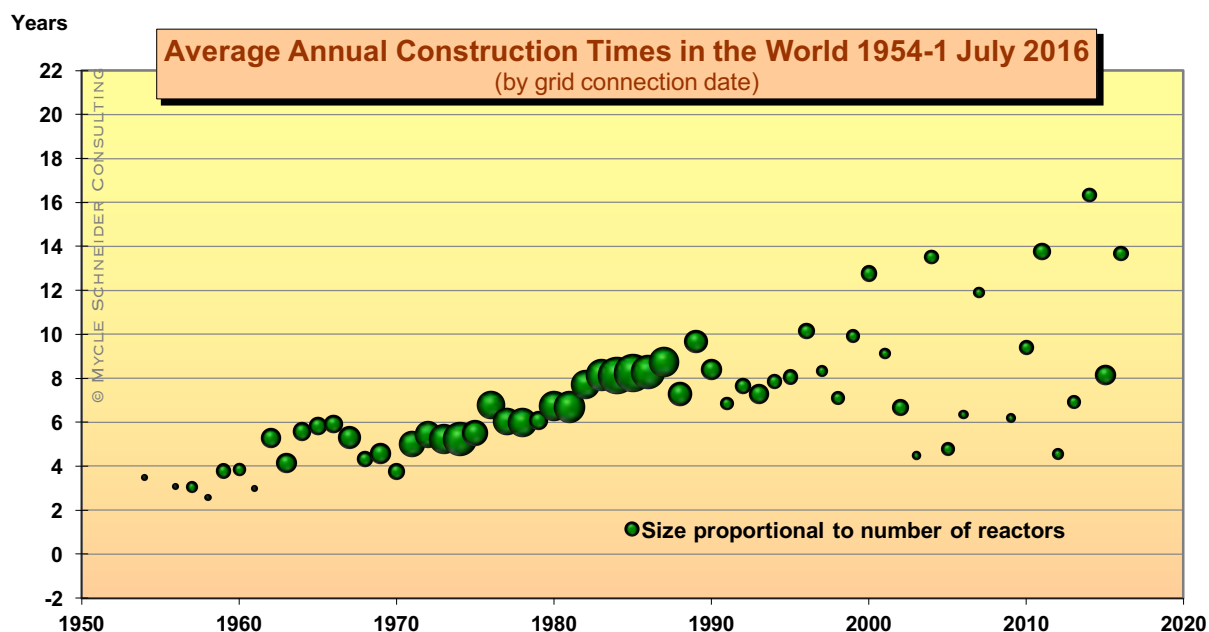
Average construction time of the 10 units that started up in 2015—eight Chinese, one Korean and one Russian that took almost 31 years to complete—was 8.2 years, while it took an average of 6.2 years to connect four units—three Chinese and one South Korean—to the grid in the first half of 2016, 13.7 years when including the veteran Watts-Bar-2.

Table 2: Reactor Construction Times 2006–2016

Construction Times (in years) – Startups Between 2006 and July 2016				
Country	Units	Mean Time	Min	Max
China	25	5.7	4.3	11.2
India	6	7.7	5.0	11.6
South Korea	5	5.3	4.0	7.2
Russia	4	28.8	25.3	32.0
Argentina	1	33.0	33.0	33.0
Iran	1	36.3	36.3	36.3
Japan	1	5.1	5.1	5.1
Pakistan	1	5.2	5.2	5.2
Romania	1	24.1	24.1	24.1
USA	1	43.5	43.5	43.5
Total	46	10.4	4	43.5

Sources: IAEA-PRIS, MSC, 2016

Figure 9: Average Annual Construction Times in the World 1954–1 July 2016

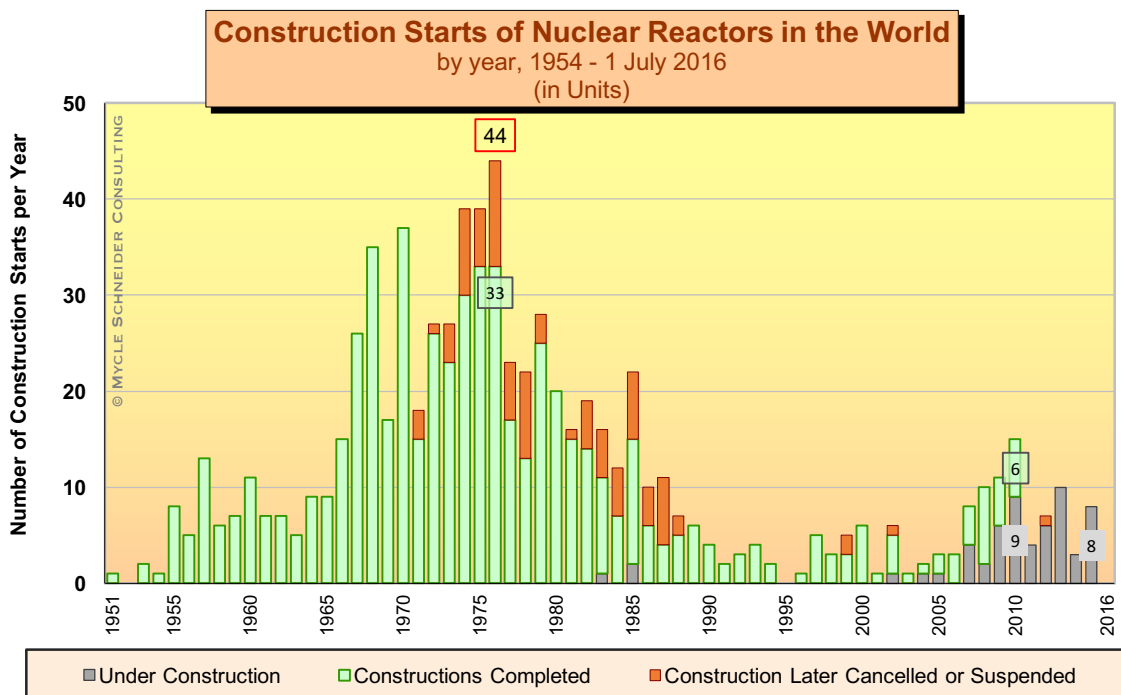


Sources: MSC based on IAEA-PRIS, 2016

Construction Starts and Cancellations

The number of annual construction starts³² in the world peaked in 1976 at 44, of which 11 projects were later abandoned. In 2010, there were 15 construction starts—including 10 in China alone—the highest level since 1985 (see Figure 10 and Figure 11). However, in 2014, the level had dropped to three units and China did not launch a single new project. Between 2012 and 1 July 2016, first concrete was poured for 28 new plants worldwide—less than in a single year in the 1970s. Over the decade 2006–2015, construction began for 79 reactors (of which one has been cancelled), that is more than twice as many as in the decade 1996–2005, when works started at 33 units (of which three have been abandoned). However, more than half (43) 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 10: Construction Starts in the World 1951 – 1 July 2016



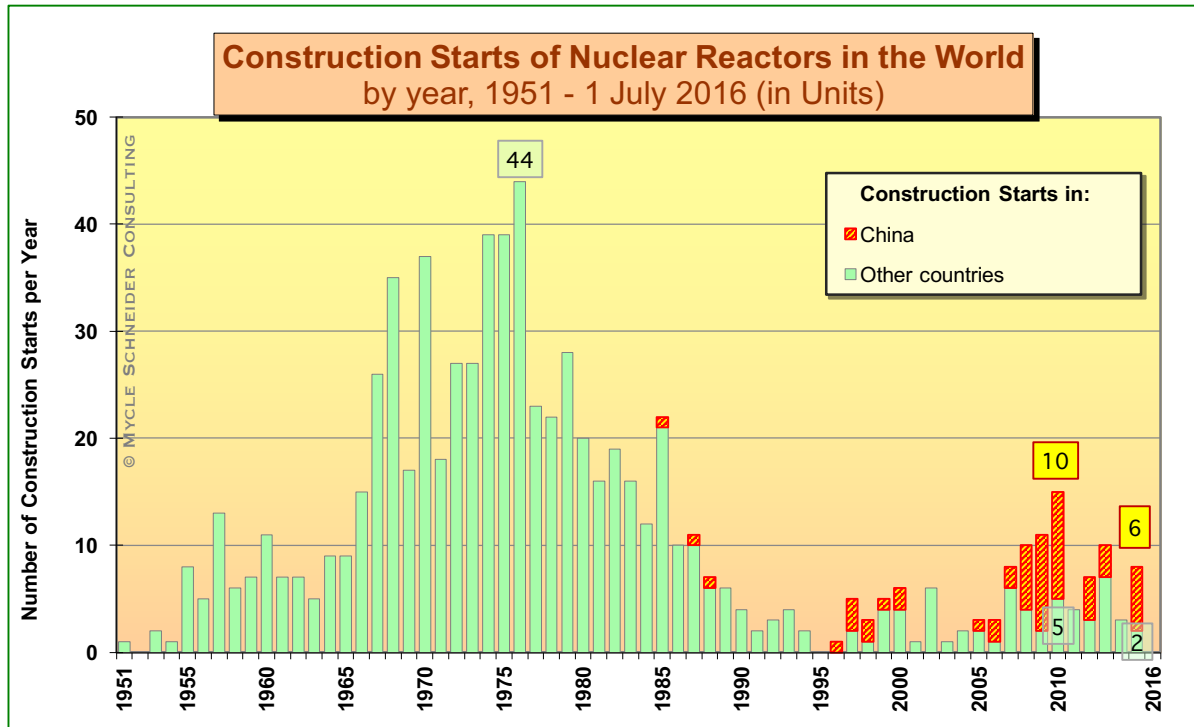
Sources: IAEA-PRIS, MSC, 2016

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. 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 12). The United States alone accounted for 138 of these order cancellations.³³

³² Generally, a reactor is considered under construction, when the base slab of the reactor building is being concreted. Site preparation work and excavation are not included.

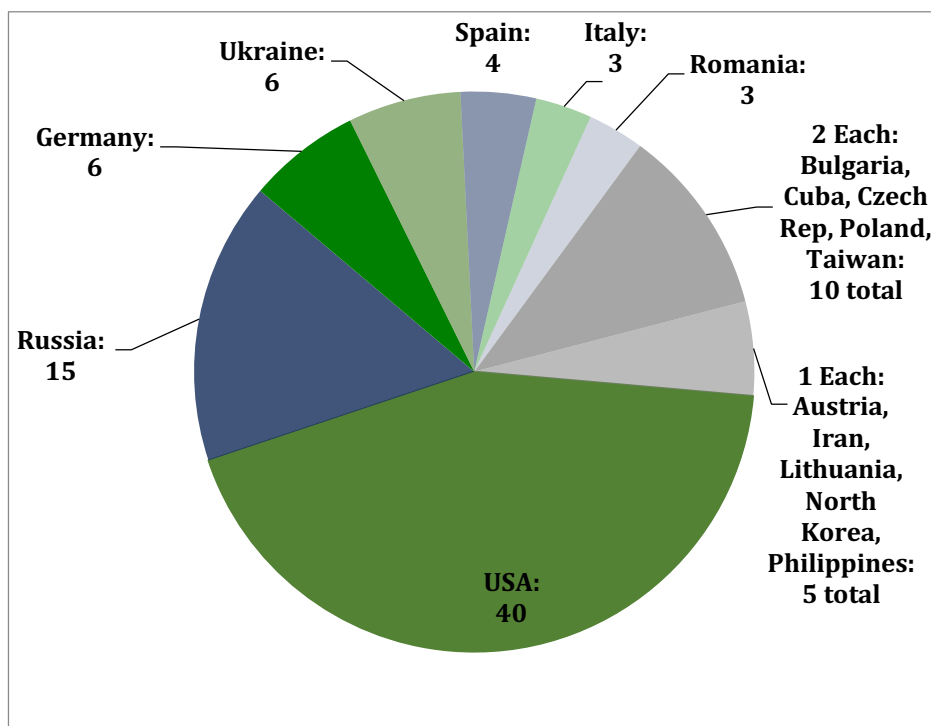
³³ French Atomic Energy Commission (CEA), “Elecnucl - Nuclear Power Plants in the World”, 2002. The section “cancelled orders” has disappeared after the 2002 edition.

Figure 11: Construction Starts in the World/China 1951–1 July 2016



Sources: IAEA-PRIS, MSC, 2016

Figure 12: 92 Cancelled or Suspended Reactor Constructions 1977–July 2016



Sources: IAEA-PRIS, MSC, 2016

Of the 754 reactor constructions launched since 1951, at least 92 units (12.2 percent) in 17 countries have been abandoned, 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.

Over three-quarters (71) 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 20-year period between 1993 and 2012.

Close to three quarters (67 units) of all cancelled projects were in four countries alone—the U.S. (40), Russia (15), 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.

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-2016 stands at 29 years, up from 28.8 a year ago (see Figure 13 and Figure 14).³⁴ 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 NRC.

As of June 2016, 81 of the 100 operating U.S. units have received an extension, with another 12 applications under NRC review. Since WNISR2015, seven license renewals (Davis-Besse, Sequoyah 1-2, Braidwood 1-2, Byron 1-2) have been granted and an additional one applied for (Waterford 3).³⁵

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 31.4 years on average, and the oldest have started the process with the French Nuclear Safety Authority (ASN) evaluating each reactor before allowing a unit to operate for more than 30 years. Only few got have passed the procedure yet and 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) has clearly stated that, for economic reasons, it plans to prioritize lifetime extension beyond 40 years over

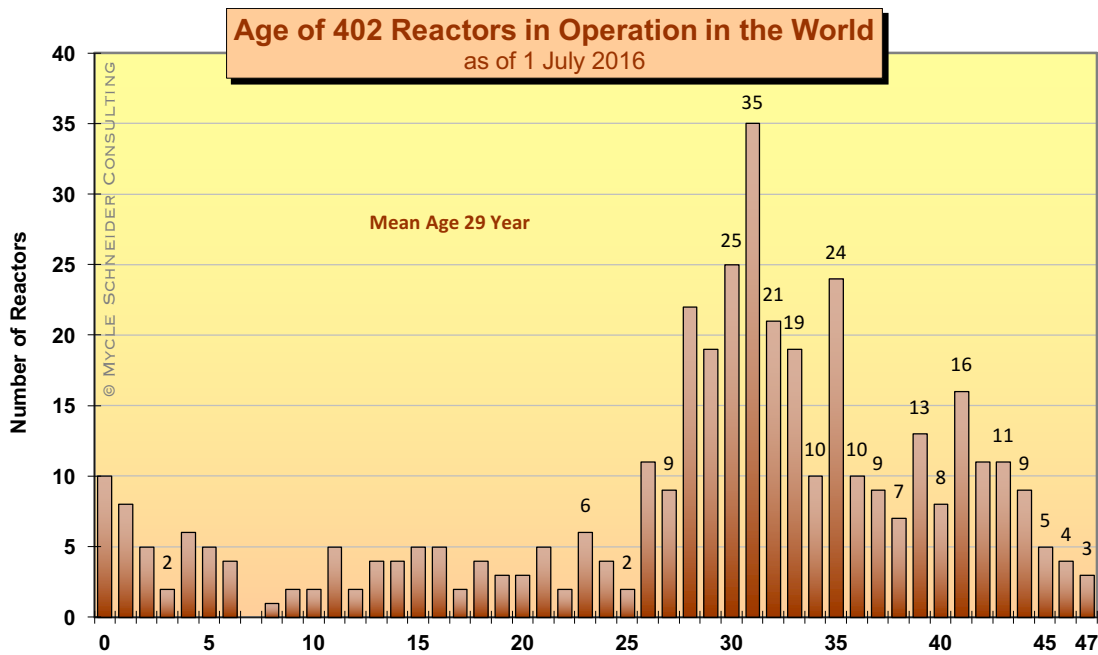
³⁴ WNISR calculates reactor age from grid connection to final disconnection from the grid. In WNISR statistics, “startup” is synonymous with grid connection and “shutdown” with withdrawal from the grid. In previous editions of the WNISR, the reactor age was automatically rounded to the year. In order 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.

³⁵ NRC, “Status of License Renewal Applications and Industry Activities”, Updated 14 April 2016, see <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>, accessed 1 July 2016.

large-scale new-build. Having assessed EDF’s lifetime extension projects, ASN Chairman Pierre-Franck Chevet stated during the presentation of the Annual Report 2015:

The continued operation of the nuclear power plants beyond 40 years cannot be taken for granted. The operating conditions for the nuclear power plants beyond 40 years is still a subject of some considerable debate.³⁶

Figure 13: Age Distribution of Operating Nuclear Power Reactors



Sources: IAEA-PRIS, MSC, 2016

However, only one of the 33 units that have been shut down in the U.S. had reached 40 years on the grid—Vermont Yankee, the latest one to be closed, in December 2014, at the age of 42. In other words, at least a quarter of the reactors connected to the grid in the U.S. never reached their initial design lifetime. On the other hand, of the 100 currently operating plants, 37 units have operated for more than 40 years. In other words, 46 percent of the units with license renewals have already entered the life extension period, and that share is growing rapidly with the mid-2016 average age of the U.S. operational fleet standing at 36.2 years (see United States Focus).

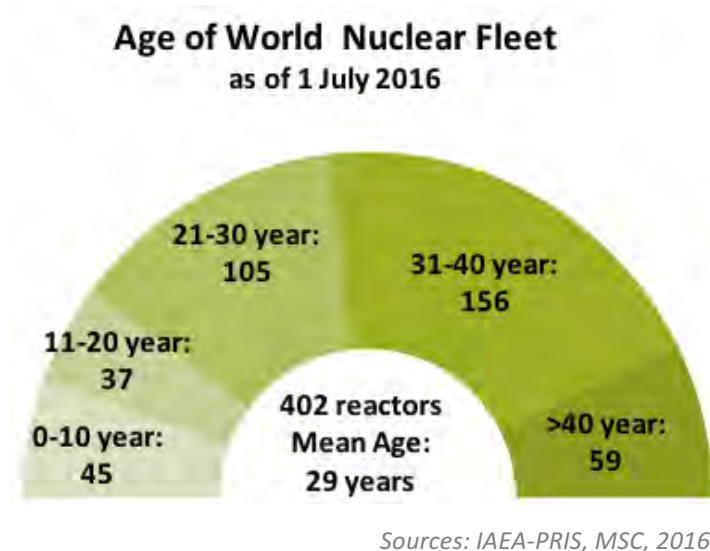
If ASN gave the go-ahead for all of the oldest units to operate for 40 years, 22 of the 58 French operating reactors would reach that age already by 2020.

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 13 and Figure 15). As of mid-2016, 59 of the world’s reactors have operated

³⁶ ASN, “The nuclear safety and radiation protection situation is of major concern. ASN is remaining vigilant”, Press Release, 22 January 2016, see <http://www.french-nuclear-safety.fr/Information/News-releases/The-nuclear-safety-and-radiation-protection-situation-is-of-major-concern>, accessed 1 July 2016.

for 41 years and more.³⁷ As the age pyramid illustrates, that number could rapidly increase over the next few years. A total of 215 units have already exceeded age 30.

Figure 14: Age Distribution of Operating Reactors in the World



The age structure of the 164 units already shut down completes the picture. In total, 56 of these units operated for 30 years and more, and of those, 22 reactors operated for 40 years and more (see Figure 15). Many units of the first generation designs only operated for a few years. Considering that the average age of the 164 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 seems rather optimistic. The operating time prior to shutdown has clearly increased continuously, as Figure 16 shows. But while the average annual age at shutdown got close to 40 years, it only passed that age once: in 2014, when the only such unit shut down that year (Vermont Yankee in the U.S.) after 42 years of operation.

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.

³⁷ 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 15: Age Distribution of 164 Shut Down Nuclear Power Reactors

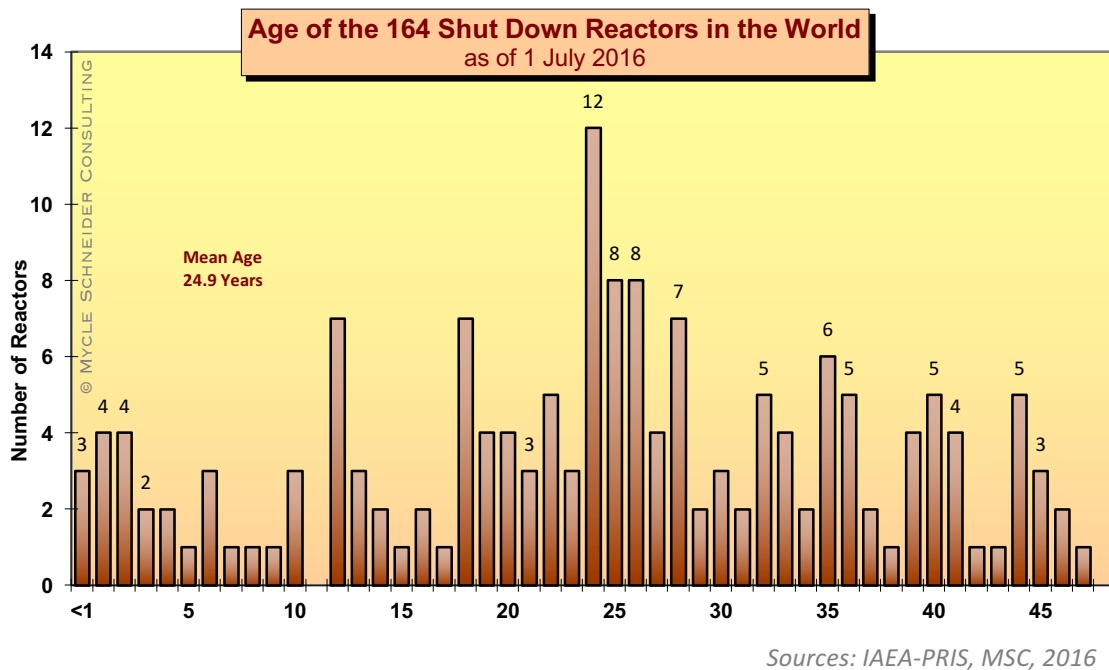
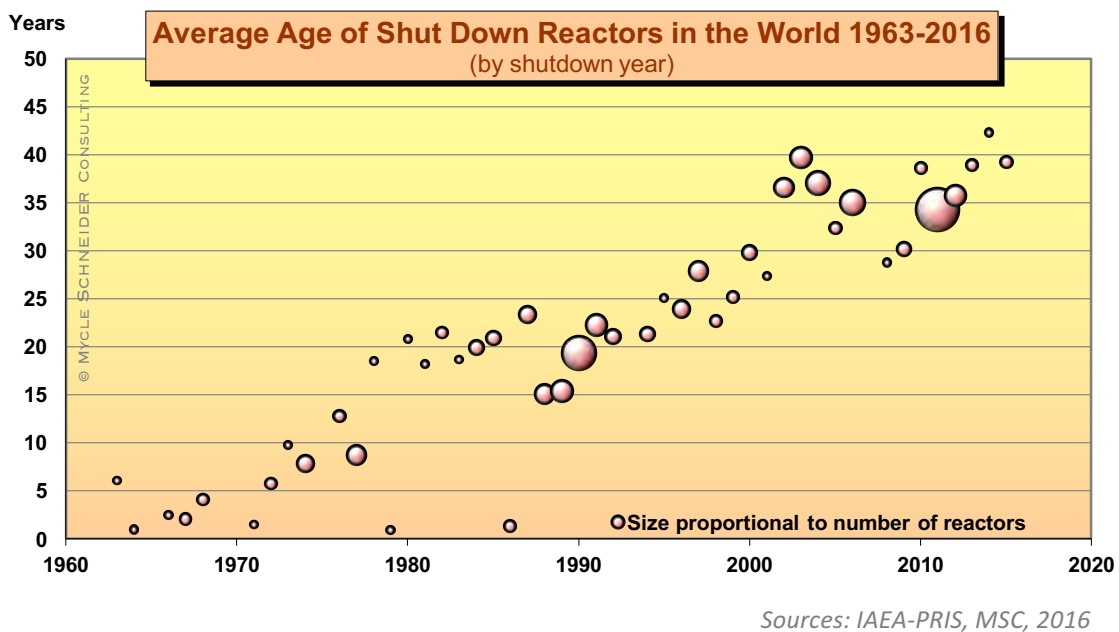


Figure 16: Average Age Profile of Shut Down Nuclear Power Reactors



Lifetime Projections

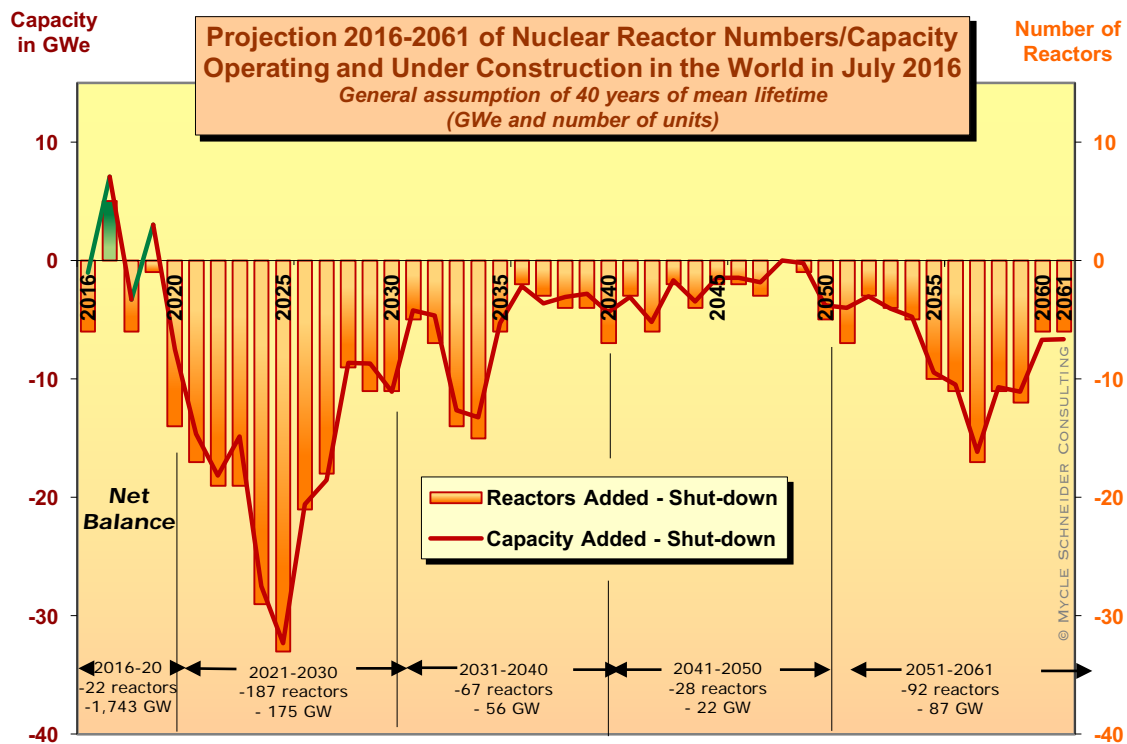
Many countries continue to implement or prepare for lifetime extensions. As in previous years, WNISR has therefore created two lifetime projections. A first scenario (40-Year Lifetime Projection, see Figure 17), assumes a general lifetime of 40 years for worldwide operating reactors (not including reactors in LTO, as they are not considered operating). For the 59 reactors

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

A second scenario (Plant Life Extension or PLEX Projection, see Figure 18) 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. Even with all units under construction assumed to have gone online by 2021, an installation rate of about 10.5 per year—installed nuclear capacity would drop by 1.7 GW by 2020, which is marginal. However, in total, 22 additional reactors (compared to the end of 2015 status) would have to be ordered, built and started up prior to the end of 2020 in order to maintain the status quo of the number of operating units. This corresponds to about four additional grid connections per year and would raise the annual startups to about 15. This installation rate would be three times as high as the actual 46 grid connections over the decade 2006–July 2016. In fact, considering even the lowest average construction times, 17 of these 22 units (5 have come on-line in the first half of 2016) would have to be launched over the coming year and be completed without delay.

Figure 17: The 40-Year Lifetime Projection (not including LTOs)



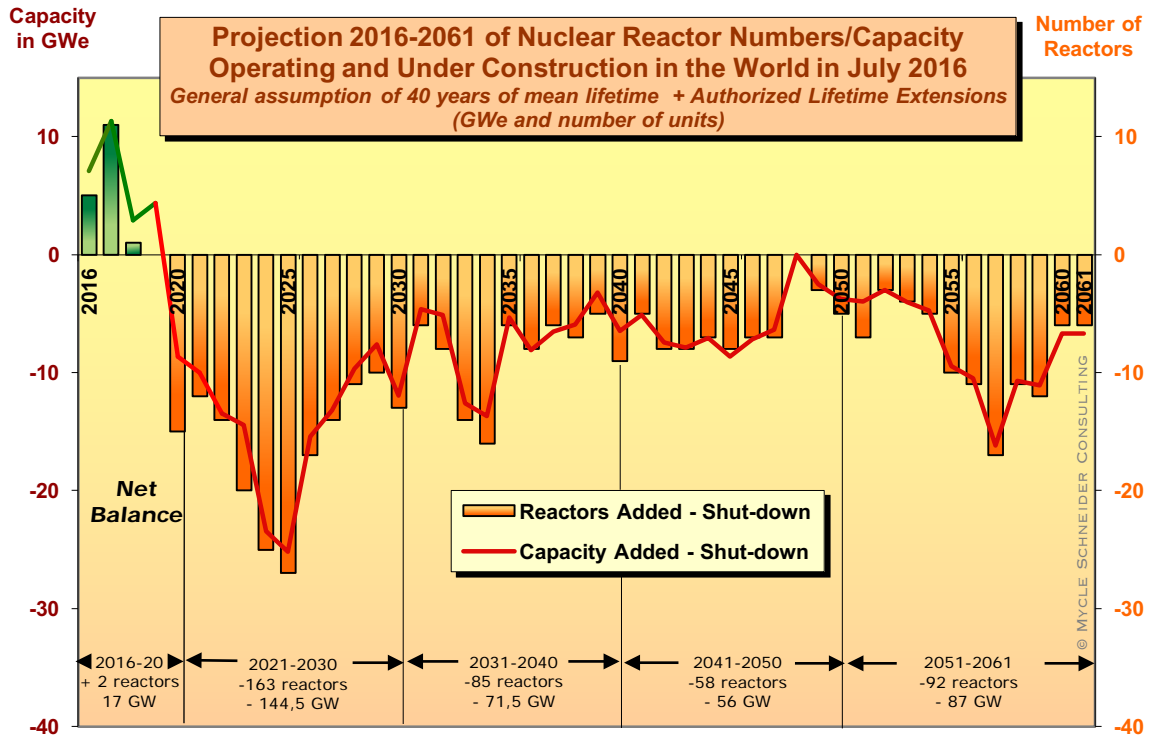
Sources: IAEA-PRIS, WNA, various sources compiled by MSC 2016

In the following decade to 2030, 187 new reactors (175 GW) would have to be connected to the grid to maintain the status quo, four times the rate achieved over the past decade.

The achievement of the 2020 targets will mainly depend on the number of Japanese reactors currently in LTO possibly coming back on line and the development pattern of the Chinese construction program. Any major achievements outside these two countries in the given

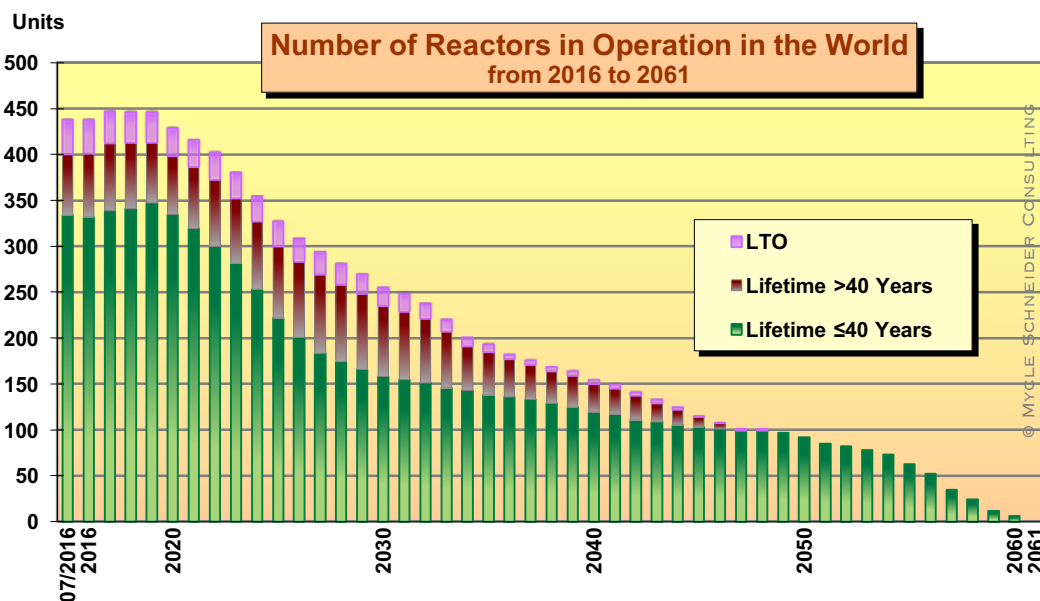
timeframe are highly unlikely given the existing difficult financial situation of the world's main reactor builders and utilities, the general economic environment, the decline of power consumption in many countries, widespread skepticism in the financial community, and generally hostile public opinion—aside from any other specific post-Fukushima effects.

Figure 18: The PLEX Projection (not including LTOs)



Sources: IAEA-PRIS, WNA, various sources compiled by MSC 2016

Figure 19: Forty-Year Lifetime Projection versus PLEX Projection



Sources: IAEA-PRIS, US-NRC, MSC 2016

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 beyond 40 years become widespread. Such generalized lifetime extensions are, however, even less likely after Fukushima.

Also, soaring maintenance and upgrading costs, as well as decreasing system costs of nuclear power's main competitors, create an economic environment with sharply decreasing bulk electricity prices that leads to the situation of an increasing number of nuclear plants "at risk" of early closures, notably in the U.S., Sweden and Germany, as discussed below.

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 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 reduced Chinese ambitions.

In addition, the average construction time for the 25 units started up in China over the past decade was 5.7 years. At present, 21 units with about 21.5 GW are under construction and scheduled to be connected by 2020, which would bring the total to 51 GW, far short of the current 58 GW target (see China Focus). The continuing controversy about whether new reactors should be allowed not only at coastal but also inland sites, is restricting the number of suitable sites immediately available.

As usual, 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 two (down from an increase of eight in the WNISR2014 projection) and the installed capacity would grow by 17 GW (down from an increase of 25 GW in the WNISR2014 projection). This decline 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.

In the following decade to 2030, still 163 new reactors (144.5 GW) 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 17, Figure 18 and the cumulated effect in Figure 19).

Potential Newcomer Countries

At time of the signing of the Kyoto Protocol, in 1997, the installed capacity of nuclear power in the world was 344 GW, and by the time of the signing of the Paris agreement, at the end of 2015, this had risen to 378 GW (including 35.5 in LTO). This equates to a 10 percent increase in capacity with an associated increase in electricity production of 178TWh per year, an approximately 8 percent increase in output. However, due to rising global demand over the same time period nuclear contribution to global commercial electricity generation has fallen from 17.5 percent to below 11 percent. Therefore, despite the promotion of nuclear power as a technology to address climate change over the past two decades its contribution is diminishing.

If nuclear is to make a difference on the global level, it will need to revise this trend and significantly increase its production both within its current markets and expand into new countries.

The IAEA says that, “seven countries have moved forward in actively developing nuclear programs and two countries (Belarus and the United Arab Emirates (UAE)) have already started constructing their first NPP [Nuclear Power Plant].”³⁸ The source of this statement is not original IAEA research, but the World Nuclear Association (WNA), whose aim is to promote and represent the nuclear industry. WNA places the seven countries cited by the IAEA in two categories³⁹:

- Contracts signed, legal and regulatory infrastructure well-developed or developing: Bangladesh, Lithuania, Turkey and Vietnam;
- Committed plans, legal and regulatory infrastructure developing: Jordan, Poland and Egypt.

WNA, also claims that there are an additional 11 countries in which nuclear power is planned, which includes, those with “well-developed plans”, Chile, Indonesia, Kazakhstan, Thailand and Saudi Arabia and those “developing plans” including, Israel, Kenya, Laos, Malaysia, Morocco, and Nigeria. They further list another 20 countries in which nuclear is a “serious policy option”.⁴⁰ The following section reviews the development of nuclear power in those countries in which WNA believes that there are at least “well-developed plans” for new nuclear. Table 3 provides an overview per category and country.

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 two 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.⁴¹ The project assumes the supply of all fuel and repatriation of spent fuel for the life of the plant. The fuel is to be reprocessed 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 2018.⁴² However, these dates were revised, and when construction started, it was stated that the reactors will not be completed until 2018 and 2020.⁴³ In May 2016, the startup months were reported as November 2018 and

³⁸ IAEA, “Climate Change and Nuclear Power 2015”, Vienna, September 2015, see www-pub.iaea.org/MTCD/Publications/PDF/CCANP2015Web-78834554.pdf, accessed 1 July 2016.

³⁹ WNA, “Emerging Nuclear Energy Countries”, Updated February 2016, see <http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx>, accessed 1 April 2016.

⁴⁰ Namibia, Mongolia, Philippines, Singapore, Albania, Serbia, Croatia, Estonia & Latvia, Libya, Algeria, Kuwait, Azerbaijan, Sri Lanka, Tunisia, Syria, Qatar, Sudan, Venezuela, Bolivia, Peru.

⁴¹ *NIW*, “Belarus, Aided by Russia and Broke, Europe’s Last Dictatorship Proceeds With NPP”, 28 September 2012.

⁴² 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.

⁴³ *WNN*, “Ostrovets plant meets construction safety rules”, *World Nuclear News*, 7 November 2014, see <http://www.world-nuclear-news.org/NN-Ostrovets-plant-meets-construction-safety-rules-07111401.html>, accessed 1 July 2016.

July 2020 respectively.⁴⁴ As of April 2016, the two units were said by deputy energy minister Mikhail Mikhadyuk to be 38 percent complete.⁴⁵

In March 2015, Atomstroyexport admitted the plant would cost over 1,400 billion roubles compared to the forecast from 2014 of 840 billion Rubles. However, the falling price of the rouble against the dollar will significantly affect the dollar price of the project.

The project is the focus of international opposition and criticism, with formal complaints from the Lithuanian government.⁴⁶ 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.⁴⁷ The extent of international opposition to the project was reported in *Nuclear Intelligence Weekly*, where it said that during the IAEA's general conference, "a slick presentation from the major government players in the Belarussian nuclear program did little to impress international experts and diplomats."⁴⁸ The trade journal also reported domestic criticism of the project on the grounds of the signing of contracts with a Russian company of poor reputation and that no detailed economic justification of the plant had been presented.

While Belarus is currently 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.⁴⁹ 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 Government is seeking to ban electricity imports from the Belarus nuclear power plant due to its safety concerns over the reactor.

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, commissioning and fuel loads

⁴⁴ 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 1 July 2016.

⁴⁵ NEI, "Progress continues at Belarus NPP", 20 April 2016, see <http://www.neimagazine.com/news/newsprogress-continues-at-belarus-npp-4870105/>, accessed 1 July 2016.

⁴⁶ 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 1 July 2016.

⁴⁷ United Nations Economic Commission for Europe (UNECE), "Parties to UNECE treaties adopt declaration on applying environmental assessment procedures to nuclear energy issues", Press Release, 13 June 2014.

⁴⁸ NIW, "Belarus—A chilled Reception in Vienna", 27 September 2014.

⁴⁹ 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 1 July 2016.

for four units equaled approximately US\$20 billion, with a high percentage of the contract being offered under a fixed-price arrangement”.⁵⁰

The original 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 commercial banks.⁵¹ However, it is unclear what other financing sources have been used for the project, and it is reported that the cost of the project has risen significantly, with the total cost of the plant including infrastructure and finance now expected to be about US\$32 billion,⁵² with others putting the cost of the contracts at US\$40 billion, including fuel management and operation,⁵³ although little independent information is available.

In July 2010, a site-preparation license and a limited construction license were granted for four reactors at Barakah, 53 kilometers from Ruwais.⁵⁴ A tentative schedule published in late December 2010, and not publicly altered since, suggests that Barakah-1 will 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, on Barakah-3 on 24 September 2014 and unit 4 on 30 July 2015.⁵⁵ In May 2016, ENEC stated that Barakah-1 is about 87 percent complete, unit 2 is at 68 percent, unit 3 at 47 percent and unit 4 at 29 percent.⁵⁶

All official sources indicate that the unit 1 will be completed and start operating next year. If this occurs, it will be a remarkable achievement for a country to complete their first new commercial scale nuclear reactor on time although the extent of conformity with the existing budget is unknown. No independent assessment of quality-control conditions—a key driver of construction delays in most countries—is available.

⁵⁰ ENEC, “UAE Selects Korea Electric Power Corp, as Prime Team as Prime Contractor for Peaceful Nuclear Power”, 27 December 2009, see <http://www.enec.gov.ae/media-centre/news/content/uae-selects-korea-electric-power-corp.-as-prime-team-as-prime-contractor-fo>, accessed 1 July 2016.

⁵¹ 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_%20Barakah%20presentation.pdf, accessed 29 March 2016.

⁵² WNA, “Nuclear Power in the United Arab Emirates”, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Arab-Emirates/>, accessed 29 March 2016.

⁵³ *Business Korea*, “Nuclear Power Korea Builds Nuclear Reactor in United Arab Emirates”, 20 May 2014, see <http://www.businesskorea.co.kr/article/4728/nuclear-power-korea-builds-nuclear-reactor-united-arab-emirates#sthash.FVVVoXWp.xqt8U0nj.dpuf>, accessed 1 July 2016.

⁵⁴ *ArabianBusiness.com*, “ENEC Welcomes Regulator’s License Approval”, 11 July 2010, see <http://www.arabianbusiness.com/enec-welcomes-regulator-s-licence-approvals-306150.html>, accessed 1 July 2016.

⁵⁵ 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 1 July 2016.

⁵⁶ *NIW*, “United Arab Emirates”, 20 May 2016.

Contracts Signed or in Advanced Development

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 2018 at a cost of US\$2 billion.⁵⁷ 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).⁵⁸ 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 the last year.⁵⁹ The deal was only for US\$500 million⁶⁰ to cover the site preparatory work.⁶¹ In October 2013, a ceremony was held for the formal start of the preparatory stage,⁶² 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.⁶³ 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.⁶⁴ In 2015, the Bangladeshi Finance Minister was quoted as saying the project was now expected to cost US\$13.5 billion.⁶⁵ 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.⁶⁶

⁵⁷ *Bloomberg*, “Bangladesh to Sign Deal With Russia to Build Nuclear Power Plant”, 2 November 2011, see <http://www.bloomberg.com/news/articles/2011-11-02/bangladesh-to-sign-deal-with-russia-to-build-nuclear-power-plant>, accessed 1 July 2016.

⁵⁸ Energy Bangla, “Bangladesh, Russia sign nuclear power pact”, 17 January 2013.

⁵⁹ 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 1 July 2016.

⁶⁰ 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.

⁶¹ *The Star*, “Russia to lend \$1.5B to Bangladesh to build nuclear power station, buy arms”, 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 1 July 2016.

⁶² *BBC*, “Bangladesh nuclear power plant work begins”, *British Broadcasting Corporation*, 2 October 2013, see <http://www.bbc.co.uk/news/world-asia-24371991>, accessed 1 July 2016.

⁶³ Bangladesh Awami League, “PM Sheikh Hasina inaugurates Rooppur Power Plant”, Undated, see <http://www.albd.org/index.php/en/updates/news/281-pm-sheikh-hasina-inaugurates-rooppur-power-plant>, accessed 1 July 2016.

⁶⁴ *News From 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 1 July 2016.

⁶⁵ *NIW*, “Bangladesh: Newbuild Financing Talks with Russia in Tricky Territory”, 6 November 2015.

⁶⁶ Rahman A., “Ruppur Nuclear Power Plant: Bangladesh's Potential Blackhole”, *British Nuclear Institute*, *The Daily Star*, Updated 31 December 2015, see <http://www.thedailystar.net/op-ed/politics/ruppur-nuclear-power-plant-bangladeshs-potential-blackhole-194017>, accessed 1 July 2016.

Over the past year, the design selected for construction has also changed. Earlier, the plan was to construct two VVER-1000 units but in 2015, the Bangladesh government reportedly became interested in the VVER-1200 design during “a high-level meeting in Vietnam”.⁶⁷ 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 2023.⁶⁸ 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. However, four months later, the project was delayed again, this time with a scheduled construction start on 1 August 2017. By April 2016, site preparation was reportedly 80 percent complete.⁶⁹ However, in late June 2016, a “siting licence ceremony” was held in Dhaka allowing for “preliminary site works”.⁷⁰ The obvious contradiction between the two pieces of information could not be cleared up.

In late May 2016, negotiations were concluded over the US\$12.65 billion project, with Russia making available US\$11.385 billion, with a final agreement expected to be signed “within two months”.⁷¹ By the end of June 2016, Bangladesh's cabinet had approved a draft of the agreement and a signature was expected in “July or August”.⁷²

The deal has been criticized by many in the media. One concern has been that the project will result in a major debt burden. In October 2015, Bangladesh's Finance Minister Abul Muhith, was quoted as saying that the “country's debt burden is now US\$18 billion, which will go up to US\$30 billion after five years at the current pace of external borrowing. The amount would reach US\$42 billion if the Russian loan is added to it”.⁷³

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. The most recent proposal was confirmed in 2012 when the Government, along with its partners in Estonia and Latvia, chose Hitachi together with its Hitachi-GE Nuclear Energy Ltd. unit as a

⁶⁷ *Energy Bangla*, “Rooppur Will Be A Modern, Safe and Money Saving Nuclear Plant”, Interview with Maksim V. Elchishchev, NIAEP Vice President, 15 October 2015, see <http://energybangla.com/rooppur-will-be-a-modern-safe-and-money-saving-nuclear-power-plant/>, accessed 1 July 2016.

⁶⁸ *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.

⁶⁹ *NW*, “Bangladesh will begin construction of first nuclear unit in August 2017: official”, *Nucleonics Week*, 14 April 2016.

⁷⁰ *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 1 July 2016.

⁷¹ *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 1 July 2016.

⁷² *WNN*, “Bangladesh moves forward with Rooppur”, op.cit.

⁷³ *Click Ittefaq*, “\$13.5 billion estimated for Rooppur Nuclear Power Plant”, Updated 28 October 2015, see <http://www.clickittefaq.com/13-5-billion-estimated-for-rooppur-nuclear-power-plant/>, accessed 1 July 2016.

strategic investor and technology supplier to construct a nuclear plant by the end of 2020.⁷⁴ In May 2012, the percentage breakdown of the initially US\$6.5 billion project was announced with a 20 percent ownership for Hitachi, and 38 percent for Lithuania, while Estonia would take 22 percent and Latvia 20 percent.⁷⁵

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.⁷⁶ 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 expressed their wish in the referendum, and I will follow the people’s will”.⁷⁷ In January 2013, the Minister set up a Working Group on the energy development in the country, which concluded in April 2013 that the development of the nuclear new-build project could be continued under the condition of the involvement of regional partners, the availability of a strategic investor and “the use of the most modern and practically tested nuclear technology”.⁷⁸

In March 2014, in response to the political situation in Ukraine and growing concerns over energy security, the seven parties represented in the Lithuanian Parliament signed an agreement on strategic priorities through 2020. This included the construction of a liquefied natural gas (LNG) plant, the synchronization of the grid with other EU countries, and that the nuclear project to be implemented “in accordance with the terms and conditions of financing and participation improved in cooperation with partners”.⁷⁹ In July 2014 the Lithuania Energy Ministry and Hitachi signed an agreement to set up a joint venture for the construction of the Visaginas nuclear power plant.

Little progress was made in signing agreements with other international partners and in December 2015, Lithuanian press announced that the staff in the preparation company VAE SPB was reduced from 13 to 4 people.⁸⁰ In early 2016, the Energy Minister of Lithuania, Rokas Masiulis, said that the project had been shelved indefinitely, due to unfavorable market conditions.⁸¹

⁷⁴ *Bloomberg*, “Lithuania Seeking Lower Electricity Prices at New Nuclear Plant”, 15 February 2012, see <http://www.bloomberg.com/news/2012-02-15/lithuania-seeking-lower-electricity-prices-at-new-nuclear-plant.html>, accessed 1 July 2016.

⁷⁵ *NIW*, “Lithuania”, 11 May 2012.

⁷⁶ *Reuters*, “Lithuanians send nuclear plant back to drawing board”, 15 October 2012, see <http://www.reuters.com/article/us-lithuania-nuclear-idUSBRE89E0BW20121015>, accessed 1 July 2016.

⁷⁷ *NIW*, “Lithuania—Prospective PM Wants to Scrape Visaginas”, 9 November 2012.

⁷⁸ Ministry of Energy of Lithuania, “Working Group’s Conclusions for Preparation of Proposals Regarding Cost-Effective and Consumers-Favorable Self-Provision with Power and Other Energy Resources”, 25 April 2013, unofficial translation, distributed by the Ministry, see

http://www.enmin.lt/lt/naujienos/Conclusions_of_the_Working_Group2.pdf, accessed 29 March 2016.

⁷⁹ Ministry of Energy of Lithuania, “Lithuanian Parliamentary Parties Reached an Agreement Regarding the Key Strategic Energy Projects”, 31 March 2014, see <https://enmin.lrv.lt/en/news/lithuanian-parliamentary-parties-reached-an-agreement-regarding-the-key-strategic-energy-projects>, accessed 1 July 2016.

⁸⁰ *Verslo Žinios*, “VAE projekto bendrovė mažina apskukas”, (in Lithuanian), 29 December 2015, see <http://vz.lt/2015/12/29/vae-projekto-bendrove-mazina-apsukas>, accessed 23 May 2016.

⁸¹ *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 1 July 2016.

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”.⁸²

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, but now delayed until at least 2016, and to cost US\$20–25 billion for 4.8 GW. 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, where the average industrial price was 24.4 kurus/kWh (\$US 0.08/kWh) in 2015.⁸³

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-2020.⁸⁴ However, further delays have occurred as there were problems with Akkuyu JSC's Environmental Impact Assessment, which 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 2021.⁸⁵ In January 2015, both the Chamber of Turkish Engineers and Architects (TMMOB)⁸⁶ and Greenpeace started legal proceedings against the approval, claiming that the Agency had insufficient qualified staff to make the decision and that there were no clear waste management plans or nuclear liability arrangements.⁸⁷ As a result of these domestic developments and financing problems, it was reported in November 2015 that the operation would now occur only in 2022⁸⁸ and at an estimated budget for the two units of

⁸² İzak Atiyas, “A Review of Turkey’s Nuclear Policies and Practices”, Sabancı University, 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 1 July 2016.

⁸³ Turkish Statistical Institute, “Electricity and Natural Gas Prices, II. Period: July-December, 2015”, Press Release, 30 March 2016, see <http://www.turkstat.gov.tr/PreHaberBultenleri.do?id=21585>, accessed 1 July 2016.

⁸⁴ Orhan Coskun, 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 1 July 2016.

⁸⁵ *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 1 July 2016.

⁸⁶ *Hurriyet Daily News*, “Chamber to sue state over abrupt green light to Turkey’s first nuclear plant”, 2 January 2015, see <http://www.hurriyetaidailynews.com/chamber-to-sue-state-over-abrupt-green-light-to-turkeys-first-nuclear-plant.aspx?pageID=238&nID=76419&NewsCatID=340>, accessed 1 July 2016.

⁸⁷ *NIW*, “Briefs—Turkey”, 9 January 2015.

⁸⁸ *Sputnik International*, “First reactor of Turkey’s Akkuyu nuclear plant to start operating by 2022”, 19 November 2015, see <http://sptnkne.ws/afe3>, accessed 24 June 2016.

US\$22 billion.⁸⁹ Site preparation work started in April 2015 ⁹⁰ and it was estimated that US\$3 billion had been spent as of autumn 2015.⁹¹ In January 2016, Akkuyu Nuclear submitted to the Atomic Energy Authority its final site parameter report, which must be approved before a construction license can be granted.⁹² There are suggestions that Rosatom may sell a 49 percent of its stake to one of Turkey's leading construction conglomerates, Cengiz Insaat, and that this is part of a political maneuver to keep the deal alive given the souring of relations between Russia and Turkey.⁹³ This claim was widely published in the Turkish media but denied by Rosatom.⁹⁴ It was also reported in October 2015 that Turkish President Recep Tayyip Erdogan warned Russia risked losing the Akkuyu deal as a result of Russian intervention in Syria.⁹⁵ In June 2016, Russia's permanent representative to the IAEA said that work on Akkuyu "is likely to resume following the rapprochement between the two countries", which evidently indicates that work is suspended as of the time of the statement.⁹⁶

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.⁹⁷ In April 2015, Turkish President Erdogan approved parliament's ratification of the intergovernmental agreement with Japan.⁹⁸

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

⁸⁹ *Vatan*, "Russian pressed for money, Akkuyu delayed 2 years", 24 March 2015, see <http://www.gazetevatan.com/ruslar-paraya-sikisti-akkuyu-2-yil-gecikecek-752934-ekonomi/>, accessed 29 March 2016.

⁹⁰ *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 1 July 2016.

⁹¹ *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 1 July 2016.

⁹² *NIW*, "Briefs—Turkey", 15 January 2016.

⁹³ *NIW*, "Newbuild, Moscow Eyes Turkish Partners for Akkuyu", 29 April 2016.

⁹⁴ *ITAR/TASS*, "Russia's Rosatom denies plans for sale of Turkish NPP project share — CEO", *Information Telegraph Agency of Russia/Telegraph Agency of the Soviet Union, Russian News Agency*, 27 April 2016; see <http://special.itar-tass.com/en/economy/872784>, accessed 1 July 2016.

⁹⁵ *AFP*, "Erdogan warns Russia risks losing Turkey energy deals over Syria", *Agence France Presse*, 8 October 2015, see <https://www.yahoo.com/news/erdogan-warns-russia-over-turkey-nuclear-gas-deals-090402732.html?ref=gs>, accessed 1 July 2016.

⁹⁶ *Sputnik International*, "Russian Nuclear Power Plant Deal With Turkey to Progress After Thaw", 30 June 2016; see <http://sputniknews.com/business/20160630/1042237791/akkuyu-russia-turkey.html>, accessed 4 July 2016.

⁹⁷ *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 1 July 2016.

⁹⁸ *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 1 July 2016.

electricity generating company (EÜAS).⁹⁹ The ongoing problems with the financial viability of AREVA will affect its ability to invest in the project. Construction is currently expected to start in 2017. However, an Environmental Impact Assessment, which could take up to two years, is still outstanding.¹⁰⁰

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. Reports at the end of 2014 suggested that the project would be further delayed, by up to two years—the fourth delay in two years. This has led to extreme frustration with the bidders, with one company representative saying of the process: “They’re basically at the point where no one believes them anymore.”¹⁰¹

İğneada

In October in 2015, the government suggested that it was aiming to build a third power plant, at the İğneada site. The most likely bidders for the project are said to be Westinghouse and the Chinese State Nuclear Power Technology Corporation (SNPTC), with Chinese companies “aggressively” pursuing the contract, said to be worth US\$22-25 billion.¹⁰² The *Daily Sabah* newspaper noted that “the İğneada district is located some 10 kilometers south of Turkey’s border with Bulgaria and famous for its natural beauty and beach, which is likely to raise questions as to its environmental impact.”¹⁰³ Additional doubts have been raised by the Deputy Undersecretary for the Turkish Ministry of Energy and National Resources, who stated that “having three different projects with three different technologies is not sound.”¹⁰⁴

A decision by the Prime Minister 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. The previous October 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 December 2015, Atomic Energy Agency Director-General Hoang Anh Tuan that construction would start in 2020, a six-year delay of the

⁹⁹ 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 1 July 2016.

¹⁰⁰ NW, “IEA head voices support for Turkish nuclear program”, 1 October 2015.

¹⁰¹ NIW, “Weekly Review”, 27 September 2015.

¹⁰² NEI, “Turkey finalizes site for third NPP”, 18 March 2016, see <http://www.neimagazine.com/news/newsturkey-finalizes-site-for-third-npp-4843161/>, accessed 1 July 2016.

¹⁰³ *Daily Sabah*, “Turkey reveals location of planned third nuclear plant”, 14 October 2015, see <http://www.dailysabah.com/energy/2015/10/14/turkey-reveals-location-of-planned-third-nuclear-plant>, accessed 1 July 2016.

¹⁰⁴ NIW, “Akkuyu EIA Approved: A New Consortium Emerges”, 1 December 2014.

original plan.¹⁰⁵ “The national electricity development plan, approved by the government in March 2016, envisioned the “first nuclear power plant put into operation in 2028”.¹⁰⁶

Rosatom has confirmed that Russia’s Ministry of Finance is prepared to finance at least 85 percent of this first plant, and that Russia will supply the new fuel and take back spent fuel for the life of the plant. An agreement for up to US\$9 billion finance was signed in November 2011 with the Russian government’s state export credit bureau, and a second US\$0.5 billion agreement covered the establishment of a nuclear science and technology center.

Like Turkey, Vietnam has also signed an intergovernmental agreement with Japan for the construction of a second nuclear power plant, with two reactors projected to come on line in 2024–25. The agreement calls for assistance in conducting feasibility studies for the project, low-interest and preferential loans, technology transfer and training of human resources, and cooperation in the waste treatment and stable supply of materials for the whole life of the project.

The delay in the ordering of the new nuclear units is not of concern due to a slower than expected increase in electricity demand, according to the Director General of the Atomic Energy Agency. However, other analysts have suggested that the slowdown in demand has given Vietnam a reason to abandon its nuclear development program altogether. Nguyen Khac Nhan, who formerly taught nuclear engineering at the Grenoble Institute of Technology in France and who has advised French state utility EDF for three decades, stated in 2015: “The nuclear power projects will most certainly be stopped.”¹⁰⁷

“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 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, but 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. Since then, there have been various attempts and reports that a tender process would be restarted, all of which have come to nothing. But Russia’s Rosatom determinedly pursued its strategy of pushing “through a series of bilateral agreements, with each one more detailed than the previous” so that “a commercial contract is ultimately inevitable”.¹⁰⁸ As a result, in February 2015, Rosatom and Egypt’s Nuclear Power Plant Authority signed an agreement that could lead to the construction and financing of two reactors and possibly two additional ones.

¹⁰⁵ *NIW*, “Vietnam”, 11 December 2015.

¹⁰⁶ *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 7 June 2016.

¹⁰⁷ *Beyond Nuclear*, “Nguyen Khac Nhan: ‘the Vietnamese person who is most well-informed about nuclear energy and most vehemently opposed to it’”, 28 April 2015, see <http://www.beyondnuclear.org/other-region/2015/4/28/nguyen-khac-nhan-the-vietnamese-person-who-is-most-well-info.html>, accessed 1 July 2016.

¹⁰⁸ *NIW*, “Egypt: Moscow’s Push to Lock In Nuclear Contract”, 16 October 2015.

However, Rosatom highlighted the “need to prepare for signing two intergovernmental agreements—one on nuclear power plant construction and one on financing”.¹⁰⁹

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 with Russia providing up to 90 percent of the finance,¹¹⁰ to be paid back through the sale of electricity. Reports suggest that a spokesman for Rosatom said the first plant could be completed by 2022¹¹¹, which is technically impossible, given that construction, if at all, would not start for another two years. In May 2016, it was announced that Egypt concluded a US\$25 billion loan with Russia for nuclear construction.¹¹² 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 2029.¹¹³

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.¹¹⁴ 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.¹¹⁵ WorleyParsons was “to evaluate the nuclear power plant technology most suitable for Jordan (...) conduct a feasibility study and financial assessment of the project, as well as assist in [issuing] the tender for the plant vendor”.¹¹⁶ In Jordanian energy plans from that period, the timeline assumed for starting nuclear power production was as early as 2015.¹¹⁷

JAEC and WorleyParsons narrowed down the choices to the ATMEA-1 design from AREVA and Mitsubishi (as projected in Turkey); the Enhanced Candu-6 (EC6) from Atomic Energy of Canada Limited; the APR-1400¹¹⁸ from Korea Electric Power Corporation, and the AES-2006 and AES-92 variants of the VVER design from Rosatom.¹¹⁹ Eventually, the ability of Rosatom to potentially

¹⁰⁹ Rosatom, “Russia Helps Egypt To Explore Opportunities Of Nuclear Power Plant Construction”, 10 February 2015, see <http://rosatom.ru/en/press-centre/news/124-russia-helps-egypt-to-explore-opportunities-of-nuclear-power-plant-construction/>, accessed 1 July 2016.

¹¹⁰ *NIW*, Cairo and Moscow Ink Deal for Four-Unit Dabaa Plant, 20 November 2015.

¹¹¹ *Reuters*, “Egypt, Russia sign deal to build a nuclear power plant”, 19 November 2015, see <http://www.reuters.com/article/us-nuclear-russia-egypt-idUSKCN0T81YY20151119>, accessed 1 July 2016.

¹¹² *Reuters*, “Russia to lend Egypt \$25 billion to build nuclear power plant”, 19 May 2016, see <http://www.reuters.com/article/us-egypt-russia-nuclear-idUSKCN0YA1G5>, accessed 1 July 2016.

¹¹³ *NIW*, “Egypt Approves \$25 Billion Loan From Russia for Nuclear Project”, 20 May 2016.

¹¹⁴ Mark Hibbs, “Jordan reactor siting study to be done in 2009, JAEC says”, *NW*, xlviii, 2007.

¹¹⁵ Ann MacLachlan, “Worley Parsons to Help Jordan Run Program for First Nuclear Power Plant”, *NW*, 2009.

¹¹⁶ *WNN*, “Worley Parsons awarded Jordanian contract”, 16 November 2009, see http://www.world-nuclear-news.org/C-Worley_Parsons_awarded_Jordanian_contract-1611094.html, accessed 1 July 2016.

¹¹⁷ *Energy Tribune*, “Jordan Wants Nuclear Power, Signs Agreements with Spain, France”, 2 February 2010, see <http://www.energytribune.com/3375/jordan-wants-nuclear-power-signs-agreements-with-spain-france>, accessed 1 July 2016.

¹¹⁸ APR = Advanced Power Reactor

¹¹⁹ Ann MacLachlan, “Worley Parsons to Help Jordan Run Program for First Nuclear Power Plant”, *NW*, 2009.

finance, as well as its offer to take back spent fuel to Russia,¹²⁰ 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.¹²¹ 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. It is now envisaged the earliest that construction start would be 2019,¹²² which would make completion by the original objective of 2021¹²³ impossible and even the revised dates of 2023 highly unlikely.

This financing arrangement is being revised because JAEC is finding it very hard to come up with its part of cost of the reactor. This was suggested by JAEC Chairman Khaled Toukan who told Associated Press that the probability of the two reactors being built is “70 to 75 (percent) ... it is not 90 percent” in a recent interview.¹²⁴ Earlier, in October 2015, Toukan told the press that JAEC is “now in trilateral discussions and seeking strategic partners—technology providers as well as finance partners”.¹²⁵ Among the partners mentioned by Toukan are the China National Nuclear Corporation (CNNC), which is being approached to take on a potential equity stake, as well as participation in the construction phase for the turbine islands and other aspects of the plant, the Industrial and Commercial Bank of China, which is being approached for non-equity financing, and Rolls-Royce about potentially providing cooling systems for the plant.¹²⁶ JAEC’s current preference is for the equity stake in the project divided three ways with Rosatom and CNNC, and Jordan itself taking the last third. Elsewhere, Toukan has suggested that China might fund an even higher share, “not less than 50 percent”, according to one report.¹²⁷ For the JAEC part, Toukan has set up the Jordan Nuclear Power Co., which is to raise funds on the trading market by selling shares.¹²⁸ One reason that this arrangement might be attractive to Rosatom is uncertainty about its own finances. Over the past year, its budget has been cut and the Russian government was

¹²⁰ Rosatom, “Russia and Jordan signed Intergovernmental Agreement on NPP construction in Jordan”, 24 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 1 July 2016.

¹²¹ 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 1 July 2016.

¹²² *NIW*, “Briefs—Jordan”, 18 April 2014.

¹²³ *NIW*, “Newbuild—Jordan and Russia Move Closer on Newbuild Plans”, 26 September 2014.

¹²⁴ Karin Laub, “AP Interview: Jordan Eager to Reach Nuke Deal with US,” *The Herald*, 4 July 2016, see <http://www.heraldonline.com/news/business/technology/article87545887.html>, accessed 4 July 2016.

¹²⁵ Anthony McAuley, “Jordan closes in on deal with Russia to build two nuclear reactors”, *The National*, 31 October 2015, see <http://www.thenational.ae/business/energy/jordan-closes-in-on-deal-with-russia-to-build-two-nuclear-reactors>, accessed 1 July 2016.

¹²⁶ *Ibidem*.

¹²⁷ Nuclear.Ru, “Toukan: China can fund not less than 50% of nuclear build in Jordan”, 16 September 2015, see http://en.nuclear.ru/news/97045/?sphrase_id=3655595, accessed 1 July 2016.

¹²⁸ Chaffee P., “Jordan Looks to China for Financing”, *NIW*, 2015.

reportedly considering “suspending loans to other countries”.¹²⁹ But in the meanwhile, JAEC and Rosatom have signed a cooperation agreement on nuclear safety.¹³⁰

There is opposition in Jordan's parliament and local opposition is building up at the pre-selected Al Amra site. On 30 May 2012, the Jordanian parliament approved a recommendation to shelve the program, as it was said it would “drive the country into a dark tunnel and will bring about an adverse and irreversible environmental impact”. The parliament also recommended suspending uranium exploration until a feasibility study is done.¹³¹ Prior to the vote, the Parliament's Energy Committee had published a report accusing the JAEC of deliberately “misleading” the public and officials over the program by “hiding facts” related to costs.¹³² The JAEC responded by saying it wouldn't be able to produce a full evaluation until the start of construction of the plant.¹³³ At least one member of the royal family, Princess Basma bint Ali, has publicly spoken out against the nuclear program.¹³⁴

Local opposition comes in particular from members of the Beni Sakher tribe that lives around the Al Amra area.¹³⁵ One member of the tribe, Hind Fayez, is a prominent parliamentarian and a noted opponent.¹³⁶ 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”.¹³⁷ A particular concern is water requirements for the reactor, which is to come from the Al-Samra Waste Water Treatment Plant in nearby Irbid.¹³⁸ If and when the reactor is commissioned, over 20 percent of the total capacity of the Treatment Plant will be used to supply water to the reactors. The output of the Treatment Plant is currently being used for irrigation;¹³⁹ diversion of water to the reactor is, naturally, of public concern. The treatment of

¹²⁹ *The Moscow Times*, “Russia Considers Suspending Loans to Other Countries”, 18 January 2016, see <http://www.themoscowtimes.com/business/article/russia-considers-suspending-loans-to-other-countries/556181.html>, accessed 1 July 2016.

¹³⁰ *Jordan Times*, “Jordan, Russia sign nuclear safety deal”, 16 April 2016, see <http://www.jordantimes.com/news/local/jordan-russia-sign-nuclear-safety-deal>, accessed 1 July 2016.

¹³¹ *Jordan Times*, “Deputies vote to suspend nuclear project”, Updated 30 May 2012, see <http://vista.sahafi.jo/art.php?id=5cc50fcb54819dcb7c741cc651bb71531178b08e>, accessed 1 July 2016.

¹³² *Ibidem*.

¹³³ *Monitor Global Outlook*, “Jordan clings on to nuclear ambitions, despite delays”, 10 January 2014.

¹³⁴ On 28 June 2011, Princess Basma gave a stinging anti-nuclear speech in a public event in Amman, Jordan, entitled “Pros and Cons of Nuclear Energy”; see also Aaron Magid, “Time to Reconsider Jordan's Nuclear Program,” Middle East Institute, 20 June 2016, see <http://www.mei.edu/content/article/time-reconsider-jordan-s-nuclear-program>, accessed 23 June 2016.

¹³⁵ 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 25 June 2016.

¹³⁶ David Schenker, “The Middle East's Next Nuclear Power?”, Washington Institute for Near East Policy, *Politico*, 28 January 2015, see <http://www.politico.com/magazine/story/2015/01/jordan-nuclear-power-114712.html>, accessed 25 June 2016.

¹³⁷ *Jordan Times*, “Nuclear programme ‘to lower electricity costs by 70%’”, 30 October 2013.

¹³⁸ 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 25 June 2016.

¹³⁹ *Water Technology*, “As-Samra Wastewater Treatment Plant (WWTP), Jordan”, Undated, see <http://www.water-technology.net/projects/as-samra-wastewater-treatment-plant-jordan/>, accessed 1 July 2016.

wastewater will also add to the already high costs of generating nuclear power.¹⁴⁰ 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”.¹⁴¹

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.¹⁴² The Programme was subject to a Strategic Environmental Assessment (SEA), which was also approved in January 2014. In April 2014, Greenpeace started legal procedures against the Assessment, alleging its public participation process was inadequate. The SEA drew around 60,000 submissions, a majority coming from neighboring Germany. The plan includes proposals to build 6 GW of nuclear power 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 (Advanced Boiling Water Reactor).

In January 2013, the Polish utility PGE (Polska Grupa Energetyczna) 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.¹⁴³ 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 2019.¹⁴⁴ A number of vendors, including AREVA, Westinghouse, and GE-Hitachi, all lobbied Warsaw aggressively.¹⁴⁵ 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 tendering 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 2017.¹⁴⁶ Final design and permits for the first plant were expected to be ready in 2018, allowing construction

¹⁴⁰ Steve Thomas, “Jordan’s Nuclear Power Plans”, Istanbul, 2013.

¹⁴¹ John C.K. Daly, “Water shortages may end Jordan’s nuclear power hopes”, *oilprice.com*, 18 June 2013, see <http://www.mining.com/web/water-shortages-may-end-jordans-nuclear-power-hopes/>, accessed 25 June 2016.

¹⁴² 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.

¹⁴³ *NIW*, “Briefs—Poland”, 8 February 2013.

¹⁴⁴ *Economist*, “Polish Energy, Going nuclear”, 31 January 2014, see <http://www.economist.com/blogs/easternapproaches/2014/01/polish-energy>, accessed 29 March 2016.

¹⁴⁵ *NIW*, “Potential and Existing Global Nuclear Newbuild Projects”, 25 April 2014.

¹⁴⁶ *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 1 July 2016.

start in 2020 and commercial operation in 2025. That schedule has slipped to commercial operation beginning in 2030-31.¹⁴⁷

However, in April 2014, it was reported that PGE had cancelled its contract with WorleyParsons to research potential sites. It was thought that this would delay the process by at least two years, with the Supreme Audit Office suggesting that there was a high risk of further delays or that the plant wouldn't be completed at all.¹⁴⁸ An independent critical assessment stated in late May 2015: "At this point, it is central to highlight that neither the Polish administration, nor PGE have announced so far any realistic or even detailed financing plan for the NPPs' scheme."¹⁴⁹ Furthermore, coal, and in particular supporting coal miners, remains a political priority.¹⁵⁰

In December 2015, the Polish General Directorate for the Environment (GDOS) started 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.¹⁵¹ In January 2016, Poland's newly formed government further slowed down nuclear plans with the head of the Energy Ministry admitting that the 2020 target for commissioning a first unit was no longer viable.¹⁵²

“Well Developed Plans”

There seems little to indicate that **Chile** is actively developing nuclear power. The World Nuclear Agency (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 2016.¹⁵³ However, plans have not developed significantly since then. Public opinion in Chile turned strongly against nuclear power after the Fukushima accident and a poll conducted in April 2011 showed that around 84 percent of those surveyed were against the development of a nuclear power program in Chile, with only 12 percent in support.¹⁵⁴

¹⁴⁷ *NW*, "Polish nuclear program facing additional delays of at least one year: analyst", 21 April 2016.

¹⁴⁸ *Reuters*, "Poland's nuclear project pushed back at least another two years: sources", 14 April 2015, see <http://uk.reuters.com/article/2015/04/14/uk-poland-energy-nuclear-idUKKBN0N512M20150414>, accessed 29 March 2016.

¹⁴⁹ Harembski M., "Plan for Nuclear Power in Poland vs. Nuclear Energy Project Application", 21 May 2015.

¹⁵⁰ *PiE*, "Tchorzewski affirms coal's key role", 1 February 2016.

¹⁵¹ *Rynek Infrastruktury*, "PGE EJ1 rezygnuje z lokalizacji 'Choczewo'", 2 February 2016, (in Polish), see <http://www.rynekinfrastruktury.pl/wiadomosci/elektrownia-jadrowa-nie-powstanie-w-choczewie-52648.html>, accessed 23 May 2016.

¹⁵² *NIW*, "Weekly Roundup", 22 January 2016.

¹⁵³ WNA, "Emerging Nuclear Energy Countries", Updated 31 May 2016, see <http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx>, accessed 2 June 2016.

¹⁵⁴ *HydroWorld.com*, "Public increasingly opposed to HidroAysén, nuclear power – Ipsos", 13 April 2011.

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”.¹⁵⁵ 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 2050.¹⁵⁶ Over the past five years, solar capacity has quadrupled to 770 MW.¹⁵⁷

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.¹⁵⁸ 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 OPR-1000 units at a cost of US\$3 billion. The OPR-1000 is a Generation II 1000 MW PWR, developed jointly by KEPCO and KHNP. However, the actual construction plans are much more modest and envisage the construction of a 10 MW reactor in the Serpong area, to be operational in 2021¹⁵⁹, with a tender to prepare blueprints won by Rosatom in April 2015. As with a large number of countries, there have been reports of ongoing co-operation with Russia, including with proposals for the sale of

¹⁵⁵ 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 24 June 2016.

¹⁵⁶ *PV-tech*, “Chile introduces new Energy 2050 renewable-energy goals”, 6 January 2016, see <http://www.pv-tech.org/news/chile-introduces-new-energy-2050-renewable-energy-goals>, accessed 1 July 2016.

¹⁵⁷ Vanessa Dezem, Javiera Quiroga, “Chile has so much solar energy its giving it away for free”, *Bloomberg*, 2 June 2016, see <http://www.bloomberg.com/news/articles/2016-06-01/chile-has-so-much-solar-energy-it-s-giving-it-away-for-free>, accessed 1 July 2016.

¹⁵⁸ Hanan Nugroho, “Development of Nuclear Power in Indonesia: Stop or Go?”, State Ministry of National Development Planning, Bappenas, *Jakarta Post*, 5 May 2010, see <http://www.thejakartapost.com/news/2010/05/05/development-nuclear-power-indonesia-stop-or-go.html>, accessed 1 July 2016.

¹⁵⁹ Hendro Tjahjono, “Recent status of nuclear power and assessment in Indonesia”, National Nuclear Energy Agency (BATAN), Republic of Indonesia, as presented at the Technical meeting on Technology Assessment for New Nuclear Power Programs, IAEA, September 2015, see https://www.iaea.org/NuclearPower/Downloadable/Meetings/2015/2015-09-01-09-03-NPTDS41894/DAY1/3_Recent_Status_of_NPP_Assessment_in_Indonesia.pdf, accessed 25 June 2016.

floating reactors.¹⁶⁰ There is also talk about “on-land” reactors, with “breaking of ground” to start in 2024/5.¹⁶¹

Then in December 2015, the Indonesian government pulled the plug on all nuclear plans, even for the longer term future. Energy and Mineral Resources Minister Sudirman Said stated: “We have arrived at the conclusion that this is not the time to build up nuclear power capacity. We still have many alternatives and we do not need to raise any controversies.” The Minister made that statement after the National Energy Council, a presidential advisory body, completed its latest National Energy Plan. *Nuclear Engineering International* comments: “This effectively cancels a previous [US]\$8bn plan to operate four nuclear plants with a total capacity of 6 GWe by 2025.”¹⁶² 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. Planning documents and Indonesian officials consider nuclear power to be merely a “last resort” option.

Kazakhstan is the world’s largest producer of uranium, with 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 deals 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, with an intergovernmental agreement expected by some in 2016.¹⁶³ However, others are less positive about the timetable and, in October 2015, the Vice Minister of Energy Bakhytzhhan Dzhaksaliyev said that finding a suitable site and strategic partner might take two to three years.¹⁶⁴ In December 2015, a draft Atomic Energy Law was referred to the Senate, in order to address licensing, security, environmental protection rules and standards.¹⁶⁵ An April 2016 joint declaration by the energy ministers of Kazakhstan and the U.S. notes that the 2016 work plan

¹⁶⁰ *Russia Insider*, “Russia to Build Floating Nuclear Power Plants for Indonesia”, 22 September 2015, see <http://russia-insider.com/en/business/russia-build-floating-nuclear-power-plants-indonesia/ri9854>, accessed 25 June 2016.

¹⁶¹ *Jakarta Globe*, “Russia-Indonesia Partnership to Build Future of Indonesian Nuclear Sector”, 7 October 2015, see <http://jakartaglobe.beritasatu.com/news/russia-indonesia-partnership-build-future-indonesian-nuclear-sector/>, accessed 1 July 2016.

¹⁶² *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 1 July 2016.

¹⁶³ *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 1 July 2016.

¹⁶⁴ *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 1 July 2016.

¹⁶⁵ 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 1 July 2016.

“encourages the use of alternative energy sources in Kazakhstan, reduces emissions, and enhances nuclear safety”.¹⁶⁶

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, importantly 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.¹⁶⁷ Thailand’s largest private power company has announced that it will invest US\$200 million for a 10 percent stake of the China General Nuclear Corporation (CGN) and Guangxi Investment Group’s Fangchenggang nuclear power plant in China.¹⁶⁸ CGN obviously eyes a role in the potential 2 GW nuclear project in Thailand. However, as *Nuclear Intelligence Weekly (NIW)* puts it, “in the near term CGN may have to content itself first with renewable opportunities in the region”.¹⁶⁹

In 2012, the IAEA suggested that in 2013 the Kingdom of Saudi Arabia might start building its first nuclear reactor.¹⁷⁰ This confident prediction was based on the fact that in April 2010 a royal decree said: “The development of atomic energy is essential to meet the Kingdom’s growing requirements for energy to generate electricity, produce desalinated water and reduce reliance on depleting hydro-carbon resources.”¹⁷¹ The King Abdullah City for Atomic and Renewable Energy (KA-CARE) was set up in Riyadh 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. However, the KA-CARE nuclear proposal has still not been approved by the country’s top economic board, then headed by the late King Abdullah, and in March 2013, it was reported that a KA-CARE official has said that a tender is now unlikely for seven or eight years. In November 2013, it was

¹⁶⁶ 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 28 May 2016.

¹⁶⁷ WNA, “Emerging Nuclear Energy Countries”, Updated 31 May 2016, see <http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx>, accessed 1 April 2016.

¹⁶⁸ 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 1 July 2016.

¹⁶⁹ NIW, “CGN Pairs Nuclear with Renewables in Global Push”, 1 April 2016.

¹⁷⁰ 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 24 June 2016.

¹⁷¹ *World Politics Review*, “Saudi Arabia’s Nuclear Ambitions Part of Broader Strategy”, 16 June 2011, see <http://www.worldpoliticsreview.com/articles/9186/saudi-arabias-nuclear-ambitions-part-of-broader-strategy>, accessed 24 June 2016.

nonetheless suggested that the project would be put back on track faster than this, with a suggestion that KA-CARE could bring forward proposals for new-build in 2015.¹⁷²

Hashim Yamani, president of the King Abdullah City for Atomic and Renewable Energy has said: “Recently, however, we have revised the outlook together with our stakeholders to focus on 2040 as the major milestone for long-term energy planning in Saudi Arabia.”¹⁷³ No reason was given for the delay or when the first nuclear and solar plants would be operational. The falling oil price and subsequent drop in Government revenues is likely to delay or curtail capital intensive project, such as nuclear.

During 2015, new co-operation agreements were signed with France, Russia, China and South Korea. The last seemed to be the most advanced and includes proposals for the building of two SMART small modular reactors and ongoing research and collaboration.¹⁷⁴

Conclusion on Potential Newcomer Countries

Historically, the expansion of nuclear power into new countries is extremely slow; in the last two decades only two countries, Romania (1996) and Iran (2011), started power reactors for the first time, while over the same time period two countries, Kazakhstan and Lithuania, closed theirs. In the next few years, two countries are expected to start generating electricity from nuclear reactors for the first time, but their experiences are extremely different. On the one hand is the UAE, which if it starts the first unit at the Barakah nuclear power plant next year, will be a remarkable achievement, as it will be completed on time. In Belarus, at the Ostrovets site, project costs seem to have risen, and officially the construction phase is on schedule, but without any independent verification, there is considerable skepticism over the validity of the claim. As the summary table shows in all of the emerging new countries their programs have experienced significant delays and most are exhibiting rises in expected costs. In reality, beyond Turkey it is difficult to imagine any of the countries that are so far not yet building any nuclear power plants, completing new reactors before the 2030s.

Furthermore, it is important to note the dominance of Russian technology in the proposed projects. Most, if not all, of these proposed sales are backed by Russian finance. However, given the economic problems in Russia in particular relating to the lower global fossil fuel prices and ongoing economic embargoes, it is likely that many of these are to be further delayed or curtailed.

¹⁷² *NIW*, “Briefs—Saudi Arabia”, 15 November 2014; and Ahmad A., Ramana M.V., “Too costly to matter: Economics of nuclear power for Saudi Arabia”, *Energy Journal*, 1 May 2014.

¹⁷³ *Reuters*, “Saudi Arabia's nuclear, renewable energy plans pushed back”, 19 January 2015, see <http://www.reuters.com/article/2015/01/19/saudi-nuclear-energy-idUSL6N0UY2LS20150119>, accessed 24 June 2016.

¹⁷⁴ *NIW*, “Saudi Arabia, Will Water Scarcity Spur Nuclear Growth?”, 31 July 2015.

Table 3: Reactor Construction Schedules in Potential Newcomer Countries

Country	Reactor Name	Proposed Vendor	Initial Startup Date	Latest Suggested Construction Start	Latest Startup Date
IAEA Category: Under Construction					
Belarus	Ostrovets	Rosatom	2019/20		2019/20
UAE	Barakah	KEPCO	2017/18/19/20		2017/18/19/20
IAEA Category: Contract Signed or Advanced Development					
Bangladesh	Rooppur	Rosatom	2018	2016	
Lithuania	Visegrade	Hitachi	2020	Suspended	
Turkey	Akkuyu	Rosatom	2015		2022
	Sinop	Mitsubishi/Areva		2017	
	Ingeada	SNPTC/Westinghouse		2019	
Vietnam	Ninh Thuan	Rosatom	2020	Suspended	
Egypt		Rosatom	2019		
Jordan		Rosatom		2019	
Poland				2020	
IAEA Category: Well Developed Plans					
Chile			2024	Suspended	
Indonesia		Rosatom		Abandoned	
Kazakhstan		Rosatom or Westinghouse		?	
Thailand			2020-28	?	2036
Saudi Arabia			2020	?	2040

Sources: Various, compiled by WNISR, 2016

Nuclear Finances: Corporate Meltdown?

Nuclear power has a significantly different finance profile to the other conventional power plant technologies, with, under normal circumstances, large upfront construction costs, relatively small fuel costs and at the end of operational life, increasing operational costs as well as significant decommissioning and waste management costs. Furthermore, as other sections of the report have shown, nuclear construction projects have recently demonstrated an almost inherent inability to be built to time and cost. Under these circumstances, the views and actions of the markets, credit-rating companies and analysts can be decisive for the competitiveness of nuclear power.

Some years ago, many saw the call for decarbonization as an opportunity for nuclear power to expand, given that no greenhouse gases are emitted during operation—although significant CO₂ emissions are generated during other parts of the fuel and operational chain. However, as illustrated in the nuclear vs renewables chapter, this has not occurred and it is renewables, particularly solar and wind power, that have over the last decades been deployed at scale. Steve Kidd, long-term nuclear industry strategist, has gone as far as suggesting “to abandon climate change as a prime argument for supporting a much higher use of nuclear power to satisfy rapidly-rising world power needs”.¹⁷⁵ The reason:

The nuclear industry giving credence to climate change from fossil fuels has simply led to a stronger renewables industry. Nuclear seems to be “too difficult” and gets sidelined - as it has within the entire process since the original Kyoto accords. And now renewables, often thought of as useful complements to nuclear, begin to threaten it in power markets when there is abundant power from renewables when the wind blows and the sun shines.

Indeed, there is growing conflict between the power produced by variable renewables, such as wind and solar power, and the large centralized capacity operating around the clock (traditionally known as base-load capacity), such as nuclear power and coal. In particular, many renewable energy sources have priority access to the grid system and/or have lower operating costs than conventional sources and therefore, when they are able to generate, it is their electricity that enters the grid system. As more and more solar and wind is deployed, they are taking a greater and greater share of the market at particular times, therefore, restricting the production sales of other power sources¹⁷⁶, especially in North America and Western Europe, regions where there is also flat or falling power demand. On 15 May 2016, in Germany, the world’s 4th largest economy, for a few hours over 80 percent of the country’s power was provided for by renewables¹⁷⁷; a country with 10.8 GW of installed nuclear and 48 GW of coal and lignite capacity.

Therefore, it is clear that as renewables make an ever increasing contribution to the power mix, then any conventional power capacity will need to be smaller, more flexible units that compliment

¹⁷⁵ Steve Kidd, “Is climate change the worst argument for nuclear?”, *NEI*, 21 January 2015, see <http://www.neimagazine.com/opinion/opinionis-climate-change-the-worst-argument-for-nuclear-4493537/>, accessed 1 July 2016.

¹⁷⁶ Ela E., Milligan M., et al., “Evolution of Wholesale Electricity Market Design with Increasing Levels of Renewable Generation”, National Renewable Energy Laboratory, U.S.DOE, Office of Energy Efficiency & Renewable Energy, September 2014, see <http://www.nrel.gov/docs/fy14osti/61765.pdf>, accessed 12 June 2016.

¹⁷⁷ *Renewables international*, “Reports of 100% renewable power in Germany vastly overstated”, 17 May 2016, see <http://www.renewablesinternational.net/reports-of-100-renewable-power-in-germany-vastly-overstated/150/537/95397/>, accessed 1 July 2016.

rather than conflict with the increasingly cheap renewables, as well as interact rapidly with other balancing options, such as energy storage or flexible demand. This view is shared by many politicians,¹⁷⁸ financiers¹⁷⁹, and industry experts, including Steve Holliday, then CEO of the U.K.'s National Grid, which owns and operates the infrastructure and is responsible for grid balancing, who stated:

From a consumer's point of view, the solar on the rooftop is going to be the baseload. Centralized power stations will be increasingly used to provide peak demand¹⁸⁰.

The falling manufacturing costs—the solar PV module costs have fallen 80 percent since 2008—and the subsequent lower operating cost of renewables—the levelized costs of onshore wind power has fallen 50 percent since 2009¹⁸¹—is also reducing the market price for power. This is most starkly seen in Europe, with major utilities seeing this not as a cyclical trend but as a permanent change. “I think that the price of electricity has no reason to rise. It will never be like it was before,” stated Isabelle Kocher, chief executive of French company ENGIE, the world's largest non-state-owned producer of electricity.¹⁸²

Most traditional utility companies have been slow to invest in renewable energies and most onshore wind and solar PV are not owned by the incumbent utilities. Given that solar and wind have been and are expected, by the International Energy Agency (IEA), amongst others, to be the largest source of new capacity to be deployed on the medium term¹⁸³, many utilities are changing their business focus. In Germany, two of the largest power companies, E.ON and RWE, have announced that they will both split in two and develop a conventional business arm and another deal with renewable energy and energy services. While in France, the bastion of large scale, centralized electricity planning, ENGIE, formally known as GDF-Suez, has also announced that it too will focus on energy services.¹⁸⁴

In addition to, and in part as a result of, these changes the short-term prices of fossil fuels have fallen considerably, with coal prices in Europe in 2008 were approximately US\$200/ton, while in Asia achieved only about US\$175/ton, but both fell to less than US\$75/ton in 2015¹⁸⁵ and are expected to fall to US\$50/ton during 2016 in Europe.¹⁸⁶ Globally natural gas prices have also fallen

¹⁷⁸ Giles Parkinson, “The end of baseload? It may come sooner than you think”, *RenewEconomy*, 20 February 2012, see <http://reneweconomy.com.au/2012/the-end-of-baseload-it-may-come-sooner-than-you-think-29425>, accessed 19 May 2016.

¹⁷⁹ Frank Wouters, “Inflexible baseload power is just what we don't need”, Gore Street Capital, Letter in the *Financial Times*, 20 April 2016, see <https://next.ft.com/content/311ac492-0250-11e6-99cb-83242733f755>, accessed 19 May 2016.

¹⁸⁰ Karel Backman, “Steve Holliday, CEO National Grid: “The idea of large power stations for baseload is outdated””, *Energy Post*, 11 September 2015, see <http://www.energypost.eu/interview-steve-holliday-ceo-national-grid-idea-large-power-stations-baseload-power-outdated/>, accessed 1 July 2016.

¹⁸¹ Michael Liebreich, “In search of the miraculous”, Bloomberg New Energy Finance (BNEF) Summit, 5 April 2016, see <http://about.bnef.com/content/uploads/sites/4/2016/04/BNEF-Summit-Keynote-2016.pdf>, accessed 31 May 2016.

¹⁸² Michael Stothard, “Low European power prices her to stay, says utility CEO”, *Financial Times*, 15 May 2016.

¹⁸³ IEA, “Renewable Energy, Medium-term market Report 2015—Market Analysis and Forecasts to 2020”, 2015.

¹⁸⁴ Geert De Clercq, “UPDATE 3-Engie shifts focus to regulated power as oil and gas take toll”, *Reuters*, 25 February 2016, see www.reuters.com/article/engie-results-idUSL8N1641DY, accessed 8 July 2016.

¹⁸⁵ IEA, “Coal Information 2015”, 2015.

¹⁸⁶ *Bloomberg*, “European Coal Prices Slump to a Record Level”, 22 September 2015, see <http://www.bloomberg.com/news/articles/2015-09-22/coal-for-2016-declines-below-50-in-europe-as-glut-persists>, accessed 1 July 2016.

in the U.S. in 2013 from US\$5/MBTU ¹⁸⁷to less than US\$2/MBTU in 2016, while in Asia and Europe, over the same time period they, respectively, fell from US\$20/MBTU and US\$11/MBTU to less than US\$5/MBTU in 2016.¹⁸⁸ The falling prices of fossil fuels are likely to further drive down the market prices for electricity, particularly affecting the relative economics for nuclear power.

Low interest rates are of huge significance for large capital intensive projects like nuclear power. A study published by the Oak Ridge National Laboratory in the U.S., suggested that halving the annual interest rate for a nuclear power plant that cost US\$6000/kW, from 10 to 5 percent, would reduce the final production cost of power by around 40 percent.¹⁸⁹ This approximate assessment is in line with findings from the IAEA, that notes that interest rate and construction period are fundamental to the economics of a project and that :

this can be shown by comparing the relative amounts of interest during construction (IDC) incurred by two projects of identical value ([US]\$5.75 billion) in terms of overnight costs (costs of materials, equipment, labour, etc.), but which differ in terms of project duration and the rate of interest paid on financing. The total amounts of IDC incurred by these two projects was almost [US]\$2.8 billion if a 7 year construction duration and 10% rate of interest was assumed, versus [US]\$1 billion if a 5 year duration at a 5% rate of interest was assumed.¹⁹⁰

Given that interest rates are at a historic low and have been for some time, from a cost of borrowing money perspective there has never been a better time for building a nuclear power plants. Despite this, and the availability of capital, there is very little private sector investment in nuclear power.

Given this combination of circumstances, it is not surprising that the views of the financial sector towards large incumbent power utilities and the nuclear industry in particular remains as nervous and unforgiving.

Credit ratings companies assign ratings on companies' or government's expected ability to pay back debt, in a timely manner and therefore, "can and should provide a robust forward looking indication of relative credit risk."¹⁹¹ There are three main ratings agencies, Moody's Investors Service and Standard & Poor's (S&P), which together control 80 percent of the global market, while Fitch Ratings controls a further 15 percent. The views of the rating agencies have a large impact on the financial situation of companies and states. It was said, in 2011, of head of S&P, "David Beers might be the most powerful man in the world you have never heard of."¹⁹²

The rating companies assign score cards to companies or governments. S&P's long-term rating system has 10 categories: AAA, AA, A, BBB, BB, B, CCC, CC, C and D. The rating is given a + or - to indicate that the company is in the upper or lower end of the category. All of the ratings are supplemented with an "outlook"; this is the rating agency's opinion on the probable short-term

¹⁸⁷ MBTU = million British thermal units

¹⁸⁸ *Financial Times*, "Gas price tumble comes as markets are increasingly interlinked", 10 March 2016, see <https://next.ft.com/content/3bc0116c-e681-11e5-a09b-1f8b0d268c39>, accessed 15 May 2016.

¹⁸⁹ T Jay Harrison, "Economic Conditions and Factors Affecting New Nuclear Power Deployment", Oak Ridge National Laboratory, DOE, October 2014, see info.ornl.gov/sites/publications/files/Pub52713.pdf, accessed 1 July 2016.

¹⁹⁰ IAEA, "Climate Change and Nuclear Power 2015", October 2015.

¹⁹¹ Paul Taylor, "The role of credit ratings agencies in the International financial system", President and CEO of Fitch Group, United National General Assembly Thematic Debate, 10 September 2013.

¹⁹² Stephen Foley, "S&P's power chief steps out of the shadows", 7 August 2011, *The Independent*, see <http://www.independent.co.uk/news/business/news/sampps-powerful-chief-steps-out-of-the-shadows-2333592.html>, accessed 1 July 2016.

trend in the company's credit quality. The outlooks are positive (up), stable or negative (down). The highest rating is AAA, down to BBB, which are also said to be a safe investment. However, BB down to C is described as speculative or "junk".¹⁹³

Table 4: Standard and Poor's Long-Term Credit Rating of Major European Utilities

Company	Latest Rating	Outlook	2016 May	2015 May	2014 June	2013 June	2012 June	2011 April	2010	2009	2008	2007
CEZ	Oct. 2006	Stable	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-
EDF	May 2016	Negative	A	A+	A+	A+	A+	A+	A+	AA-	AA-	AA-
ENEL	July 2013	Stable	BBB	BBB	BBB	BBB+	BBB+	A-	A-	A-	A-	A
E.ON	May 2015	Negative	BBB+	BBB+	A-	A	A	A	A	A	A	A
ENGIE	April 2016	Negative	A-	A	A	A	A	A	A	A	A	A
RWE	Aug. 2015	WatchNeg	BBB	BBB+	BBB+	BBB+	A-	A-	A	A	A	A+
TVO	May 2016	Stable	BB+	BBB-	BBB	BBB	BBB	BBB	BBB	BBB	BBB	BBB
Vattenfall	Sept. 2015	Negative	BBB+	A-	A-	A-	A-	A-	A	A	A-	A-

Sources: Standard & Poor's; Companies' Financial Reports

Table 4, shows the trends in rating from S&P for a selection of major electricity utilities. What is clear, is that S&P recognizes the prevailing conditions in the power sector in Europe with negative or stable reviews of the companies and, indeed, all of the assessed ones having lower credit rating than nine years ago. In February 2016, S&P published a summary of its views on 16 European parent companies of power utilities, which concluded that falling power prices, structural changes, including a new market design across Europe, and falling earnings could result in downgrades across the sector this year.¹⁹⁴

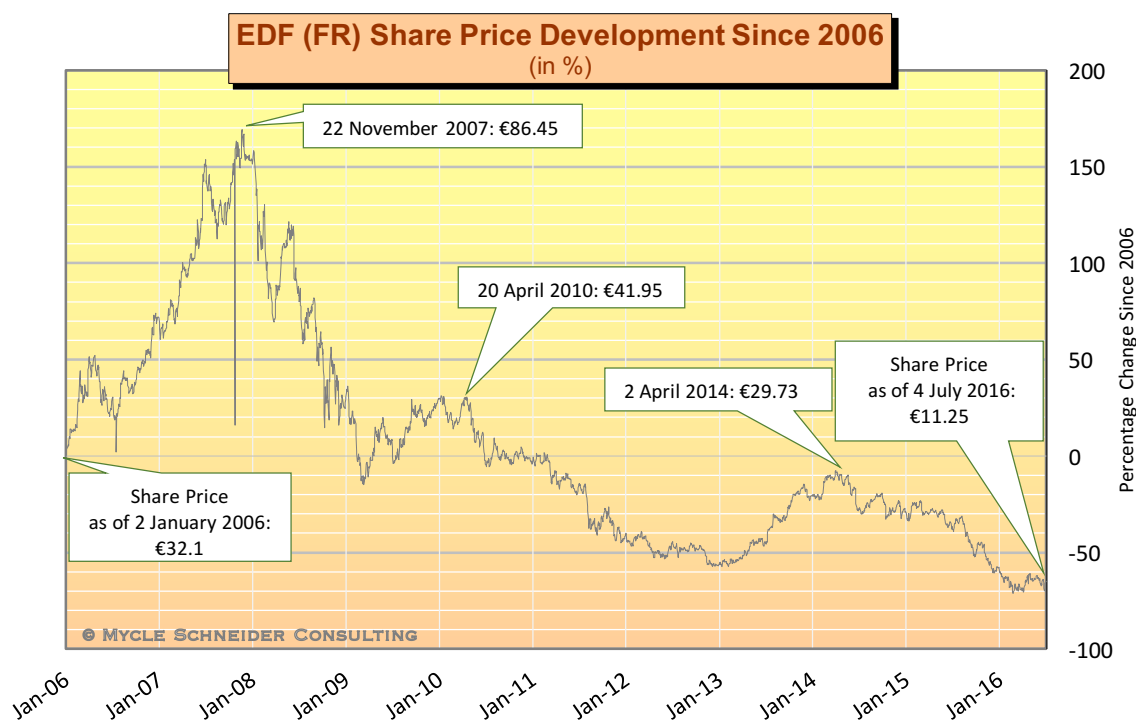
As shown in the France Focus section of this report, EDF has particular financial troubles. This is recognized by the rating agencies. In May 2016, Moody's issued a credit opinion, which highlighted three key problems for EDF; exposure to declining market prices in France and the U.K.; increased competition in its domestic supply market; and the substantial investment program required to upgrade its nuclear reactors. Moody's also noted that the "rating could be downgraded if Hinkley Point C were to go ahead" and that "the outlook could return to stable provided that EDF

¹⁹³ Rebecca Marston, "What is a rating agency?", *BBC*, 20 October 2014, see <http://www.bbc.co.uk/news/10108284>, accessed 1 July 2016.

¹⁹⁴ S&P, "Weak Power Prices And Regulatory Risks Trigger Mainly Negative Rating Actions On European Utilities", 24 February 2016.

decides not to proceed with Hinkley.”¹⁹⁵ This is all the more remarkable as during the same week, Jean-Bernard Levy, EDF chief executive told its shareholders that Hinkley was “essential”, adding: “Without Hinkley Point, the group would have no credibility to reach new nuclear markets.”¹⁹⁶ During the year 2015, EDF’s company debt rose by nearly €3 billion (US\$3.6 billion) to €37.4 billion (US\$40.9 billion). As EDF’s credit-rating was downgraded, the debt load will likely increase further as debt becomes more expensive.

Figure 20: EDF Share Price Development 2006–2016



Source: Yahoo Finances, July 2016¹⁹⁷

This is a similar view to S&P, which in May 2016 lowered its long-term corporate credit rating by S&P to A from A+, which “reflects the increasing share of revenues that EDF derives from unregulated activities following the partial liberalization of the French energy market. This comes at a time of a sharp decrease in power prices.”¹⁹⁸ In June Fitch ratings also downgraded its assessment of EDF from A to A-, one of the key reasons for this was “in view of further potential

¹⁹⁵ Moody’s, “Electricite de France – update following recent downgrade to A2 negative”, Credit Opinion, 17 May 2016.

¹⁹⁶ Emily Gosden, “Hinkley Point costs could rise to £21bn, EDF admits”, *The Telegraph*, 12 May 2016, see <http://www.telegraph.co.uk/business/2016/05/12/hinkley-point-costs-could-rise-to-21bn-edf-admits/>, accessed 1 July 2016.

¹⁹⁷ Data extracted from Yahoo Finance refers to EDF’s share value performance on the Paris Stock Market (EDF.PA). Percentage changes are calculated on the basis of the closing price on 2 January 2006.

¹⁹⁸ S&P, “France-Based Integrated Energy Company EDF Downgraded To ‘A/A-1’ On Weaker Business Profile; Outlook Negative”, 13 May 2016.

major commitments, its biggest challenge will be to reduce underlying negative free cash flow.”¹⁹⁹ EDF shares lost 87 percent of their value since they peaked in 2007 (see Figure 20).

While EDF has sought and achieved increased government support and finance to maintain its structure, GDF-SUEZ, has taken a different route, by redefining its business model and renamed itself as ENGIE, in April 2015 and in doing so it stated²⁰⁰:

That’s why GDF SUEZ is now ENGIE. The world of energy is undergoing profound change. The energy transition has become a global movement, characterized by decarbonization and the development of renewable energy sources, and by reduced consumption thanks to energy efficiency and the digital revolution.

The rating agency S&P was receptive to this restructuring, saying:

We view ENGIE's recently announced asset rotation plan as a positive, albeit ambitious, strategic shift. We expect this will change the group's business mix over time.²⁰¹

Despite this, the prevailing conditions in the European market have resulted in an overall downgrading of the company by S&P and Moody’s.²⁰² During the 2015/16 financial year the financial debt of ENGIE rose from €38.3 billion (US\$42.5 billion) to €39.2 billion (US\$43.4 billion). Furthermore, despite this rebranding, ENGIE still describes itself as a “player in the worldwide nuclear revival”, with projects including in the U.K.; with part ownership of NuGen, which together with Toshiba plan to build 3.4 GW of capacity; in Turkey it is involved in the Sinop project; and is active in projects in Brazil, Saudi Arabia and Poland.²⁰³

Of all countries in Europe, the incumbent companies in Germany are experiencing the most visible transformation. On 1 January 2016, E.ON completed its restructuring, whereby it will focus on renewables, energy networks and customer solutions, while a separate company, Uniper will focus on conventional power (hydro, natural gas, coal) and global energy trading. However, somewhat surprisingly, E.ON retained responsibility for its remaining four nuclear power plants, which was said to avoid delay in the establishment of Uniper.²⁰⁴ S&P’s stated, prior to the final agreement on nuclear power, that the new structure of E.ON would strengthen their risk profile, but that it was still being downgraded.²⁰⁵

RWE, have taken a similar approach separating its renewables, grids and retail distribution into a subsidiary, floating 10 percent in an initial public offering in 2016, which “allows RWE to tap

¹⁹⁹ Fitch, “Fitch Downgrades EdF to ‘A-’; Stable outlook”, 7 June 2016.

²⁰⁰ ENGIE, “As the world changes, all energies change with it”, 24 April 2016 see <http://www.engie.com/en/journalists/press-releases/gdf-suez-becomes-engie/>, accessed 1 July 2016.

²⁰¹ S&P, “France-Based Energy Company ENGIE Downgraded To ‘A-/A-2’ On Weaker Business Profile; Outlook Negative”, 29 April 2016.

²⁰² Moody’s, “Moody’s downgrades ENGIE to A2; stable outlook”, 27 April 2016.

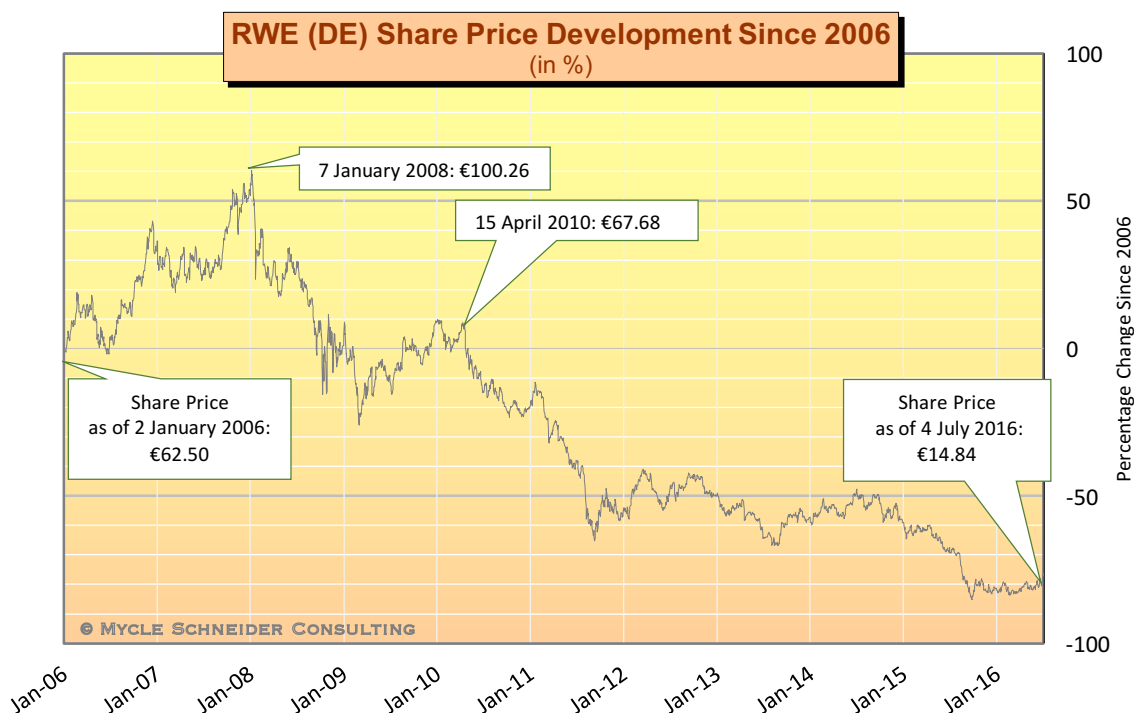
²⁰³ ENGIE, “Nuclear Energy”, Undated, see <http://www.engie.com/en/businesses/electricity/nuclear-energy/>, accessed 26 May 2016.

²⁰⁴ E.ON, “E.ON making good progress implementing its strategy: retaining its nuclear power business in Germany means spinoff can remain on schedule”, Press Release, 9 September 2015, see <http://www.eon.com/en/media/news/press-releases/2015/9/9/eon-making-good-progress-implementing-its-strategy-retaining-its-nuclear-power-business-in-germany-means-spinoff-can-remain-on-schedule.html>, accessed 1 July 2016.

²⁰⁵ *Utility Week*, “Eon’s credit rating downgraded ahead of spin-off plans”, 28 May 2015, see <http://utilityweek.co.uk/news/eon-s-credit-rating-downgraded-ahead-of-spin-off-plans/1135702#.V0cF7PkrIZg>, accessed 1 July 2016.

market capital for renewable energy while winding down conventional operations”.²⁰⁶ In May 2016, Moody’s downgraded RWE, as its “generation fleet is primarily fixed-cost in nature, with over half of output represented by lignite and nuclear, making it exposed to movements in wholesale power prices as RWE’s hedges roll off” as well as concerns over the risks associated with nuclear liabilities and political expose to its coal and lignite generation.²⁰⁷ RWE shares lost about 85 percent of their value since they peaked in January 2008 (see Figure 21).

Figure 21: RWE (DE) Share Price Development 2006–2016



Source: Yahoo Finance, July 2016²⁰⁸

Vattenfall, which owns significant capacity in Sweden and Germany, is also suffering and its outlook according to Moody’s and S&P is negative. This is in part due to lower fuel prices, but also, to exposure to carbon pricing, given its ownership, although it is trying to sell it, of significant lignite capacity in Germany and uncertainty over nuclear decommissioning policy also in Germany.²⁰⁹

The fragility of the European utilities and the impacts of nuclear construction are extremely pronounced in Finland with the impact of Olkiluoto on Teollisuuden Voima Oyj (TVO). The reactor should have been completed in 2009, but is now scheduled for completion in 2018 and has experienced a considerable cost over-run (see Finland section in Annex 1 for further details). As

²⁰⁶ Nikki Houston, “RWE’s Supervisory Board Approves Company’s Split”, *Wall Street Journal*, 11 December 2015, see <http://www.wsj.com/articles/rwes-supervisory-board-approves-companys-split-1449840584>, accessed 1 July 2016.

²⁰⁷ Moody’s, “Moody’s downgrades RWE to Baa3/P-3; stable outlook”, 13 May 2016.

²⁰⁸ Data extracted from Yahoo Finance refers to RWE’s share value performance on the Frankfurt Stock Market (RWE.F). Percentage change is calculated on the basis of the closing price on 2 January 2006.

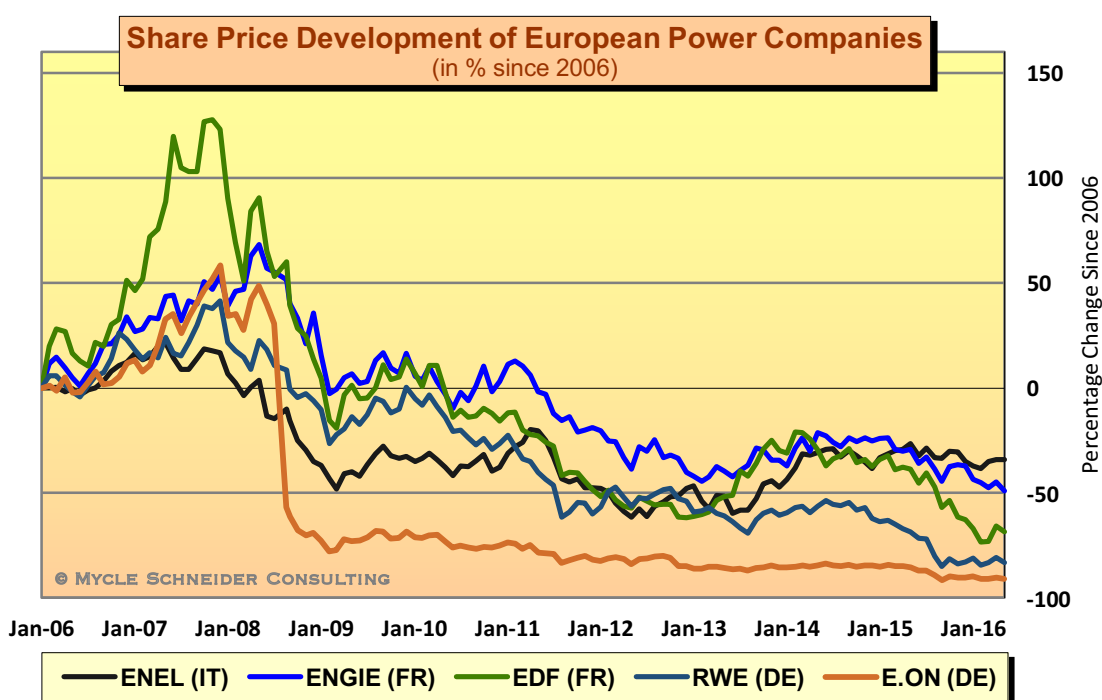
²⁰⁹ Moody’s, “Moody’s confirms Vattenfall’s A3 rating; negative outlook”, 13 May 2016.

this news emerged year on year, it has had a negative impact on the company's credit ratings. In May 2016, S&P lowered its rating for the company to 'BB+/B' from 'BBB-/A-3'. 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 2018/2019.²¹⁰

In 2009, the Fitch Long term rating was A-, but by May 2016 it had fallen to BBB with a negative outlook.²¹¹ Fitch also revised its outlook for TVO from stable to negative in May 2016 and said that it may downgrade the rating in the next 12 to 18 months depending support from the shareholders with particular concern “when the Olkiluoto 3 (OL3) nuclear power plant will be commissioned in late 2018, leading to substantially higher electricity production costs”.²¹² TVO's rating by Fitch and S&P is now just two notches above “junk”.

Figure 22: Share Price Development of European Power Companies



Source: Yahoo-Finance, Google Finances, 2016²¹³

This news should be particularly troublesome for those building or considering building nuclear power plants, as the perceived wisdom was that the main financial risk was during construction and that once operational, the financial risks would decline. However, these agencies are highlighting a danger that, once complete, the reactors are unlikely to be profitable, which may well

²¹⁰ S&P, “Finland-Based Nuclear Power Producer TVO Downgraded To 'BB+' From 'BBB-' On Reduced Cost Competitiveness; Outlook Stable”, 23 May 2016.

²¹¹ Fitch, “Fitch Revises Teollisuuden Voima Oyj’s Outlook to Negative; Affirms at 'BBB'”, 18 May 2016.

²¹² Ibidem.

²¹³ Share prices represented here are in general closing prices and based on the following stock markets: ENEL: “ENEL.MI” Milan Stock Market; ENGIE: “ENGIE.PA” Paris; EDF: “EDF.PA”, Paris; RWE: “RWE.DE”, XETRA market; E.ON: “E.OAN.DE” XETRA market

apply across the whole European market and therefore raise concerns for the other construction projects, in France, Slovakia and even Belarus, who plans to sell into the Baltic market.

ENEL, which is primarily an Italian company, but with other European assets including in Spain and Slovakia, is one of the few European power companies deemed by the credit agencies to have a stable outlook. This is primarily because despite falling power prices, “Enel's earnings exposed to merchant generation in Europe is low relative to other European utilities”. Moody's estimates that approximately 70 percent of group EBITDA comes from a combination of regulated/contracted activities that support cash flow stability'.²¹⁴

In Central Europe, the large centralized utilities are also suffering. In April 2016, Moody's downgraded the Czech Utility, CEZ, as it said its generating fleet was “predominantly fixed-cost in nature, with around 90 percent of output represented by lignite, nuclear and hydro, thus making it particularly exposed to movements in wholesale power prices”.²¹⁵

The falling revenues and negative outlook from the rating agencies is mirrored in the stock market, with European stock market prices for major utilities falling since the turn of the decade, as can be seen in Figure 22. Of the five selected decade companies, only ENEL of Italy has retained most of its value, still losing one third of its value a decade ago.

In Japan the power companies are financially suffering, which is not surprising given the immediate impact that Fukushima had on the power companies with the closure of all of the country's nuclear power stations. However, what is now also clear is that the longer term political impacts with the introduction of market liberalization may affect the longer term viability of the incumbent utilities. This raises concerns over the longer term viability of the companies, as Moody's notes on the proposed reforms that, “the utilities' relatively high ratings have been underpinned by their protected monopoly position, and a supportive and relatively predictable regulatory framework”.²¹⁶

In April 2016, the next wave of Japanese electricity market liberalization entered into force, this enabled non-commercial customers to choose their electricity supply for the first time. In response to this some of the previously monopolistic regional power companies are proposing restructuring. For example, Tokyo Electric Power Corporation (TEPCO), has adopted a new business slogan “Energy for Every Challenge”, and established a holding company, which will continue to own the nuclear, hydro and other renewables, with three additional subsidiaries; fuel and thermal power generation, general power transmission and distribution and retail electricity.²¹⁷ Moody's have stated that the restructuring will have no impact on their ratings.²¹⁸ However, as the operator of Fukushima, TEPCO's credit rating and financial outlook in general has experienced massive downward turn as a result of the accident.

The situation is very different in Korea, where the Korean Electric Power Corporation (KEPCO), remains in a strong position due to its virtual monopoly of generation (85 percent), through its

²¹⁴ Moody's, “Moody's affirms Enel's Baa2 ratings; outlook stable”, 13 February 2016.

²¹⁵ Moody's, “Rating Action: Moody's downgrades CEZ's rating to Baa1; outlook stable”, 6 April 2016.

²¹⁶ Moody's, “Moody's: Proposed reforms for Japan's electric sector could weaken the utilities' credit quality”, 30 September 2015.

²¹⁷ *Metering & Smart Energy International*, “TEPCO readies itself for Japan's electricity market deregulation”, 23 May 2016, see http://www.metering.com/magazine_articles/tepco-readies-japans-electricity-market-deregulation/, accessed 1 July 2016.

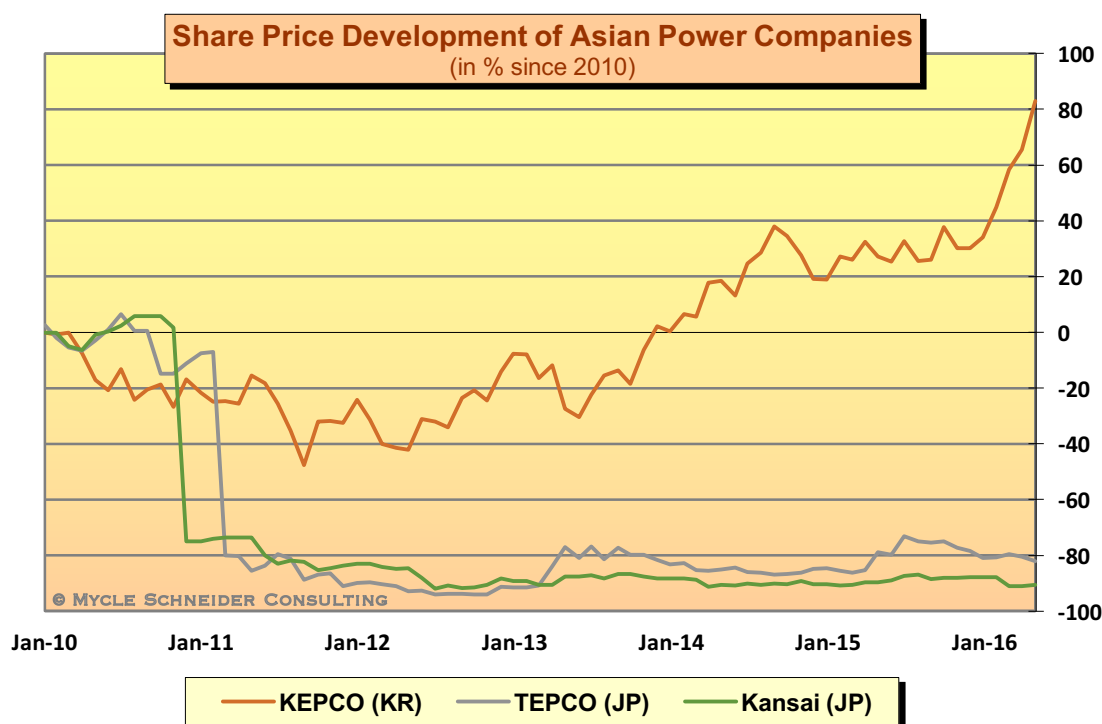
²¹⁸ Moody's, “Moody's: No rating impact from TEPCO's corporate restructuring”, 1 April 2016.

ownership of the six generating companies as well as its monopoly operation of the transmission and distribution systems. Furthermore, with falling fossil fuel costs and the absence of an automatic pass-through to customers, its earning almost doubled in 2015. Consequently, Moody's have noted that the strong operating results support a stable outlook rating.²¹⁹

The difference between the Japanese and Korean utilities can be seen in Figure 23, which track the share of top two Japanese companies TEPCO and Kansai Electric and the Korea virtual monopoly KEPCO. The impact on the share prices of the Japanese companies of the beginning of the Fukushima catastrophe in March 2011 is clear and expected. However, the failure to show any recovery in the intervening five years is remarkable. This is likely to be for a variety of reasons including: the failure to restart a significant number of reactors and the ongoing uncertainty over the future role for nuclear power; the introduction of new electricity market liberalization legislation, opening up the market to new actors; and the development of new technologies, enabling decentralized power production and storage. In Korea, KEPCO remains in a regulated market and has been able to increase its revenue significantly in the past 12 months, hence its rapid upturn in its share value.

Figure 23: Share Price Development of Asian Power Companies

(in % since 2010)



Source: Yahoo Finances, Google Finances, 2016²²⁰

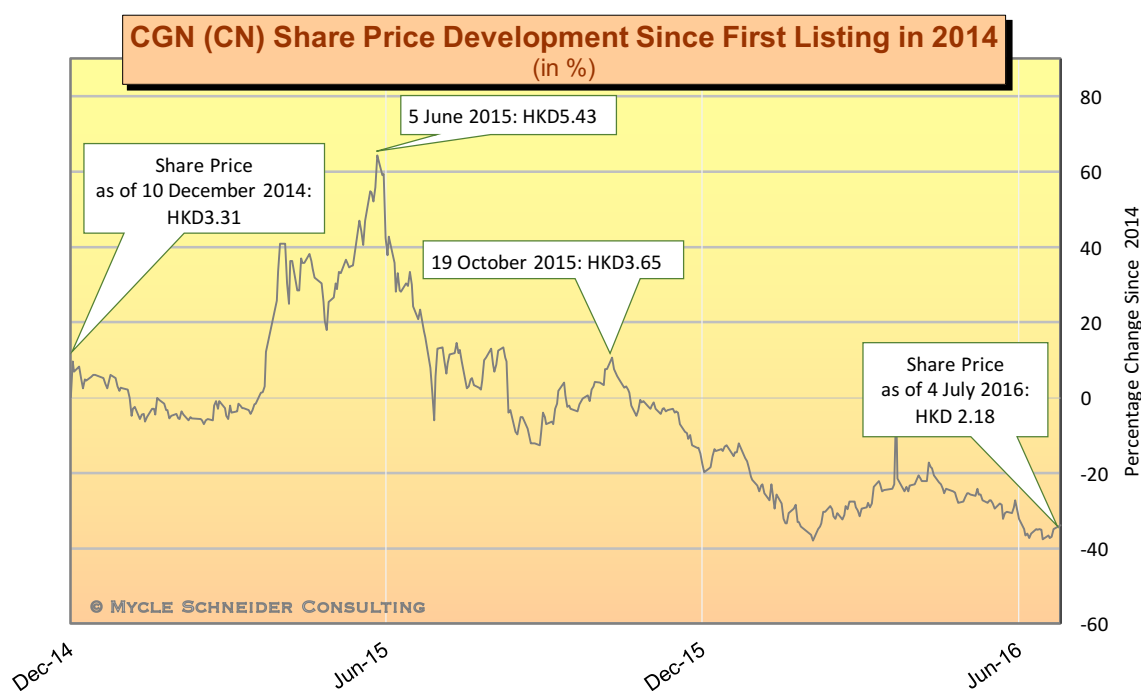
China General Nuclear Corporation (CGN), one of the three nuclear operators in China, was established in 1994 and is wholly owned and directly supervised by the State-owner Assets

²¹⁹ Moody's, "Moody's: KEPCO's robust 2015 results uphold company's credit quality", 5 February 2016.

²²⁰ Share prices represented here are in general closing prices and based on the following stock markets: KEPCO: "KEP" New York Stock Exchange market; TEPCO: "TKECF"; and Kansai: "KAEPY", Other OTC market.

Supervision and Administration Commission under China's State Council. A CGN subsidiary, CGN Co Ltd, was established in March 2014 and in December 2014, the company made its first public listing, which raised US\$3.16 billion and was deemed credit positive by Moody's. The ownership of the company is 64 percent by CGN, 24.56 percent by Hong Kong Shareholders, 7.54 percent by Hengjian Investment and 3.70 percent by China National Nuclear Corporation.²²¹ In May 2015, Moody's said of CGN, when reviewing its proposed bond for a wholly owned subsidiary: "CGN's standalone credit metrics will remain weak for the next two to three years, given its massive capital expenditure pipeline, potential delays in projects and slowing electricity demand growth in China." The rating agency also stated that CGN's outlook remained stable, reflecting that "the company will not undertake further aggressive debt-funded acquisitions or expansion".²²² In July 2015, Moody's assigned a definitive rating, of A3, to the US\$600 million bond, which was said to be for "refinancing short term borrowings, replenish working capital and for general corporate purposes."²²³ The share price of CGN Corporation's subsidiary, CGN Co. Ltd, on the Hong Kong stock exchange, has fallen by 60 percent since June 2015, as can be seen in Figure 24.

Figure 24: CGN Co Ltd. (China) Share Price Development Since First Listing



Source: Yahoo Finance, July 2016

In June 2016, Exelon, announced that it was going to shut down the reactor at Clinton Power stations in June 2017 and the two reactors at Quad Cities station in June 2018 since it had failed to get the financial support from the State of Illinois, as the power plants had lost a total of US\$800 million over the past seven years. One utility analyst was quoted as saying: "The lesson

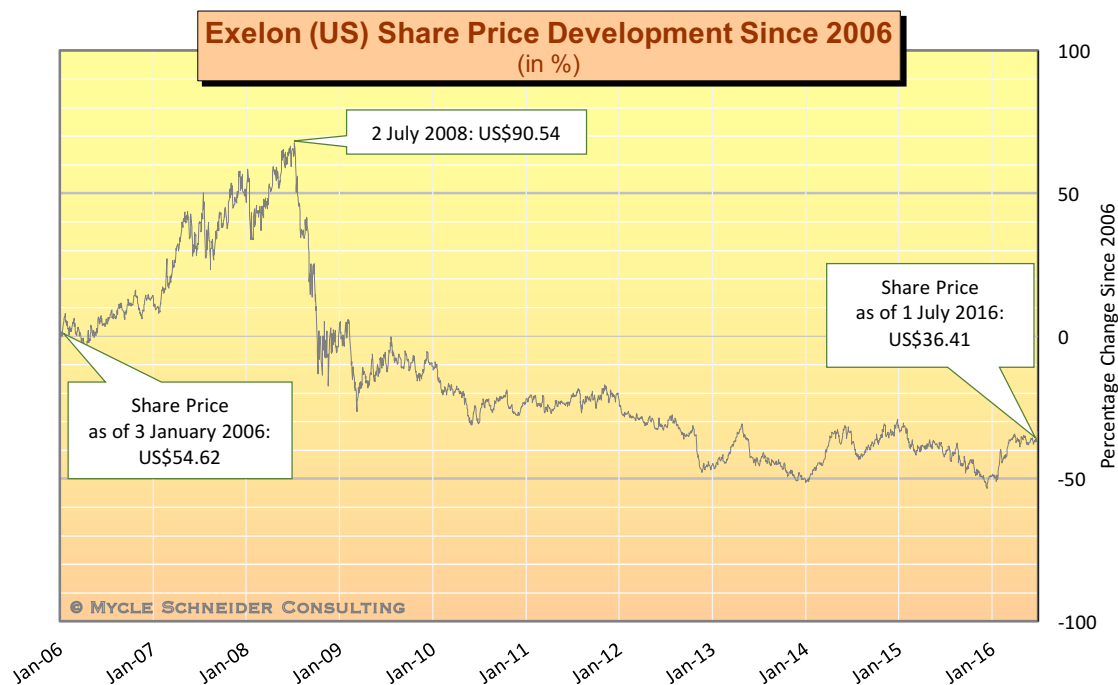
²²¹ CGN, "Annual Report 2014", March 2015.

²²² Moody's, "Moody's assigns (P)A3 to China General Nuclear's proposed USD bond ", 6 May 2015.

²²³ Moody's, "Moody's assigns definitive A3 to China General Nuclear's guaranteed bonds", 31 July 2015.

here is that there's not going to be much subsidizing of merchant nuclear plants."²²⁴ Exelon shares lost about 40 percent compared to their level a decade ago and they are over 60 percent below their peak level in 2008 (see Figure 25).

Figure 25: Exelon (US) Share Price Development 2006-2016



Source: Yahoo Finances, July 2016²²⁵

All four reactors under construction in the U.S. are being built in regulated markets. Two of these are being built by Georgia Power at the Vogtle site. In May 2016 Moody's downgraded its parent company, Southern Company from Baa1 to Baa2—just two notches above “junk”—as a result of its acquisition of AGL Resources and the additional debt it was taking on. However, Moody's noted that Southern's financial position had been weakened over a number of factors, including the Vogtle site “that has experienced costs increases and delays, with commercial operation currently three years behind schedule.”²²⁶

Nuclear Builders and Vendors

In addition to the utilities, the nuclear builders and vendors are suffering in part as a result of the changes in the power market. The traditional reactor suppliers, namely, AREVA, Atomic Energy of Canada Limited (AECL), Westinghouse and General Electrics (GE), are losing what remains of the

²²⁴ Bloomberg, “Exelon Shutting Two Nuclear Plants After Legislation Fails”, 2 June 2016, see <http://www.bloomberg.com/news/articles/2016-06-02/exelon-closing-2-illinois-nuclear-plants-after-legislation-fails>, accessed 1 July 2016.

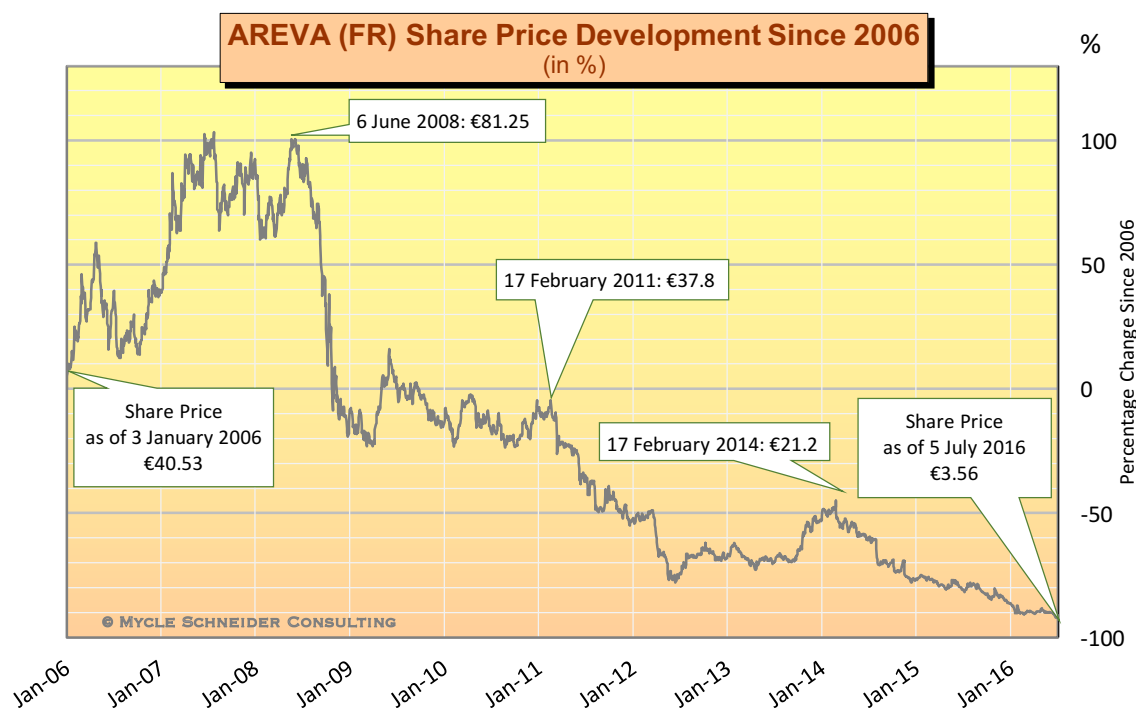
²²⁵ Data extracted from Yahoo Finance refers to Exelon's share value performance on the New York Stock Exchange Market (EXC). Percentage change is calculated on the basis of the closing price on 3 January 2006.

²²⁶ Moody's, “Moody's downgrades South Company to Baa2 stable; affirms subsidiary ratings and outlooks”, 14 May 2016.

export market to countries such as China, Russia and South Korea, (see Potential Newcomer Countries), which is partly due to their greater ability to potentially access (cheaper) finance.

Over the past few years, AREVA has experienced wide-ranging financial problems, which are reflected in its credit rating. S&P downgraded AREVA to “junk” (BB+) in November 2014²²⁷, and by another two notches in March 2015, deep into the speculative domain (BB-).²²⁸ Then in December 2015, following further revelations on the extent of its financial problems S&P’s downgraded the stock further to B+.²²⁹

Figure 26: AREVA Share Price Development 2006-2016



Source: Investing, June 2016²³⁰

The rising debt—from €4.47 billion (US\$5.4 billion) in 2014, to €6.32 billion (US\$7 billion) in 2016—and lack of financial credibility has led the Government to propose that the company’s reactor construction arm, AREVA NP, become incorporated into EDF²³¹, the details of which are still to be finalized (see Focus France section). However, the impact of these developments can be seen

²²⁷ S&P, “French Nuclear Group AREVA Downgraded To ‘BB+/B’ On Expected More Negative Cash Flows; Outlook Negative”, 20 November 2014.

²²⁸ S&P, “French Nuclear Group AREVA Downgraded to ‘BB-’ on Further Profit Challenges and Cash Burn; Outlook Developing”, 5 March 2015.

²²⁹ Reuters, “S&P says Areva downgraded to ‘B+’ – RTRS”, 22 December 2015, see <http://www.reuters.com/finance/stocks/AREVA.PAp/key-developments/article/3314652>, accessed 1 July 2016.

²³⁰ Data extracted from Investing.com refers to AREVA’s share value performance on the Paris stock market. Percentage change is calculated on the basis of the closing price on 2 January 2006.

²³¹ Areva, “Annual Results”, Press Release, 26 February 2016, see <http://www.areva.com/finance/liblocal/docs/2016/PR%20AREVA%202015%20annual%20results%20%20VUK.pdf>, accessed 26 May 2016.

in the evolution of AREVA’s share price, which, as of early July 2016, is 96 percent lower than it was in June 2008 (see Figure 26).

The nuclear industry in Russia is largely state owned and operated. However, Rosatom State Atomic Energy Corporation of Russia is the 100 percent owner of the joint stock company JSC Atomenergoprom, which is rated by the major credit agencies. In January 2015, S&B downgraded the company to BB+ (“junk”). In April 2016, it was given a negative outlook by Moody’s, primarily in response to the sovereign credit ratings of the Russian Federation as a whole, but the rating company warned that “the lack of adequate liquidity could put pressure on the company’s rating.”²³² This is particularly important given that Rosatom stated that it is currently building nine reactors in Russia and an additional 11 overseas (with said to a total of 29 reactors in the portfolio). They further stated that the overseas order portfolio is worth US\$101.4 billion.²³³

Table 5: Standard and Poor’s Long-Term Credit Rating of Major Nuclear Vendors

Company	Latest Rating	Outlook	2016 May	2015 May	2014 June	2013 June	2012 June	2011 April	2010	2009
Atomenergoprom (Rosatom)	January 2015	Negative	BB+	BB+	BBB-	BBB	BBB	BBB-	BBB-	BBB-
AREVA	May 2016	Developing	B+	BB-	BBB-	BBB-	BBB-	BBB+	BBB+	A

Sources: Standard & Poor’s, Companies’ Annual Reports

Toshiba purchased Westinghouse from British Nuclear Fuels Limited in 2006 for US\$5.4 billion. In April 2016, it announced that it expected to have US\$2.3 billion in impairment losses, in recognition that it had overpaid for the company and falling revenues. Toshiba’s current fiscal year estimate for sales revenue from the nuclear firm is US\$3.1 billion in 2015/6 — US\$540 million below what it was in November 2015 and US\$180 million below what the company projected in March 2016.²³⁴ Even before the latest financial situation had come to light, Toshiba admitted that it was looking for a partner so that it would reduce its 87 percent ownership of Westinghouse.²³⁵

Atomic Energy of Canada Limited, is one of the world’s largest nuclear constructors, with sales across the world, including in Europe, Asia and the Americas. However, AECL, is a federal Crown corporation and so is not listed on stock exchanges or given rating by the Agencies.

²³² Moody’s, “Moody’s concludes ratings reviews on 12 Russian utilities and infrastructure GRI and subsidiaries”, 27 April 2016.

²³³ Rosatom, “Annual Public Report 2014”, see <http://www.rosatom.ru/upload/iblock/661/661e5b99fa4ad0eca00bfde76055b503.pdf>, accessed 13 June 2016.

²³⁴ Power Source, “Westinghouse worth \$2.3 billion less, Toshiba says”, *Pittsburgh Post-Gazette*, 26 April 2016, see <http://powersource.post-gazette.com/powersource/companies/2016/04/26/Westinghouse-value-now-2-3-billion-less-Toshiba-says/stories/201604260158>, accessed 30 May 2016.

²³⁵ Reuters, “Amid accounting probe, Toshiba may sell Westinghouse shares: sources”, 9 July 2015, see <http://www.reuters.com/article/us-toshiba-accounting-divestiture-idUSKCN0PI2UA20150709>, accessed 1 July 2016.

Conclusion on Corporate Finances

The power sector is in a period of transformation as the need for decarbonization is leading to the larger deployment of renewable and greater energy efficiency. This, coupled with falling fossil fuel prices, is reducing the revenues of the traditional utilities, that until recently had remained focused on maximizing profits from its existing infrastructure.

Furthermore, already, in systems with higher levels of deployment of solar and wind power and other variable renewables the operational regime and economic profile of the power market has changed. This has been increasing the need for flexible generation and reduced the need for base-load capacity such as nuclear and coal. Further reducing the opportunities for further nuclear power deployment, as illustrated by the technical and/or economic problems of the world's most experienced nuclear exporters.

These factors are recognized by, and being acted upon by the financial community, with negative outlooks for many power companies particularly for those without regulated prices for conventional power. However, even in regulated market, the onward drive of new technologies is expected, by analysts, investors and the industry itself, to be only a temporary block of the development of a new power market, driven by new market actors and technologies and greater customer engagement.

In some countries, the extent of these have been recognized and the existing incumbents are restructuring to develop business models to sell; energy services, rather than just kWhs; balancing services; and smaller, often decentralized generation units. However, this is not always these case and many are retrenching and are unwilling to reform, which is likely to threaten their economic stability.

Chernobyl+30 Status Report

“The magnitude and scope of the disaster, the size of the affected population, and the long-term consequences make it, by far, the worst industrial disaster on record. Chernobyl unleashed a complex web of events and long-term difficulties, such as massive relocation, loss of economic stability, and long-term threats to health in current and, possibly, future generations....”

IAEA/WHO; 26 July 2005²³⁶

General Overview of the Chernobyl Site

The Chernobyl Power Complex, (ChNPP) owned and operated by the state company Energoatom, is situated about 130 km north of Kiev, Ukraine, and about 20 km south of the border with Belarus, and consisted of four RBMK-1000 (*reaktor bolshoy moshchnosty kanalny* or high-power channel reactor) a 1000 MWe pressurized light-water cooled reactor with individual fuel channels, and using graphite as moderator.

The first unit, commissioned in 1977, was followed by unit 2 in 1978, unit 3 in 1981, and unit 4 in 1983. Unit 1 was subject to a partial core meltdown on 9 September 1982 and was repaired.²³⁷ Contamination was observed in the area within 14 km radius but no public information was disclosed about the accident at the time.

Two more reactors, units 5 and 6, were under construction at the time of the 1986 accident. Unit 5 was then about 70 percent complete and was scheduled to start operation on 7 November 1986. However, construction work was halted and eventually cancelled in April 1989. Unit 6 was never completed.

The three remaining units, resumed operation a few days after the 1986 accident. Unit 2 was shut down in 1991 following a major fire in the turbine hall.²³⁸ Unit 1 was shut down in November 1996, and unit 3 in 2000.

²³⁶ IAEA/WHO, “Health Effects of the Chernobyl Accident and Special Health Care Programs Report of the UN Chernobyl Forum”, Expert Group “Health” (EGH), Working draft, 26 July 2005.

²³⁷ In 2001, the Security Services of Ukraine (SSU) published a report on the 1986 nuclear accident in Chernobyl, which included documents concerning the partial meltdown of the Chernobyl nuclear power reactor number 1 on 9 September 1982. The report consisted largely of documents from the files of Soviet KGB archives. The report written by Voldymyr Tykhyy was entitled “From Archives of VUChK-GPU-NKVD-KGB Chernobyl Tragedy in Documents and Materials”. In May 2008, a Summary was edited and featured pp. 252-263: T. Imanaka, “Many-sided Approach to the Realities of the Chernobyl NPP Accident: Summing-up of the Consequences of the Accident Twenty Years After (II)”, Kyoto University, Research Reactor Institute. See : Volodymyr Tykhyy, “From Archives of VUChK-GPU-NKVD-KGB Chernobyl Tragedy in Documents and Materials (Summary)”, see <http://www.rri.kyoto-u.ac.jp/NSRG/reports/kr139/pdf/tykhyy-2.pdf>, accessed 5 June 2016.

²³⁸ *The New York Times*, “Fire Reported in Generator Area At the Chernobyl Nuclear Plant”, 12 October 1991, see <http://www.nytimes.com/1991/10/12/world/fire-reported-in-generator-area-at-the-chernobyl-nuclear-plant.html>, accessed 1 July 2016.

Sequence and Origin of the Accident on 26 April 1986

The Chernobyl nuclear accident happened on 26 April 1986 at 01.23 a.m. in the course of a technical test in unit 4. The “beyond design-basis accident” was caused by inappropriate reactor operation at low-power level. The reactor was under extremely unstable conditions because of the withdrawal of almost all control rods. This was a very dangerous operation in RBMK reactors as these had positive void coefficients, meaning that runaway nuclear reactions could take place. This duly occurred with the result of a sudden power surge, and, when an emergency shutdown was attempted by inserting the remaining control rods, a much larger spike in power output—output increased about 100-fold in about four seconds—which led to at least two massive steam and hydrogen explosions and the rupture of the entire reactor vessel and a major conflagration. This released a large volume of radioactive gases, aerosols and particulates into the atmosphere. Radionuclides released from the explosion included very short-lived fission products, which resulted in very high dose rates in adjacent areas.

These events exposed the reactor’s graphite moderator (1600 tons) to air, causing it to ignite. After the initial release, larger releases of radionuclides occurred over a period of 10 days due to the continuous graphite fire. It has been estimated that the explosions and fires released about a third of the reactor’s radioactive inventory into the atmosphere and across much of Europe.

The accident was classified as a level 7 event (the maximum classification) of the IAEA’s International Nuclear Event Scale (INES).

Onsite Challenges

Following two explosions, the first being the initial steam explosion, followed a few seconds later by a second explosion, possibly from the build-up of hydrogen due to zirconium-steam reactions, a significant part of the fuel, the graphite and structural materials were ejected. One worker, whose body was never recovered, was killed in the explosions, and a second worker died in hospital a few hours later as a result of injuries received in the explosions.

Fires started in what remained of the unit 4 building, giving rise to clouds of steam and dust, and fires also broke out on the adjacent bitumen covered turbine hall roof. The chimney effect of the ten-day-lasting graphite fire ejected smoke, radioactive fission products and debris from the core and the building several kilometers into atmosphere. The heavier debris was mostly deposited within 5 km of the site, but lighter components, including most fission products and noble gases, and were blown by the prevailing winds to create the radioactive plumes, which contaminated over 40 percent of the land area of Europe.

A first group of 14 firemen arrived on the scene of the accident on 26 April 1986 at 01:28. Over 100 fire fighters from the site and called in from Pripyat were deployed, and it was this group that received the highest radiation exposures. Reinforcements were brought in until about 04:00, when 250 firemen were available and 69 firemen participated in fire control activities. According to corroborating reports from various sources,²³⁹ the fires on the roofs of units 3 and 4 were localized

²³⁹ See for example WNA, “Sequence of Events—Chernobyl Accident Appendix 1”, Updated November 2009, see <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/appendices/chernobyl-accident-appendix-1-sequence-of-events.aspx>, accessed 4 June 2016; and INSAG-7, “The Chernobyl Accident: Updating of INSAG-1”, International Nuclear Safety Advisory Group, IAEA, Safety Series No. 75-INSAG-7, 1992.

at 02:10 and 02:20 respectively, and the fire was quenched at 05:00. Unit 3, which had continued to operate, was shut down at this time, and units 1 and 2 were only shut down in the morning of 27 April.

The main challenges were to prevent the fire from spreading to unit 3, to localize the fire on the roof of the common machine hall of units 3 and 4, to protect the undamaged parts of unit 4 (the control room, inside the machine room, the main circulating pump compartments, the cable trays), and to protect the flammable materials stored on-site, such as diesel oil, stored gas and chemicals.

Figure 27: Graveyard of Abandoned Highly Contaminated Trucks and Helicopters



Source: chnpp.gov.ua

On 28 April 1986, a massive accident management operation began. This involved dropping large amounts of different materials, each one designed to combat a different source of the fire and the radioactive release. The first measures taken to control fire and the radionuclides releases consisted of dumping neutron-absorbing compounds and fire-control material into the crater that resulted from the destruction of the reactor. The total amount of materials dumped on the reactor was about 5,000 t including about 40 t of boron carbide, 2,400 t of lead, 1,800 t of sand and clay, and 800 t of dolomite. About 1,800 helicopter flights were carried out to dump materials onto the reactor (see Figure 27).

During the first flights, the helicopter remained stationary over the reactor while dumping materials. As the dose rates received by the helicopter pilots during this procedure were too high, it was decided that the materials should be dumped while the helicopters travelled over the reactor. This procedure caused additional destruction of the standing structures and spread the contamination. Boron carbide was dumped in large quantities from helicopters to act as a neutron absorber and prevent any renewed chain reaction. Dolomite was also added to act as heat sink and

a source of carbon dioxide to smother the fire. Lead was included as a radiation absorber, as well as sand and clay, which it was hoped would prevent the release of particulates.

A system was installed by 5 May to feed cold nitrogen to the reactor space, to provide cooling and to blanket against oxygen thus avoiding further hydrogen explosions. By 6 May when most of the graphite had burned, the core temperatures fell and there was a sharp reduction in the rate of radionuclide releases. In addition, work began on a massive reinforced concrete slab with a built-in cooling system beneath the reactor. This involved digging a tunnel from underneath unit 3. About 400 people worked on this tunnel, which was completed in 15 days, allowing the installation of the concrete slab. This slab would not only be of use to cool the core if necessary, it would also act as a barrier to prevent penetration of melted radioactive material into the groundwater.

In addition to the two workers that had died from the explosions on the day of the accident, by the end of July, six firemen, a further 21 plant staff and a visitor had died of acute radiation poisoning as a result of the accident.

Following the accident and the large contamination by the radioactive cloud, a 2,800 km² exclusion zone designated for evacuation has been established and placed under military control. More than 130,000 people were moved out of their homes and villages in the immediate aftermath of the accident. But many more people were eventually displaced. The U.N. Office for the Coordination of Humanitarian Affairs (OCHA) stated in 2004: “Nearly 400,000 people were resettled but millions continued to live in an environment where continued residual exposure created a range of adverse effects.”²⁴⁰

While units 1, 2, 3, unaffected by the explosions, resumed operation a few weeks later, the Soviet army engaged (and poorly trained) more than 550,000 workers called the “liquidators”, who were engaged in the disaster management. Their tasks included evacuation of contaminated debris, cleaning emergency areas, repairing equipment and buildings etc.

Dispersion of Radioactivity

The graphite fire at unit 4 caused the ejection of radioactive gases, aerosols and particulates high into the atmosphere. These were distributed in plumes by prevailing winds and rainfall throughout Europe and eventually across the northern hemisphere. The consequent caesium-137 fallout patterns in Europe were later measured by the European Commission (see Figure 28).

In total, 40 percent of Europe’s land area was contaminated significantly (>4,000 Bq per m²) by Chernobyl’s fallout.²⁴¹ The most seriously affected countries (ranked by *magnitude* of Cs-137 fallout) were the former USSR Republics adjacent to the stricken reactor—Belarus, Russia and Ukraine.

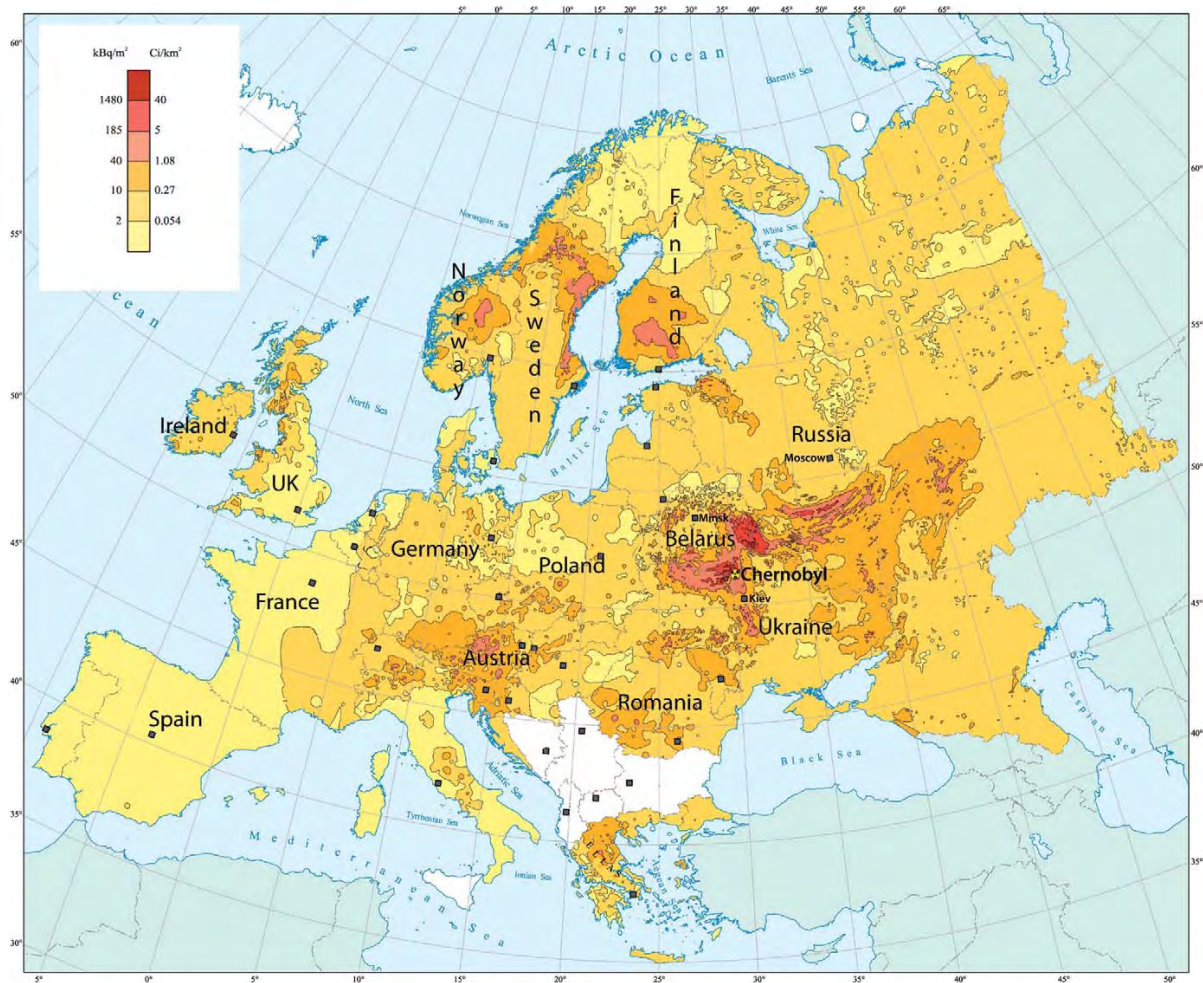
Other seriously affected countries were, in area size order, former Yugoslavia, Finland, Sweden, Bulgaria, Norway, Romania, Germany and Austria. Although former Yugoslavia was not measured by the EC teams (because of the Balkan civil war), earlier measurements had been made by the U.S. Department of Energy.

²⁴⁰ UN-OCHA, “Chernobyl: Needs great 18 years after nuclear accident”, 26 April 2004, see <http://reliefweb.int/report/belarus/chernobyl-needs-great-18-years-after-nuclear-accident>, accessed 1 July 2016.

²⁴¹ Ian Fairlie, “TORCH-2016—An independent scientific evaluation of the health-related effects of the Chernobyl nuclear disaster”, 31 March 2016, see https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf, accessed 4 June 2016.

In terms of the percentages of their land areas, which were contaminated, Austria, Finland, Sweden, Slovenia, and Slovakia were also significantly affected outside the former USSR.

Figure 28: Cesium-137 Concentrations in Europe in 1996 (in 1,000 Bq per m²)



Source: De Cort et al., 1998²⁴²

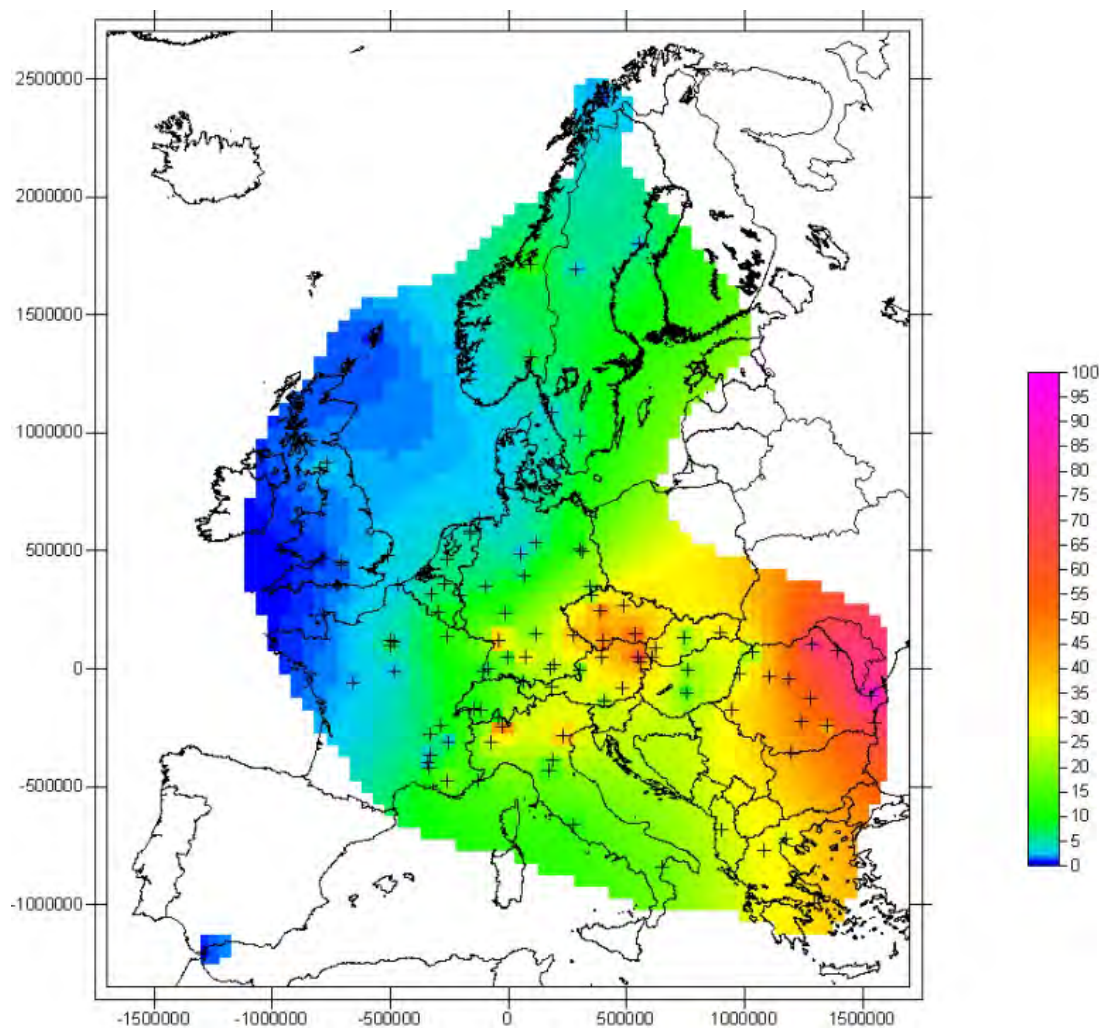
In terms of average Cs-137 concentrations (Bq per m²), Austria, Slovakia, Slovenia, and Moldova were also affected. The most relevant parameter for health was the average concentration of Cs-137 in diet during the year 1986 to 1987 and the countries (outside former USSR) with the highest levels were Austria, Moldova, Bulgaria, Croatia, Liechtenstein, Finland and Romania.²⁴³

As shown in Figure 29, radioiodine distribution patterns in Europe were very different from those for caesium-137. This is because the iodine isotopes were distributed largely in gaseous and aerosol forms and not as particulates.

²⁴² De Cort M, Dubois G, et al., "Atlas of Caesium Deposition on Europe after the Chernobyl Accident. EUR Report 16733", Office for Official Publications of the European Communities, Luxembourg.

²⁴³ V. Drozdovitch et al., "Radiation exposure to the population of Europe following the Chernobyl accident", *Radiation Protection Dosimetry*, Volume 123, Issue 4, 2007, pp 515– 528.

**Figure 29: Cumulative I-131 Concentrations in Air Over Europe in May 1986
(in Bq*d/m³)²⁴⁴**



Source: C. Seidel et al., 2012²⁴⁵

Populations Affected

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)²⁴⁶, over six million people still live in contaminated areas of Belarus, Russia and Ukraine. Over half a million clean-up workers were exposed to high doses at an average of 120 mSv (see Table 6).

²⁴⁴ Bq*d/m³ = becquerels x days per cubic metre of air

²⁴⁵ Claudia Seidel et al, "25 Jahre Tschernobyl—Kurzfassung ; Gesundheitliche Folgen in Oberösterreich 25 Jahre nach Tschernobyl – neue Betrachtungen hinsichtlich der Inhalations- und Ingestionsdosis durch ¹³¹I und ⁹⁰Sr", Low Level Counting Labor Arsenal, University of Natural Resources and Applied Life Sciences of Vienna, (in German), 15 March 2016, see http://www.atomfreie.eu/fileadmin/Daten/Studiathek/2012_03_15_Tschernobylstudie_Kurzfassung_2012.pdf, accessed 7 July 2016.

²⁴⁶ UNSCEAR, "2008 Report to the General Assembly, with scientific annexes—Annex D Health Effects Due to the Chernobyl Nuclear Accident", United Nations, New York. Note: Although UNSCEAR's publication date was stated as 2008, the report was not released until 2011.

Table 6: Populations Exposed to Chernobyl Fallout: Average Effective Dose

Population	Number	Average Dose in mSv
Clean-up workers	530,000	120.0
Evacuees	130,000	31.0
Inhabitants of contaminated areas of Belarus, Russia and Ukraine	6,400,000	9.0
Inhabitants of Belarus, Russia and Ukraine	98,000,000	1.3
Inhabitants of Western Europe	500,000,000	0.3

Source: UNSCEAR 2008

Health Impacts

The Chernobyl accident resulted in epidemics of thyroid cancer in Belarus, Ukraine and Russia starting after 1990. Over 6,000 thyroid cancers have arisen so far²⁴⁷ and at least another 16,000²⁴⁸ are expected to arise in future decades. It is notable that radiogenic thyroid cancers are still occurring among the Japanese bomb survivors nearly 60 years after their exposures.²⁴⁹

In 2015, continuing increases in thyroid cancer cases were seen among adults in Belarus and Ukraine. The estimated thyroid cancer risks per gray (Gy)²⁵⁰ in the most contaminated areas are high, with relative risks of 8.7 per Gy in Belarus and 8.0 per Gy in Ukraine. This translates into 770 percent to 700 percent increases respectively over the background rates in these countries. The raised incidence rates for adults are expected to peak in the near future in Belarus but will continue above the pre-accident rates for many years. Similarly, 500 percent increases were observed in leukemia risk in both Belarus and Ukraine.²⁵¹ These are extraordinarily high risk increases, perhaps the largest increases in risk ever measured after exposures to toxic substances.

²⁴⁷ Ibidem.

²⁴⁸ Ian Fairlie, "TORCH-2016 — An independent scientific evaluation of the health-related effects of the Chernobyl nuclear disaster", 31 March 2016, see https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf, accessed 5 June 2016.

²⁴⁹ Imaizumi M. et al., "Radiation Dose-Response Relationships for Thyroid Nodules and Autoimmune Thyroid Diseases in Hiroshima and Nagasaki Atomic Bomb Survivors 55-58 Years after Radiation Exposure", *The Journal of the American Medical Association*, 1 March 2006, Vol. 295, No. 9, see <http://jama.jamanetwork.com/article.aspx?articleid=202461>, accessed 5 June 2016.

²⁵⁰ The gray (Gy) is a derived unit of ionizing radiation dose in the International System of Units. It is defined as the absorption of one joule of radiation energy per kilogram of matter. It is generally used for large dose assessments.

²⁵¹ Ivanov VK, Tsyb AF, et al., "Leukemia incidence in the Russian cohort of Chernobyl emergency workers", *Radiat Environ Biophys.*, May 2012.

In total, TORCH-2016 (The Other Report on Chernobyl) estimated that 40,000 fatal cancers will arise over the next 50 years from Chernobyl, about eight times greater than the expected number of fatal cancers from arising in future from Fukushima.

TORCH 2016 revealed new evidence of increased thyroid cancer cases in Austria, similar to previous indicative studies of increased thyroid cancers in the U.K., Czech Republic, Poland and Slovakia. TORCH 2016 estimated that between eight and 40 percent of increased thyroid cancer cases after 1986 in Austria may be due to Chernobyl.

After thirty years, sufficient time has elapsed for dose registries to observe statistically significant increases in other solid cancers including breast, colon, lung and kidney cancers. However, their relative risks, 20 percent to 50 percent per Gy, are about an order of magnitude lower than those observed for thyroid cancer and leukemia. The new evidence in TORCH 2016 indicates increased incidences of cardiovascular effects, stroke, mental health effects, birth defects and various other radiogenic effects in the most affected countries.

Recent studies provide strong evidence of decreased health indicators among children living in contaminated areas in Belarus and Ukraine, including

- impaired lung function and increased breathing difficulties²⁵²
- lowered blood counts²⁵³
- high levels of anemias and colds²⁵⁴ and
- raised levels of immunoglobulins²⁵⁵

²⁵² Svendsen E.R., Kolpakov I.E., et al., "Reduced Lung Function in Children Associated with Caesium 137 Body Burden", July 2015, *Annals of the American Thoracic Society*, Vol. 12, No. 7, pp 1050-1057, see <http://www.atsjournals.org/doi/abs/10.1513/AnnalsATS.201409-432OC?journalCode=annalsats>, accessed 6 June 2016.

²⁵³ Lindgren A, Eugenia Stepanova, et al., "Individual whole-body concentration of 137Caesium is associated with decreased blood counts in children in the Chernobyl-contaminated areas, Ukraine, 2008-2010", *Journal of Exposure Science and Environmental Epidemiology*, May/June 2015.

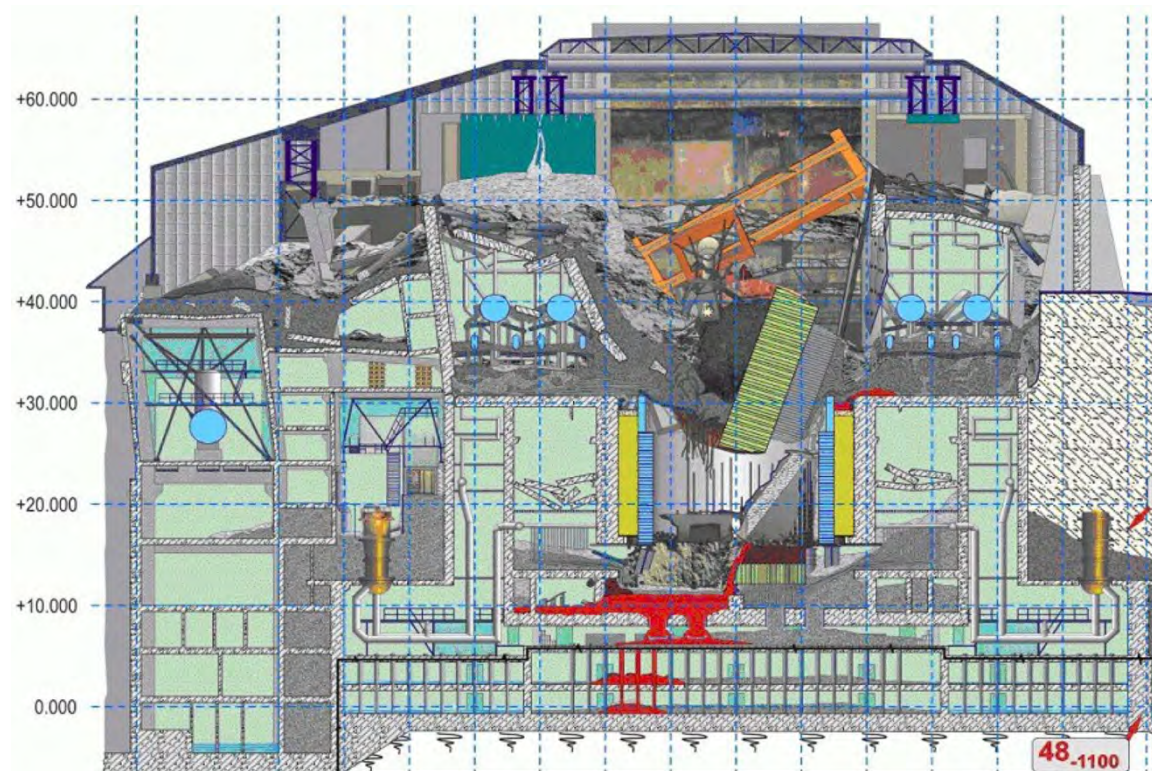
²⁵⁴ McMahon D.M., Vdovenko V., et al., "Dietary supplementation with radionuclide free food improves children's health following community exposure to 137 Caesium: a prospective study", *Environmental Health*, 22 December 2015, see <https://ehjournal.biomedcentral.com/articles/10.1186/s12940-015-0084-x>, accessed 6 June 2016.

²⁵⁵ McMahon D.M., Vdovenko V.Y., et al., "Effects of long-term low-level radiation exposure after the Chernobyl catastrophe on immunoglobulins in children residing in contaminated areas: prospective and cross-sectional studies", *Environmental Health*, 10 May 2014, see <https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-13-36>, accessed 6 June 2016.

The “Sarcophagus”

As it was impossible in the immediate aftermath of the initial explosions to work on the destroyed structure of the reactor, containing 200 tons of highly radioactive corium, 30 tons of highly contaminated dust and 16 tons of uranium and plutonium, three weeks after the accident it was decided as the first and urgent action to build a protection structure above the reactor to limit radioactive contamination and protecting it from climate exposure.

Figure 30: Cross Section of the “Sarcophagus”



Source: chnpp.gov.ua

The structure was called “sarcophagus” (see Figure 30) and was built by thousands of liquidators who participated in the construction mostly made of concrete slabs covering the entire structure.²⁵⁶ However, the sarcophagus was put together in haste under severe conditions and rapidly deteriorated in the following years.

G-7 Support of Shutdown of RBMK and VVER 440-230 Reactors

In 1993, the G7 launched an initiative on the prevention of nuclear accidents at Russian built plants and agreed that the European Bank for Reconstruction and Development (EBRD), establishes a fund aimed at the closure and decommissioning of the oldest Russian built nuclear power plants of the RBMK and VVER 440-230 types. The initiative initially included the plants of Ignalina-1 and -2

²⁵⁶ Greenpeace.org, “What happened in Chernobyl”, 20 March 2006, see <http://www.greenpeace.org/international/en/campaigns/nuclear/nomorechernobyls/what-happened-in-chernobyl/>, accessed 1 July 2016.

in Lithuania, Kozloduy units 1 to 4 in Bulgaria, Saint Petersburg units 1 to 4 in the Russian Federation and Bohunice-V1-1 and -2 in the Slovak Republic. In 1996, Chernobyl-4 was added to the scope. The fund contributors included the G7 countries, the EU, Belgium, Denmark, Finland, the Netherlands, Norway, Sweden and Switzerland. Initial contributions were in excess of €285 million (then about US\$330 million). As of 2016, 45 countries and the European Community are contributing grants for safety upgrades and decommissioning of the above nuclear power plants. The concept included for each plant a nuclear safety assessment, the implementation of essential short- and medium-term safety improvements and the final closure of the plants. Later on, an additional special fund was established for the decommissioning of each unit.^{257,258}

The Nuclear Safety Account team was created at EBRD with the purpose of establishing the safety assessment for each plant, identifying and designing the safety facilities to be built as well as the decommissioning procedures, drafting grants agreements between the EBRD, Chernobyl Nuclear Power Plant and the supplier and finalizing construction contracts. The team remains in charge of monitoring the projects and of verifying their compliance with the contracts.

EBRD Chernobyl Decommissioning/Spent Fuel Storage Program

This program has been developed by the Nuclear Safety Account team in cooperation with the European Commission TACIS program and following the grant agreements signed between the Bank and the Chernobyl Nuclear Power Plant.²⁵⁹ It includes the construction of an intermediate spent fuel storage facility, liquid and solid nuclear waste treatment plants and a long-term protection structure to cover unit 4.

An in-depth safety assessment was carried out of the local Intermediate Spent Fuel storage building (ISF-1), which was part of the original plant, and hosted most of the spent fuel assemblies from the four reactors prior to the 1986 accident. ISF-1 was found in poor conditions, judged unsafe and not suitable for the long-term as well as unable to meeting today's safety standards. Consequently, the decision was made to build a second, intermediate dry storage facility, called ISF-2 to be located 2.5 km south east of the Chernobyl plant, 12 km north-west from Chernobyl city. A turnkey contract to design and build the entire ISF-2 facility was signed in June 1999 between Energoatom and Framatome ANP (now AREVA NP), jointly with French construction giants Vinci and Bouygues. The system is based on the Transnuklear Nuhoms dry casks system.²⁶⁰

ISF-2 includes a Spent Fuel Processing Facility (SFPP) and the Spent Fuel Storage Area (SFSA), made of 232 above-ground Concrete Storage Modules (CSM). The storage employs 4,000 tons of reinforced steel, 2,700 tons of stainless steel and 26,000 cubic meters of concrete. The structure was designed to store dry fuel for a period of 100 years. A central geological repository for spent fuel and high-level waste is planned to be built after 2030. This plan also envisages the

²⁵⁷ State Specialized Enterprise (SSE) Chernobyl NPP, "ChNPP Decommissioning Strategy", Ministry of Ecology and Natural Resources of Ukraine and State Agency of Ukraine for an Exclusion Zone, see <http://chnpp.gov.ua/en/the-main-aspects-of-decommissioning>, accessed 1 July 2016.

²⁵⁸ EBRD, "Nuclear Safety Account", Undated, see <http://www.ebrd.com/what-we-do/sectors/nuclear-safety/chernobyl-nuclear-safety-account.html>, accessed 5 June 2016.

²⁵⁹ EBRD, "Nuclear Safety", February 2011, see <http://www.ebrd.com/downloads/research/factsheets/nuclear.pdf>, accessed 5 June 2016.

²⁶⁰ Jayant Bondre, "A Complete NUHOMS® Solution for Storage and Transport of High Burnup Spent Fuel", Transnuclear Inc. (AREVA Group), 14th International Symposium on the Packaging and Transportation of Radioactive Materials (PATRAM 2004), Berlin (Germany), 20-24 September 2004, see http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/37/088/37088556.pdf, accessed 5 June 2016.

decontamination of 1,500 hectares of land containing over 5,550 terabecquerel of activity. A railway was built to transport the spent fuel by train carriages.

Following the shutdown of the three operating plants, the total inventory accounted for 21,300 fuel bundles for a weight of 2,700 tons of uranium and 2,000 absorbers, partly still in the three units' cores, partly kept in the reactor cooling pools as well as transferred to the interim storage facility ISF-1. The fuel bundles and absorbers are inserted into a transfer flask and carried by a train carriage to the SFPF at the ISF-2 site. There they are introduced into a hot cell where the fuel bundle and absorbers are dried by means of a gas dehydration system and cut by means of a specially built cutting machine.

The Nuhoms system consists of an enclosure vessel comprising canisters forming separate confinements to prevent the spread of radioactive materials. Spent fuel bundles are introduced in an internal basket that is then included into a canister. Each canister is placed horizontally in the Nuhoms casks that are then introduced in individual compartments of the heavy concrete storage module built at the ISF-2 site.²⁶¹

Construction was due to be completed by March 2003. However, construction went on for about six years of construction until 2006 and several problems had arisen. Despite the near-completion of the processing building and the concrete housing structures for the Nuhoms casks, the work was interrupted due to design errors and negligence of the fact that water had penetrated through the cladding in more than 10 percent of the fuel assemblies. It was also found that the fuel included some reprocessed uranium and plutonium, for which a different neutron spectrum would require redesign of the storage shielding. Additional problems were caused by considerable cost overruns, which raised the investment into the project from an original €68 million (US\$64 million) to €275 million (US\$326 million).

In March 2006, US-based Holtec International submitted to ChNPP a feasibility study for drying the spent fuel that contained water and, in November 2006, conducted successful testing of the drying facility model. EBRD's Safety Review Group recommended that the donors continue funding the project with Holtec as the main contractor.

The Framatome ANP contract was terminated in April 2007²⁶² and following an international audit and arbitration, the company was requested to pay the client a compensation of €45 million (US\$59.4 million). In September 2007, Holtec signed a contract to complete the ISF-2. The facility's final design was approved by the Ukrainian Regulator in October 2010.

While still making use of the Nuhoms system, the project implements several Holtec technologies including an innovative double-wall canister, an advanced forced gas dehydration system, and a hot cell to dismantle the RBMK fuel assemblies. The first phase of work, which lasted 100 weeks, valued at slightly over €30 million (US\$41 million) involved the preparation of safety and environmental qualification documents in compliance with Ukrainian norms and standards.

The entire work, scheduled to span nearly eight years, involves the supply of 231 canisters manufactured at Holtec's plant in Pittsburgh to be delivered between 2016 and April 2019. The contract includes the construction of the processing facility, numerous physical modifications to the site, and issuance of the intermediate and final safety analysis reports.

²⁶¹ SSE Chernobyl NPP, "Interim Spent Nuclear Fuel Dry Storage Facility (ISF-2)", Undated, see <http://chnpp.gov.ua/en/decommissioning-projects/ongoing-projects/isf-2>, accessed 1 July 2016.

²⁶² *Le Journal de l'Énergie*, "Areva's incredible fiasco in Chernobyl", 17 February 2016, see <http://journaldelenergie.com/nucleaire/arevas-incredible-fiasco-in-chernobyl/>, accessed 1 July 2016.

The ISF-2 has been completed, pre-commissioning is scheduled to start in September 2016 and full-scale operation is to begin in the fourth quarter of 2017. The fuel loading will most likely be completed by 2022. The total cost of the facility is estimated at €400 million (US\$446 million).

Liquid Radioactive Wastes Treatment Plant

The LRWTP²⁶³ is a processing plant for liquid radioactive wastes stored during operation in five 5,000 m³ and nine 1,000 m³ tanks, as well as during the decommissioning operations. The liquids include perlites, resins and evaporator concentrates. The LRWTP also processes the liquids produced during the entire operations on site. The plant, designed by Belgian company Tractebel, was built by the consortium Belgatom (Belgium), Ansaldo (Italy), SGN (France) and by Ukrainian contractors. Construction has been completed in 2015 and has started operation. Total cost was about €35 million (US\$39 million).

Industrial Complex on Solid Radioactive Wastes Management

The Industrial Complex on Solid Radioactive Wastes Management (ICSRWM)²⁶⁴ includes the Temporary Solid and Liquid Waste Storage (SLWS) and Solid Waste Processing Plant (SWPP), comprising a plant for the sorting and segregation of all categories of solid radioactive waste and the processing of the solid waste generated from the previous retrieval activities and from the routine operational and decommissioning activities of unit 4. Short-lived wastes will be packaged and immobilized for final storage at a near surface disposal facility, whilst higher category wastes will be packaged, over-packed and stored in a temporary storage facility awaiting the construction of a final disposal facility.

A near surface repository for the disposal of short-lived waste, in accordance with the requirements of the Ukrainian Nuclear Regulatory Authorities and in the form of an Engineered Near-Surface Solid Radioactive Waste Disposal Facility (ENSWDF) is located at the Vektor Complex located in the Exclusion Zone. This facility has been built for the final disposal of conditioned LILW-SL and for wastes from the Liquid Radwaste Treatment Plant (LRTP). The storage capacity is 55,000 m³ and the design lifetime is 300 years.

The complex was designed and built by RWE NUKEM GmbH (Germany) with Ukrainian contractors. It was financed by Ukraine and the European Commission and has started operating. The total cost is €33.5 million (US\$37.3 million).

²⁶³ SSE Chernobyl NPP, "Liquid Radioactive Waste Treatment Plant (LRWTP)", Updated 1 February 2016, see <http://chnpp.gov.ua/en/decommissioning-projects/ongoing-projects/28-2010-09-13-07-21-32436>, accessed 5 June 2016.

²⁶⁴ SSE Chernobyl NPP, "Industrial Complex for Solid Radioactive Waste Management (ICSRM)", see <http://chnpp.gov.ua/en/decommissioning-projects/ongoing-projects/icsrwm>, accessed 5 June 2016.

Shelter Implementation Plan/New Safe Confinement^{265, 266, 267}

Following the construction of the “sarcophagus” above the destroyed unit 4, some additional work has been carried out in 1997 to minimize the risk of its collapse. A limited stabilization was achieved with great difficulties in high-radiation levels inside and outside the structure. Safety and protection of personnel and the environment has been improved since. A Fire Protection System and an Integrated Automated Control System have been installed with the purpose of monitoring the status of the shelter, including the “fuel containing material (FCM)” i.e. the corium, collected in the lower section of the reactor.

Additional work was carried out for the clearing of the site, the demolition of nearby buildings as well as construction of an “engineering building” for the management and control of all works. Also a computer-based system was introduced integrating radiation data, information on the structural integrity of the old shelter, measurements of seismic activities and other parameters important for the safety on site and for the future operation of the New Safe Confinement (NSC).

A new change facility with a capacity for 1,430 workers has been built which provides medical screening, training, radiation monitoring, supply of protection equipment as well as an ambulance.

However, these measures would still have not secured the long-term integrity of the structure as well as site safety. It was then decided to build an additional and major protection structure above the unit 4. This has been called the NSC.

The entire Shelter Implementation Plan has been financed separately by a new fund (Chernobyl Shelter Fund) created in 1997 and supported by 44 countries plus the European Union. As with the other fund, it is administered by EBRD and the project is managed by the Nuclear Safety Account team.

The word “confinement” is used instead of the traditional “containment” to emphasize the difference between the “containment” of radioactivity generated in case of an accident, and the “confinement” of radioactive waste that is the primary purpose of the NSC.

The NSC was designed and is being built by the French consortium Novarka with 50/50 partners VINCI Construction Grands Projects and Bouygues Travaux Publics. The contract was signed in August 2007 for an estimated amount of €1.4 billion (US\$1.9 billion). Due in particular to the complexity of the task in a radioactive environment, the budget for completion was increased to €1.54 billion (US\$2.2 billion) in April 2011. It is likely that the final total cost will exceed €1.8 billion (US\$2 billion).

The NSC design is an arch-shaped steel structure that has been designed to cover entirely the existing sarcophagus (see Figure 31). Requirements included the NSC’s resistance to the impact of seismic events of a magnitude of level 6, to tornado class 3 and to other heavy winds and snow loads. The dimensions of the arch were defined based upon the need to operate equipment inside the NSC and to dismantle the existing “sarcophagus”. A large crane and other remotely controlled equipment are installed inside and will be used to dismantle the sarcophagus and to attempt to

²⁶⁵ EBRD, “The Chernobyl Shelter Implementation Plan”, Undated, see <http://www.ebrd.com/what-we-do/sectors/nuclear-safety/chernobyl-shelter-implementation.html>, accessed 1 July 2016.

²⁶⁶ SSE Chernobyl NPP, “Project ‘New Safe Confinement Construction’”, Undated, see <http://chnpp.gov.ua/en/project-nsc-construction>, accessed 1 July 2016.

²⁶⁷ EBRD, “Chernobyl’s New Safe Confinement”, see <http://www.ebrd.com/cs/Satellite?c=Content&cid=1395236547173&d=Default&pagename=EBRD%2FContent%2FHublet>, accessed 1 July 2016.

remove the fuel-containing masses (corium) from the destroyed reactor. NSC is being assembled 600 meters away from the damaged reactor where, thanks to the remediation work over the past two decades, the relatively low ground-level radiation levels allow staff to work for up to 40 hours a week. It is planned to move the NSC above the sarcophagus and to commission it in 2017.

The dimensions of the New Confinement Structure are impressive. The internal height is 92.5 m, the external span is 257 m and the overall length of the structure is 162 m. The external cladding covers an area of 85,000 m². The NSC includes two bridge cranes of 50 t capacity suspended from the arch which have the purpose to carry out the deconstruction of the sarcophagus and the structure of the remaining reactor as well as handling of radioactive material. The cranes and other mechanical scrapping and removal equipment will be remotely operated from outside the NSC. All electrical and controls of the NSC are installed in the “engineering building” built nearby.

The NSC will be slid into its final position on a 300-meter rail system by 116 remote-controlled synchronized jacks. The sliding operation at a speed of 10 mph is expected to take two days. The final phase will include the sealing operations and interconnections between the NSC and the shelter. The New Safe Confinement has been designed and built for a 100-year lifetime. Total decommissioning may take several decades as the environmental contamination will last even longer.

Figure 31: The New Safe Confinement at Chernobyl



Source: chnpp.gov.ua

Fukushima+5 Status Report

Five years have passed since the Fukushima accident began in March 2011. The Japanese government has launched a reconstruction plan to recover from the Great East Japan Earthquake over the next five years. This chapter attempts to describe onsite and offsite challenges of the government's plan, including its impact on the people most affected by the disaster.

Onsite Challenges^{268,269}

Decommissioning Plan

In June 2015, the government revised, for the third time, the medium- and long-term roadmap for decommissioning, following the second revision made in June 2013. At that time approximately 800 m³/day of ground water was flowing from a nearby mountain into the Fukushima nuclear power plant site; specifically, about 400 m³/day of this flow was running into the buildings and the remaining 400 m³/day was running into the ocean. According to the new roadmap, the plan was, during FY2016, to reduce this inflow to the site by 75 percent.

As for the plans for the removal of spent nuclear fuel from the storage pools, the removal from unit 4 was completed in 2014. According to the new roadmap, spent fuel removal from unit 3 is planned to be carried out between financial years 2017 and 2019. Removal from unit 2 is planned for FY2020 but could stretch into FY2021. It is proposed that the removal of used fuel from unit 1 will also begin in FY2020, but its completion is not expected before FY2022.

As for the removal of fuel debris, it is planned in the roadmap to start the work within 2021 although on which unit is not yet determined. In terms of the method to remove the fuel debris, it had been planned in the previous edition of the roadmap to fill the entire interior of the containment vessel with water and then remove the debris. However, due to the concerns about water leakage from the containment vessel and the possible implications in a seismic event, a decision was made in the new roadmap to launch a comprehensive, comparative study on several methods, including implementing the task after partially filling the containment with water or in the air without using any water. The plan is to decide on the method two years later.

Current Status of Each Reactor

The temperatures in the reactor and containment vessel has dropped to about 15 to 30 degrees Celsius. However, radiation doses inside the containment vessels have remained high at 4 to 5 Sv/h. As of 23 June 2016, the amount of water injected into each of the reactor cores of unit 1, 2 and 3 is

²⁶⁸ 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", Ministry of Economics, Trade and Industry, (Provisional Translation), 12 June 2015, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20150725_01b.pdf, accessed 3 June 2016.

²⁶⁹ Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, "Summary of Decommissioning and Contaminated Water Management — Progress Status and Future Challenges of the Mid-and-Long-Term Roadmap toward the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4 (Outline)", 25 February 2016, see http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20160225_e.pdf, accessed 3 June 2016.

around 4.4 m³/hour.²⁷⁰ Therefore, five years after the beginning of the accident, every day, over 300 m³ of water have to be injected into the three reactor cores.

At unit 1, the building cover for preventing radioactive material diffusion is being dismantled to enable the removal of spent fuel from the storage pool. According to current planning, debris removal work will continue until FY2018, and then cranes and handling equipment will be installed for spent fuel removal by FY2020.

At unit 2, preparation for dismantling the building roof began in April 2016. The method of spent fuel removal has not been determined yet.

At unit 3, debris is being removed from the building roof and spent fuel pool. Similar to unit 1, cranes and handling equipment will be installed for spent fuel removal.

The spent fuel removed from unit 1 through 3 will be stored in the common storage pool as in the case of unit 4. The long-term storage method is planned to be determined around FY2020.

A large number of workers had been exposed to radiation in order to get video footage of the conditions in the containment vessels.²⁷¹ However, from April 2015, radiation surveys using robots began. For example, 9.7 Sv/h was measured in unit 1 during the first survey.²⁷² Several of these robots have only lasted for a few minutes before their electronics including computer chips were destroyed by the intense radiation fluxes.

As for the measurement of fuel debris, the data obtained from the survey implemented in March 2015 at unit 1 revealed that there is no significant volume of fuel material in the reactor core and no progress has been made in collecting detailed data of the fuel debris.

In other words, it remains unknown where the fuel is.

Contaminated Water Management

A dedicated bypass system has been operational since 2014 with pumps underground water into the sea after analyzing its quality subsequent to storage in temporary storage tanks.²⁷³ As of March 2016, the inflow of underground water to the reactor building was reduced from around 400 m³/day to about 150 to 200 m³/day.²⁷⁴

Since 2 September 2015, Tokyo Electric Power Company (TEPCO) has also started pumping groundwater using subdrains—41 wells around the buildings and 5 wells on the sea side. Similarly,

²⁷⁰ TEPCO, “The parameters related to the plants in Fukushima Daiichi Nuclear Power Station”, see http://www.tepco.co.jp/en/nu/fukushima-np/f1/pla/2016/images/table_summary-e.pdf, accessed 23 June 2016.

²⁷¹ For example, 51 workers were needed for the approx. 3-hour video-taping carried out in 2012. This is most likely because a large number of workers were required to reduce the radiation dose per person amidst implementing the task involving high-level exposures to radiation. Source: TEPCO, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/images/handouts_121011_08-j.pdf, accessed 12 April 2016.

²⁷² TEPCO, “The development of the reactor containment vessel interior investigation technology”, 30 April 2015, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/handouts/2015/images/handouts_150430_01-j.pdf, accessed 12 April 2016.

²⁷³ For example, following are the results of the pre-discharge storage tank samples collected on 5 April 2016: ND for caesium 134 and caesium 137 and 180Bq/l for tritium. See TEPCO, “The sampling results regarding the groundwater bypass drainage”, 7 April 2016, (in Japanese), see http://www.tepco.co.jp/nu/fukushima-np/f1/smp/2016/images2/pump_well_16040701-j.pdf, accessed 12 April 2016.

²⁷⁴ TEPCO, “Current conditions of subdrain and other water treatment facilities”, 31 March 2016, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2016/pdf/0331_3_1h.pdf, accessed 12 April 2016.

to the bypass system, water pumped up from the subdrains is discharged into the ocean after assessing radioactivity levels in storage tanks.²⁷⁵ Similarly to the bypass system, water pumped up from the subdrains is discharged into the ocean after assessing radioactivity levels in storage tanks²⁷⁶. These discharges have been carried out with the consent of the Fukushima Prefectural Federation of Fisheries Co-operative Associations that is concerned about further radioactive contamination and negative publicity.

Radioactive isotopes except for tritium are removed from the highly contaminated water using multi-nuclide removal equipment (Advanced Liquid Processing System, ALPS). The performance of ALPS is under review. However, the disposal method of this processed water has not been determined yet. The Federation of Fisheries Co-operative Associations has commented that reaching any further agreement on discharge would be difficult and that they are concerned about the release of large amounts of tritium.²⁷⁷ The tritium concentrations are very high, over 500,000 Bq per litre.

The operation of the frozen soil wall as a land-side impermeable barrier was started on 31 March 2016²⁷⁸; this is a controversial measure whose cost and effectiveness have been questioned in the review process of the Nuclear Regulatory Authority (NRA). Although the operation has started, the NRA has not yet fully recognized the effectiveness of this measure. Since the groundwater flow may be altered by the frozen soil wall, the area to be frozen will need to be continually expanded. It was assumed that the effects of this wall would be seen in mid-May 2016. However, on 25 April 2016, TEPCO reported to the NRA that the temperature near the frozen pipes had decreased and that the underground water level had changed.²⁷⁹ On 2 June 2016, TEPCO admitted that, while about 97 percent of the soil wall showed temperatures below 0°C, other spots remained at +7.5°C due to fast groundwater flow. TEPCO concluded that additional work, such as injecting cement, was needed.²⁸⁰

²⁷⁵ For example, following are the results of the pre-discharge storage tank samples collected on 2 March 2016: ND for caesium 134 and caesium 137 and 630Bq/l for tritium. See TEPCO, “The sampling results regarding the subdrain and groundwater drain”, 5 April 2016, (in Japanese), see https://www4.tepco.co.jp/nu/fukushima-np/f1/smp/2016/images/sd_discharge_16030401-j.pdf, accessed 12 April 2016.

²⁷⁶ For example, following are the results of the pre-discharge storage tank samples collected on 2 March 2016: ND for caesium 134 and caesium 137 and 630Bq/l for tritium. See TEPCO, “The sampling results regarding the subdrain and groundwater drain”, 5 April 2016, (in Japanese), see https://www4.tepco.co.jp/nu/fukushima-np/f1/smp/2016/images/sd_discharge_16030401-j.pdf, accessed 12 April 2016.

²⁷⁷ Kahoku Simpo, “This is the last time we consent to discharging contaminated water”, (in Japanese), see http://www.kahoku.co.jp/tohokunews/201509/20150915_63013.html, accessed 12 April 2016.

²⁷⁸ TEPCO, “Land-side Impermeable Wall (Frozen Soil)” see <http://www.tepco.co.jp/en/decommission/planaction/landwardwall/index-e.html>, accessed 12 April 2016.

²⁷⁹ TEPCO, “Current status of land-side impermeable wall (First step, Phase 1)”, 25 April 2016, see http://www.tepco.co.jp/nu/fukushima-np/handouts/2016/images1/handouts_160425_03-j.pdf, accessed 21 May 2016.

²⁸⁰ TEPCO, “Closing of the land side water shielding (First phase) and transition to Second phase”, 2 June 2016, (in Japanese), see <https://www.nsr.go.jp/data/000152044.pdf>, accessed 10 June 2016.

Current status of workers

The government is insisting that they are ensuring that there are a sufficient number of workers for decommissioning Fukushima Daiichi and that they are properly managing the workers.²⁸¹ For example, according to TEPCO, about 3,000 to 7,500 workers per day are engaged in the decommissioning work as of September 2015,²⁸² and their average monthly radiation dose is maintained at a low value of 0.51 mSv according to data from February 2016.²⁸³

But reportedly, the reality of the labor environment can be different. In March 2015, a local newspaper of Fukushima Prefecture reported that 174 workers were legally forbidden to continue working at the site because their total dose exceeded 100 mSv.²⁸⁴

In September 2015, the Fukushima Bureau of Ministry of Health, Labour and Welfare (MHLW) demanded that TEPCO fully implement labor disaster countermeasures in response to successive fatal accidents²⁸⁵ that occurred at the site.²⁸⁶ In addition, the bureau reported that as of September 2015, there had been 656 cases of violation of regulations concerning the decommissioning work such as problems with wage payments and dosimeter deficiency²⁸⁷.

On 20 October 2015, MHLW recognized, for the first time, as an occupational disease the leukemia developed by a worker who had carried out decommissioning tasks after the Fukushima accident.²⁸⁸ The worker, who was in his thirties at the time, had performed tasks involving radiation exposure for 18 months, starting in October 2011. During that period, he had worked for about one year at the Fukushima Daiichi site, beginning in October 2012. According to media reports, he was exposed to a total of about 20 mSv; specifically, he was exposed to about 16 mSv at Fukushima nuclear power plant site and about 4 mSv at Genkai NPP site of Kyushu Electric.²⁸⁹

²⁸¹ Volodymyr Tykhyy, "From Archives of VUChK-GPU-NKVD-KGB Chernobyl Tragedy in Documents and Materials (Summary)", May 2008, see <http://www.rri.kyoto-u.ac.jp/NSRG/reports/kr139/pdf/tykhyy-2.pdf>, accessed 5 June 2016.

²⁸² TEPCO, "Efforts to improve the working environment", 1 September 2015, (in Japanese), see <http://www.pref.fukushima.lg.jp/uploaded/attachment/129927.pdf>, accessed 18 April 2016.

²⁸³ For workers, exposure dose limit is regulated at 100mSv/5 years and 50mSv/year. Namely, 100mSv/5 years is converted to 20mSv/year and 1.71mSv/month. See <http://www.tepco.co.jp/decommission/principles/people/index-j.html>, (in Japanese), accessed 12 April 2016.

²⁸⁴ Fukushima Minpo, "Successive cases of workers exposed to doses above limits", 26 March 2015, (in Japanese), see http://www.minpo.jp/pub/topics/jishin2011/2015/03/post_11693.html, accessed 12 April 2016.

²⁸⁵ On 19 January 2015, a worker fell from a tank and died later. Also on 8 August 2015, a worker died from being caught between a construction vehicle's tank and its lid.

²⁸⁶ Fukushima Labour Bureau, "Request for thorough implementation of labor accident prevention measures for decommissioning activities", MHLW, 15 September 2015, (in Japanese), see http://fukushima-roudoukyoku.jsite.mhlw.go.jp/library/fukushima-roudoukyoku/anzen/pdf/1509rousaiboushi_yousei.pdf, accessed 12 April 2016.

²⁸⁷ Fukushima Labour Bureau, "Results from the supervision of the operator of decommissioning work for Fukushima Daiichi nuclear power plant", MHLW, 20 November 2015, (in Japanese), see http://fukushima-roudoukyoku.jsite.mhlw.go.jp/library/fukushima-roudoukyoku/kantoku/pdf/1511genpatsujigyousha_kantokukekka.pdf, accessed 12 April 2016.

²⁸⁸ MHLW, "Result of review at the 'review meeting on occupational/non-occupational ionizing radiation disease' and approval as occupational disease/injury", 20 October 2015, (in Japanese), see <http://www.mhlw.go.jp/file/05-Shingikai-11201000-Roudoukijunkyouku-Soumuka/kouhyousiryoku.pdf>, accessed 3 June 2016.

²⁸⁹ *Asahi Shimbun*, "First worker's compensation for leukemia as occupational disease from exposure after Fukushima accident", 20 October 2015, (in Japanese), see <http://digital.asahi.com/articles/ASHBJ7DNSHBJULBJ014.html>, accessed 12 April 2016.

Although the standard for recognizing a worker's leukemia as an occupational disease is exposure to more than 5 mSv/year of radiation, MHLW stated that "this recognition does not prove scientifically the causal relationship of radiation exposure and its health effects".²⁹⁰

Offsite Challenges

Current Status of Evacuation

The Reconstruction Agency set the five years following the earthquake of 2011 as the intensive reconstruction period, and the term from April 2016 to March 2021 as the reconstruction and revitalization period.²⁹¹ However, there have been many delays with the reconstruction efforts over the past five years.

As of May 2016, 92,600 Fukushima Prefecture residents had been forced to evacuate from their homes: Specifically, 50,600 people had evacuated to other areas within Fukushima Prefecture. The remaining 42,000 people had evacuated to other prefectures across Japan.²⁹²

As of September 2015, which are the latest available figures, about 70,000 people have been evacuated from the designated evacuation zones due to the Fukushima accident: specifically, about 24,000 people were evacuated from the difficult-to-return zone, about 23,000 people from the restricted-residence zone, and 24,000 people from the zone in preparation for the lifting of the evacuation order.²⁹³

As of the end of September 2015, the total number of disaster-related deaths—i.e. deaths that were not caused directly by the earthquake and tsunami but were due to indirect causes such as deterioration of physical conditions as a result of evacuation—was 3,407 people. These people had been living in nine prefectures and Tokyo. Of these, Fukushima Prefecture had the highest number with 1,979 deaths.²⁹⁴ This figure is particularly high among people who evacuated from cities and towns within evacuation zones such as Minami-soma, Tomioka and Namie.

Moreover, according to the statistics collected by the Cabinet Office, the number of suicides related to the Great East Japan Earthquake has decreased everywhere else but Fukushima Prefecture (see Table 7).²⁹⁵

²⁹⁰ MHLW, "Result of review at the 'review meeting on occupational/non-occupational ionizing radiation disease' and approval as occupational disease/injury", 20 October 2015, see www.mhlw.go.jp/english/policy/employ-labour/labour-standards/dl/151111-01.pdf, accessed 5 June 2016.

²⁹¹ Reconstruction Agency, "The Process and Prospects for Reconstruction", March 2016, (in Japanese), see http://www.reconstruction.go.jp/english/topics/Progress_to_date/image/20160307_process_and_prospects.pdf, accessed 12 April 2016.

²⁹² Fukushima Prefecture, "Immediate update on the damage situation of 2011 Tohoku-Pacific Ocean earthquake (Report No. 1642)", (in Japanese), see http://www.pref.fukushima.lg.jp/uploaded/ldata/206010_465920_misc.xls, accessed 21 May 2016.

²⁹³ Reconstruction Agency, "Current status of reconstruction", 4 March 2016, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat7/sub-cat7-2/20160304-4_sankousiryoku1-1.pdf, accessed 21 May 2016.

²⁹⁴ Reconstruction Agency, "The number of disaster-related deaths due to the Great East Japan Earthquake", 25 December 2015, (in Japanese) see http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-6/20151225_kanrenshi.pdf, accessed 12 April 2016.

²⁹⁵ Cabinet Office, "Number of suicides related to the Great East Japan Earthquake", 13 March 2016, (in Japanese), see <http://www8.cao.go.jp/jisatsutaisaku/toukei/pdf/h27joukyou/jishin.pdf>, accessed 12 April 2016.

The government is aggressively seeking to lift evacuation orders. In June 2015, the government announced that they will enable the lifting of evacuation orders for all restricted residence zones and zones in preparation for the lifting of the evacuation order by March 2017²⁹⁶. If this plan materializes, 47,000 people will be allowed to return to their homes.

Table 7: Suicides Related to the Great East Japan Earthquake

Year [1]	Iwate Prefecture	Miyagi Prefecture	Fukushima Prefecture	Other Prefectures [2]
2011	17	22	10	6
2012	8	3	13	0
2013	4	10	23	1
2014	3	4	15	0
2015	3	1	19	0

Notes: [1] The value of 2011 is a total from June to December. The values from 2012 onwards are the total from January to December.

[2] Total number of three prefectures (Ibaraki, Saitama, Kanagawa) and Osaka, Kyoto and Tokyo.

Source: Cabinet Office, “Number of suicides related to the Great East Japan Earthquake”, 13 March 2016.

However, evacuees have mixed feelings. In February 2016, the government held a briefing in Minami-soma city and stated that they hope to lift the evacuation order in April. In response to this, numerous residents commented that it is too soon to lift the order since progress has been slow in implementing decontamination activities.²⁹⁷ In March 2016, Fukushima Prefecture released the results of its questionnaire survey. Among the people who had evacuated to other prefectures and had no home to return to in Fukushima Prefecture after April 2017—when the program for offering rental houses free of charge will be terminated—about 70 percent did not wish to return to Fukushima while about 10 percent wanted to return to the prefecture and about 20 percent responded that they are still debating on whether or not to return.²⁹⁸

²⁹⁶ Nuclear Countermeasures Headquarters, “Accelerating post-nuclear disaster Fukushima recovery efforts”, (Revised version), 12 June 2015, (in Japanese), see http://www.meti.go.jp/earthquake/nuclear/kinkyu/pdf/2015/0612_02.pdf, accessed 12 April 2016.

²⁹⁷ *Tokyo Shimbun*, “Residents oppose plan to lift evacuation order in April at an explanatory meeting in Minami-soma city”, 21 February 2016, (in Japanese), see <http://www.tokyo-np.co.jp/article/national/list/201602/CK2016022102000126.html>, accessed 12 April 2016.

²⁹⁸ Fukushima Prefecture, “Interim report on the residence intentions survey”, 25 March 2015, (in Japanese), see <https://www.pref.fukushima.lg.jp/uploaded/attachment/158116.pdf>, accessed 12 April 2016.

Radiation Exposure and Health Effects

Fukushima Prefecture is continuing its health survey, which includes assessments of external and internal doses and thyroid examinations.²⁹⁹ In regard to the thyroid examination, the preliminary survey—ultrasound wave examination for residents who were under 18 years old or younger and lived in Fukushima Prefecture at the time of the accident—was conducted from October 2011 to March 2014. As of the end of June 2015, 113 people were diagnosed with confirmed or suspected thyroid cancer.³⁰⁰ Of these, 99 people underwent surgery.

However, the Prefectural Oversight Committee Meeting for Fukushima Health Management Survey concluded:

As a judgment based on a comprehensive assessment of the following facts, it is unlikely that the thyroid cancers discovered until now were caused by the effects of radiation: the exposure doses were generally smaller compared to those of the Chernobyl accident, the period from exposure to cancer detection was short ranging from about one to four years, cancer was not found in those aged five years old or younger at the time of the accident, and there was no significant difference in the regional detection rates.

The first full-scale survey was conducted from April 2014 to March 2016, involving the subjects of the preliminary survey and children who were born after the accident including those in utero at the time of the accident. If nodules or cysts that are larger than a predetermined size are found in the primary first examination, those people undergo a confirmatory examination.

Table 8: Confirmed or Suspected Thyroid Cancer Cases and Effective External Dose Estimates

Effective dose [mSv]	Age at the time of the accident									
	0 - 5		6 - 10		11 - 15		16 - 18		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Less than 1	0	0	3	0	1	4	2	0	6	4
Less than 2	0	0	0	1	3	4	3	3	6	8
Less than 5	0	0	1	0	0	2	1	1	2	3
Less than 10	0	0	0	0	0	0	0	0	0	0
Less than 20	0	0	0	0	0	0	0	0	0	0
20 and above	0	0	0	0	0	0	0	0	0	0
Total	0	0	4	1	4	10	6	4	14	15

Source: Prefectural Oversight Committee Meeting for Fukushima Health Management Survey, "Thyroid Ultrasound Examination

²⁹⁹ Fukushima Medical University, "Report of the Fukushima Health Management Survey (FY 2011-2013)", (revised version), 12 June 2015. see <http://fmu-global.jp/?wpdmdl=1032>, accessed 30 June 2016.

³⁰⁰ Prefectural Oversight Committee Meeting for Fukushima Health Management Survey, "Interim report on the prefectural citizens health survey", March 2016, (in Japanese), see <http://www.pref.fukushima.lg.jp/uploaded/attachment/158522.pdf>, accessed 12 April 2016; and Shinichi Suzuki et al., "Comprehensive Survey Results of Childhood Thyroid Ultrasound Examinations in Fukushima in the First Four Years After the Fukushima Daiichi Nuclear Power Plant Accident", THYROID, Volume 26, Number 6, 2016, see <http://online.liebertpub.com/doi/abs/10.1089/thy.2015.0564>, accessed 10 June 2016.

As of the end of December 2015, 51 people were diagnosed with confirmed or suspected malignant thyroid cancer in the second examination. Unfortunately, only 29 of them submitted a basic survey questionnaire that provides data on their exposure dose at the time of the accident. Among these values, the highest dose was 2.1 mSv (see Table 8).³⁰¹

In October 2015, a research group at Okayama University published an epidemiological study related to the high occurrence of childhood thyroid cancer.³⁰² According to the group, based on the results of the screening tests of Fukushima Prefecture, at the maximum, the incidence of thyroid cancer in a certain area of Fukushima Prefecture was up to 50 times higher than Japan's average annual incidence of thyroid cancer incidences. Accordingly, the group concluded that the excessive occurrence of thyroid cancer has already been detected. However, the methodology of this paper has been criticized and the academic debate on this issue is continuing.³⁰³

Food and Environmental Contamination

The intake and shipment of certain edible wild plants and freshwater fish have been restricted due to the contamination risk.³⁰⁴ Although fishermen have placed a voluntary restriction on fishing in the waters within 20 km from the Fukushima power plant site, a study is being conducted that hopes to restart fishing in that area.

Most food samples analyzed for radioactive contamination were non-contaminated or contaminated at levels "below the detection limit", except for rare cases in prefectures adjacent to Fukushima. For example, 263 cases (0.09 percent) exceeded the standard limits in the monitoring from April 2015 to January 2016.³⁰⁵

It should be noted that regarding the term "Not Detected (ND)", which has been frequently used in government reports, a recent study proposes a review of the detection limit.³⁰⁶

The Ministry of the Environment has continued to monitor wild animals and plants. For example, at a scientific meeting held in February 2016, a study conducted in FY2014 was presented that evaluated the exposure-dose rates of about 40 types of animals and plants. According to this study,

³⁰¹ Prefectural Oversight Committee Meeting for Fukushima Health Management Survey, "Thyroid Ultrasound Examination (Full-scale Thyroid Screening Program)", 15 February 2016, see <http://fmu-global.jp/?wpdmdl=1563>, accessed 10 June 2016.

³⁰² Tsuda, Toshihide et al., "Thyroid Cancer Detection by Ultrasound Among Residents Ages 18 Years and Younger in Fukushima, Japan: 2011 to 2014", *Epidemiology*, Volume 27, Issue 3, May 2016, see http://journals.lww.com/epidem/Citation/2016/05000/Thyroid_Cancer_Detection_by_Ultrasound_Among.3.aspx, accessed 12 April 2016.

³⁰³ Takahashi, Hideto et al., "Re: Thyroid Cancer Among Young People in Fukushima", *Epidemiology*, Volume 27, Issue 3, May 2016, see http://journals.lww.com/epidem/Fulltext/2016/05000/Re_Thyroid_Cancer_Among_Young_People_in.36.aspx, accessed 12 April 2016.

³⁰⁴ Fukushima Prefecture, "Results of emergency environmental radiation monitoring of agriculture, forestry and fishery products", (in Japanese), see <http://www.pref.fukushima.lg.jp/site/portal/mon-kekka.html>, accessed 12 April 2016.

³⁰⁵ Food Industry Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), "Ensuring food safety", March 2016, see http://www.maff.go.jp/j/export/e_info/pdf/160401_eigo_part1.pdf, accessed 10 June 2016.

³⁰⁶ Hiroshi Okamura et al., "Risk assessment of radioisotope contamination for aquatic living resources in and around Japan", *Proceeding of the National Academy of Science of the United States of America*, Volume 113, see <http://www.pnas.org/content/113/14/3838.abstract>, accessed 12 April 2016.

there is an undeniable possibility that reproductive rates lowered and life expectancy shortened in some species in certain areas.³⁰⁷ Another study demonstrates that the closer the area is to the Fukushima nuclear power plant, the lower the number of habitats and species of invertebrate organisms.³⁰⁸

The government has set two decontamination goals:

1. To incrementally reduce the size of the areas, but as soon as possible, with levels at 20 mSv/year or higher;
2. Reduce the exposure dose rate to 1 mSv/year or less over a long-term period for the areas with levels at less than 20 mSv/year.³⁰⁹

Decontamination work in the designated areas to be decontaminated under the direct control of the government was completed in six municipalities among the 11 designated municipalities within Fukushima Prefecture and the plan is to finish decontamination in the remaining municipalities by the end of FY2016³¹⁰ However, little progress has been made in the decontamination activities implemented by each local government for the wider area that covers seven prefectures including Fukushima³¹¹.

As for the rates of progress made in the decontamination activities for the entire Fukushima Prefecture, 80 percent of houses, 5 percent of roads, and 70 percent of the forests in areas, where daily activities are conducted, have been decontaminated.³¹² However, it should be pointed out that by “forest” is meant in general a small band around houses and roads, rather the actual dense forests, that cannot be decontaminated at all. In December 2015, the Ministry of Environment announced that they will not decontaminate areas more than 20 km away from daily-activities areas in Fukushima Prefecture.³¹³ However, as a result of local opposition, the ministry changed the policy to carrying out decontamination in *satoyama* areas—border zones of agricultural land and forested land traditionally regarded as one area—where people may enter easily.³¹⁴

³⁰⁷ Nature Conservation Bureau, Ministry of the Environment, “MOE’s research on the effects of radiation on wild fauna and flora Biodiversity Policy Division”, Research report meeting on radiation effects on wild animals and plants, 19 February 2016, (in Japanese), see http://www.env.go.jp/jishin/monitoring/results_wl_d160219.pdf, accessed 12 April 2016.

³⁰⁸ Toshihiro Horiguchi et al., “Decline in intertidal biota after the 2011 Great East Japan Earthquake and Tsunami and the Fukushima nuclear disaster: field observations”, *Scientific Reports*, see <http://www.nature.com/articles/srep20416>, accessed 12 April 2016.

³⁰⁹ Ministry of Environment, “Outline of the Implementation of the Act on Special Measures”, see <http://josen.env.go.jp/en/framework/>, accessed 21 May 2016.

³¹⁰ Ministry of the Environment, “Progress map of decontamination activities implemented under the direct control of the government”, 4 March 2016, (in Japanese), see http://josen.env.go.jp/material/pdf/josen_gareki_progress_201603.pdf, accessed 12 April 2016.

³¹¹ Ministry of the Environment, “Progress made in areas being decontaminated by municipalities”, (in Japanese), see <http://josen.env.go.jp/zone/index.html>, accessed 12 April 2016.

³¹² Ibidem.

³¹³ Environmental recovery review meeting, “Direction of radioactive materials management measures for forests (draft)”, 21 December 2015, (in Japanese), see <http://www.env.go.jp/jishin/rmp/conf/16/mat05.pdf>, accessed 12 April 2016.

³¹⁴ Project team of relevant ministries and agencies for recovering forests and the forest industry in Fukushima, “Comprehensive approach for recovering forests and the forest industry in Fukushima”, 9 March 2016, (in Japanese), see http://www.reconstruction.go.jp/topics/main-cat1/sub-cat1-4/forest/160309_3_siryu1.pdf, accessed 12 April 2016.

Costs³¹⁵

TEPCO continues to pay compensation for damages caused by the Fukushima accident. Legally required compensation costs have been increasing and the total reached about 7.1 trillion yen (US\$71 billion) as of the end of March 2016. Table 9 shows the legally required compensation costs and the amount of agreed-upon compensation payments that had been paid as of March 2016.

Table 9 : Compensation Costs

	Completed agreed-upon compensation payments [US\$ 1 million] [1]	Legally required compensation costs [US\$ 1 million] [2]
I. Amounts concerning individuals	18,674	21,203
Medical examination costs, etc.	2,383	3,235
Psychological damage	10,164	11,441
Voluntary evacuation, etc.	3,628	3,681
Incapacity damage	2,498	2,844
II. Amounts concerning corporations and sole proprietorships	23,152	25,631
Loss of business, damage and reputational damage caused by shipping restriction orders	19,601	20,554
One-time compensation (Loss of business, reputational damage)	909	2,383
Indirect damage, etc.	2,639	2,693
III. Common or other costs	13,547	17,577
Loss or decrease in property value, etc.	11,575	12,612
Damages concerning residence at evacuated destination or upon returning	1,721	4,715
Fukushima citizens health management fund	250	250
IV. Decontamination, etc.	3,900	12,173
Total	59,275	76,585

[1] As of the end of February 2016

[2] As of the end of March 2016

Source: TEPCO, "New Comprehensive Special Business Plan", 31 March 2016.

³¹⁵ TEPCO, "New Comprehensive Special Business Plan", 31 March 2016, (in Japanese), see <http://www.meti.go.jp/press/2015/03/20160331005/20160331005-1.pdf>, accessed 12 April 2016.

According to the estimation of the Board of Audit in March 2015, it will take up to 30 years for TEPCO to repay the financial subsidies of 9 trillion yen (US\$90 billion) it received from the government.³¹⁶

Based on the information from TEPCO, the total cost of damages caused by the Fukushima disaster has been estimated to be at 13.3 trillion yen (US\$ 133 billion), based on the following items:

- (1) Decommissioning and contaminated water treatment costs of 2 trillion yen. Although TEPCO already set aside a reserve of 1 trillion yen (US\$ 10 billion), the government asked the utility to secure another 1 trillion yen (US\$ 10 billion) within 10 years.
- (2) Compensation costs of about 7.1 trillion yen (US\$ 71 billion). The total of the legally required compensation costs according to the latest data is about 7.7 trillion yen (US\$ 77 billion), see Table 9.
- (3) Decontamination costs of 3.6 trillion yen (US\$ 36 billion): The Ministry of the Environment has estimated the decontamination cost at about 2.5 trillion yen (US\$ 25 billion) and the interim storage facilities cost at about 1.1 trillion yen (US\$ 11 billion).

Fukushima vs. Chernobyl

“We knew, with certainty, with arrogant certainty, that we were in control of the power we were playing with. We could make the forces of nature bend to our will. There was nothing we could not do. This was the day, of course, when we learned we were wrong.”

Sergiy Parashyn
Engineer at the Chernobyl plant
from 1977 to the day of the disaster³¹⁷

Although the Fukushima disaster in 2011 remains very serious, according to some criteria, its effects seem to pale in comparison to the Chernobyl nuclear disaster in 1986. However, it must be noted that all of these numbers are based on modelling with large ranges of uncertainties.

According to Japan’s Science Ministry,³¹⁸ the Fukushima accident contaminated an area of 30,000 km² in Japan to a level above 10,000 Bq per km² of Cs-137. Chernobyl contaminated an area of an estimated 1,437,000 km² in Europe and the former USSR above this level, a 50 times larger area.³¹⁹ The Japanese Science Ministry also stated that 8 percent of Japan’s land area was contaminated to this level.³²⁰ In comparison, 37 percent of Europe was affected to the same level.

Table 10 indicates that it was not just the land areas contaminated and collective doses but also the radionuclide amounts released to the air, and the populations affected that were larger by land

³¹⁶ Board of Audit of Japan, “Report on the results of the accounting audit regarding the implementation status of government’s assistance provided to TEPCO for compensation for nuclear damage”, March 2015, (in Japanese), see http://www.jbaudit.go.jp/pr/kensa/result/27/pdf/270323_zenbun_01.pdf, accessed 12 April 2016.

³¹⁷ *Miami Herald*, “Ruined Chernobyl nuclear plant will remain a threat for 3,000 years”, 24 April 2016, see <http://www.miamiherald.com/news/nation-world/world/article73405857.html>, accessed 23 June 2016.

³¹⁸ *Climate Progress*, “Radiation Covers 8% of Japan, Fukushima Crisis ‘Stunting Children’s Growth’ (Though Not Directly Due to Radiation)”, 28 November 2011, see <http://thinkprogress.org/climate/2011/11/28/377120/radiation-japan-fukushima-stunting-childrens-growth/>, accessed 30 June 2016.

³¹⁹ Ian Fairlie, “TORCH-2016—An independent scientific evaluation of the health-related effects of the Chernobyl nuclear disaster”, 31 March 2016, see https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf, accessed 4 June 2016.

³²⁰ *Climate Progress*, op. cit.

contamination. In all parameters listed, Chernobyl's effects were greater than those at Fukushima. Little is known about total discharges to the sea, from aerial disposal and from direct liquid releases.

Table 10 : Comparison of Selected Parameters of the Chernobyl and Fukushima Accidents

	Chernobyl	Fukushima	Factor
Area contaminated (>10,000Bq/m ² Cs-137)	1,437,000 km ² **	30,000 km ² [^]	~50 x
Percentage of landmass	37% of Europe**	8% of Japan [^]	~5 x
Cs-137 source term	85 PBq*	12 PBq*	~7 x
I-131 source term	1,760 PBq*	150 PBq*	~12 x
Collective dose	320,000-480,000** person-Sv ³²¹	48,000* person-Sv	~7-10 x
Collective dose to thyroid	2,240,000** person-Gray ³²²	112,000* person-Gray	~20 x
Evacuees (first year)	130,000**	170,000+	~0.8 x
Clean-up workers (first year)	130,000**	12,000+	~12 x

Sources: *UNSCEAR 2013³²³; **TORCH-2016³²⁴; [^] Japanese Science Ministry³²⁵, +Fairlie (2016)³²⁶

³²¹ Person-sievert is a unit of collective dose for whole body exposures

³²² Person-gray is a unit of collective dose for specific organ exposures.

³²³ UNSCEAR, "UNSCEAR 2013 Report — Volume I, Report to the General Assembly ; Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after 2011 great east-Japan earthquake and tsunami", United Nations, April 2014, see http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf, accessed 5 June 2016.

³²⁴ Ian Fairlie, "TORCH-2016", 31 March 2016, see https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf, accessed 4 June 2016.

³²⁵ *Climate Progress*, "Radiation Covers 8% of Japan, Fukushima Crisis 'Stunting Children's Growth' (Though Not Directly Due to Radiation)", 28 November 2011, see <http://thinkprogress.org/climate/2011/11/28/377120/radiation-japan-fukushima-stunting-childrens-growth/>, accessed 30 June 2016.

³²⁶ Ian Fairlie, "Summing the Health Effects of the Fukushima Nuclear Disaster", August 2015, see <http://www.ianfairlie.org/wp-content/uploads/2015/08/Summing-up-the-Effects-of-the-Fukushima-Nuclear-Disaster-10.pdf>, accessed 6 July 2016.

Source Term

There are various estimates of the amounts of radioactivity emitted to air, the so-called air source term, from Chernobyl and Fukushima.

Table 11 provides estimates for the main nuclides released according to Fairlie³²⁷, Imanaka et al.³²⁸ and UNSCEAR³²⁹.

Table 11 : Comparison of Atmospheric Releases from Nuclear Accidents (in PBq)³³⁰

Accidents	Authors	I-131	Cs-137	Xe-133
Chernobyl	Imanaka et al. 2015	1,760	85	6,500
	UNSCEAR 2008/11	1,700	86	6,500
Fukushima	Imanaka et al 2015	120	8.8	7,300
	UNSCEAR 2008/11	100-500	6-20	14,000

The key points here are:

- Broad agreement about source terms on Cs-137 and Xe-133. Wide range of I-131 estimates by UNSCEAR at Fukushima.
- Release estimates for Chernobyl are much larger than those for Fukushima, about ten times greater for Cs-137 and I-131 which are the main volatile nuclides. For the noble inert gas Xe-133, the situation is reversed, as releases from Fukushima were about double those from Chernobyl. The main reason is that at Chernobyl one reactor exploded whereas at Fukushima, meltdowns occurred at three units, with each reactor releasing its entire gaseous inventory.

Radiation Exposures

The calculation of radiation exposure is based on complex modelling of exposure paths (external, internal, air, food path, etc.), as the actual doses delivered to the body have been measured only partially for a small number of people. Therefore, the exposure numbers indicated throughout this chapter have to be considered with circumspection. Also, radiation risks between a fetus and a grown-up adult vary by two orders of magnitude, and risks show high variability between individuals.

indicates that, in the highest contaminated areas resulting from Chernobyl, the average dose was 9 mSv in the first year after the accident. This is similar to the average dose received in the most contaminated area of Japan in Fukushima prefecture.

³²⁷ Ian Fairlie, "TORCH-2016", 31 March 2016, see

https://www.global2000.at/sites/global/files/GLOBAL_TORCH%202016_rz_WEB_KORR.pdf, accessed 4 June 2016.

³²⁸ Imanaka T. et al., "Comparison of the accident process, radioactivity release and ground contamination between Chernobyl and Fukushima-1", *Journal of Radiation Research*, 14 November 2015, see <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4732534/>, accessed 5 June 2016.

³²⁹ UNSCEAR, "2008 Report to the General Assembly; Annex D Health Effects Due to the Chernobyl Nuclear Accident", United Nations, New York. Note: Although UNSCEAR's publication date was stated as 2008, the report was not released until 2011.

³³⁰ 1 petabecquerel (PBq) = 10¹⁵ becquerels

However, the average thyroid dose in Belarus and Ukraine was about 20 times greater than in Fukushima prefecture. This is because the I-131 release was about 10 to 12 times greater at Chernobyl than Fukushima and because an estimated (~80 percent) of the plumes at Fukushima were blown out to sea.³³¹

Table 12: Average Doses in Fukushima and Chernobyl (Highest Contaminated Areas)

	Fukushima Prefecture	Highly Contaminated Areas of Belarus, Russia and Ukraine	Europe / Japan
Average Dose	10 mSv	9 mSv	~1
Average Thyroid Dose	35 mGy ³³²	560 ³³³ -640 ³³⁴ mGy (range 50 to 5,000 mGy)	16 - 18 x

Source: UNSCEAR 2008, 2013

As regards collective dose, the UNSCEAR 2013 report states:

The collective effective dose to the population of Japan due to a lifetime exposure following the Fukushima accident is approximately 10-15 percent of the corresponding value for European populations exposed to radiation following the Chernobyl accident. Correspondingly, the collective absorbed dose to the thyroid was approximately 5 percent of that due to the Chernobyl accident.

This is shown in tabular form in Table 13.

Table 13 : Collective Doses from Fukushima and Chernobyl Accidents (over 80 years)

	Europe	Japan	Factor Difference
Collective Dose	320,000-480,000 Person-Sv	48,000 Person-Sv	x 7-10
Collective Dose to Thyroid	2,240,000 Person-Gy	112,000 Person-Gy	x 20

Source: UNSCEAR 2008, 2013

³³¹ UNSCEAR, “UNSCEAR 2013 Report — Volume I, Report to the General Assembly ; Scientific Annex A: Levels and effects of radiation exposure due to the nuclear accident after 2011 great east-Japan earthquake and tsunami”, United Nations, April 2014, see http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf, accessed 5 June 2016.

³³² Le Gray is a unit of collective dose for specific organ exposures.

³³³ Zablotska L.B., Ron E., et al., “Thyroid cancer risk in Belarus among children and adolescents exposed to radioiodine after the Chornobyl accident”, *British Journal of Cancer*, 2011, Edition n.104, published online 23 November 2010, see <http://www.nature.com/bjc/journal/v104/n1/full/6605967a.html>, accessed 5 June 2016.

³³⁴ Likhtarov I., Kovgan L., et al., “Thyroid cancer study among Ukrainian children exposed to radiation after the Chornobyl accident: Improved estimates of the thyroid doses to the cohort members”, *Health Phys.*, March 2014, see <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4160663/>, accessed 5 June 2016.

Nuclear Power vs. Renewable Energy Deployment

Introduction

The December 2015 United National Framework Conference on Climate Change (UNFCCC) in Paris is rightly seen as an important milestone in the global fight to avoid dangerous climate change. The foundation of the conference's outcome was the national pledges for mitigation actions through until 2030; while voluntary, they have a formal reporting and review mechanism. The Paris agreement noted that these pledges, when aggregated, did not meet the objective “with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”.

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 31 countries currently operating nuclear power, therefore, only around one in five Paris pledges. Furthermore, expansion of the sector, through construction of new reactors, is only taking place in 12 of these countries with an additional two countries, Belarus and United Arab Emirates, building for the first time.

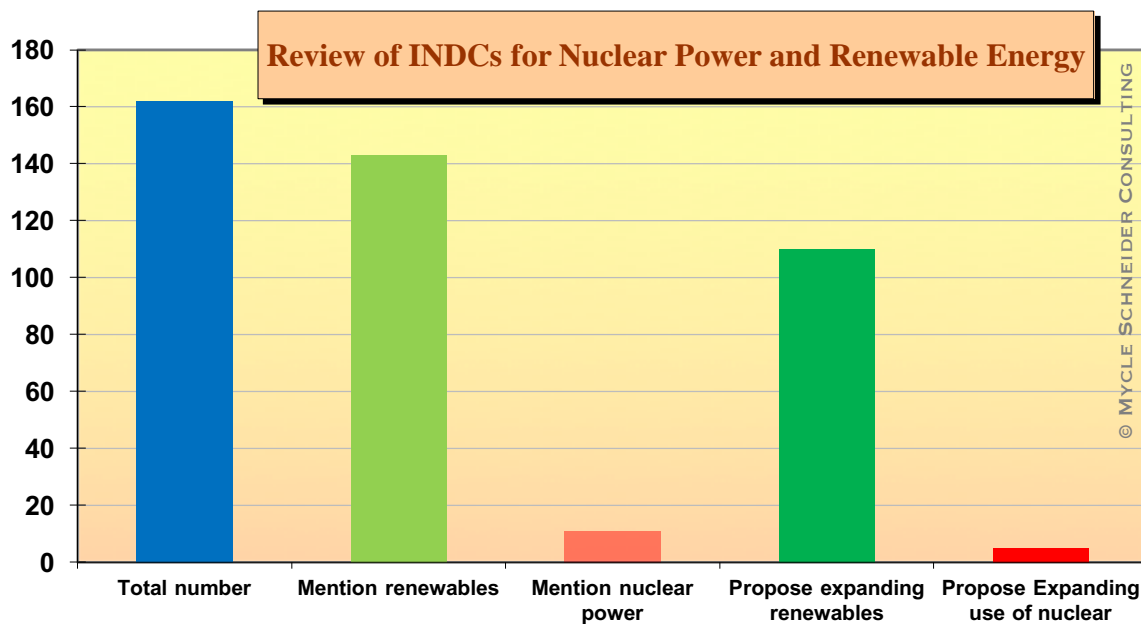
Within the actual INDCs only eleven countries mentioned that they were operating or considering to operate nuclear power as part of their mitigation strategy and even fewer (six) actually state that they were proposing to expand its use (Belarus, India, Japan, Turkey and UAE). This compares with 144 that mention the use of renewable energy and 111, which explicitly mention targets or plans for expanding its use as shown in Figure 32. This highlights the extent to which nuclear power is a niche carbon abatement strategy, compared to the use of renewables which is universal.

The limited use of nuclear power to address climate change concerns, especially compared to renewable energies is further demonstrated in the ongoing review of the Paris Agreement. This mandates meetings every five years, starting in 2018, to review progress, and assess how to increase the emissions reduction plans in order to meet the international agreed targets for 2030. However, it is highly unlikely that many, if any, countries will be able to increase their use of nuclear power over and above the level already included in their existing pledges, given the length of time that nuclear power takes to plan, license and build. Therefore, despite the need for greater action to reduce emissions through until 2030, nuclear power is unable to accelerate its deployment—in fact, as other parts of the report illustrate, more units might close than start up—and further decarbonization will heavily rely on energy efficiency and renewable energy.

In the longer term, while most global models assume that a decarbonized energy sector will include a combination of nuclear, fossil fuels with carbon capture and storage and renewables, there are a significant number of well-respected studies that assume a nuclear- and fossil-free energy future. These include:

- The Global Energy Assessment 2012, published by the Cambridge University press, states, “that it is also feasible to phase-out nuclear and still meet the sustainability targets”.³³⁵
- The Special report of the International Panel and Climate Change (IPCC) on renewable energy from 2011, reviews at a number of scenarios, which limit the use of different supply options, including renewables, nuclear power and Carbon Capture and Storage. Some of these scenarios, show no additional cost associated with the nuclear-free option, while meeting global mitigation targets.³³⁶
- Global Energy (R)evolution, published and regularly updated by Greenpeace, is a comprehensive 100-percent renewable energy scenario.³³⁷

Figure 32 : Paris Agreement, National Pledges and Nuclear Power



Source: INDCs UNFCCC³³⁸

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 as a means of climate mitigation.

While no energy source is without its 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

³³⁵ GEA and International Institute for Applied Systems Analysis, “Global Energy Assessment Towards a Sustainable Future”, Cambridge University Press, 2012.

³³⁶ IPCC, “Renewable Energy Sources and Climate Change Mitigation, Special Report of the Intergovernmental Panel on Climate Change”, International Panel on Climate Change, figure 10.11.

³³⁷ Greenpeace International, Global Wind Energy Council, and SolarPowerEurope, “Energy [r]evolution— A sustainable World Energy Outlook 2015”, September 2015, see <http://www.greenpeace.org/international/en/publications/Campaign-reports/Climate-Reports/Energy-Revolution-2015/>, accessed 30 June 2016

³³⁸ UNFCCC, “Intended Nationally Determined Contributions”, United Nations Framework Convention on Climate Change, 2015, see http://unfccc.int/focus/indc_portal/items/8766.php, accessed 3 June 2016.

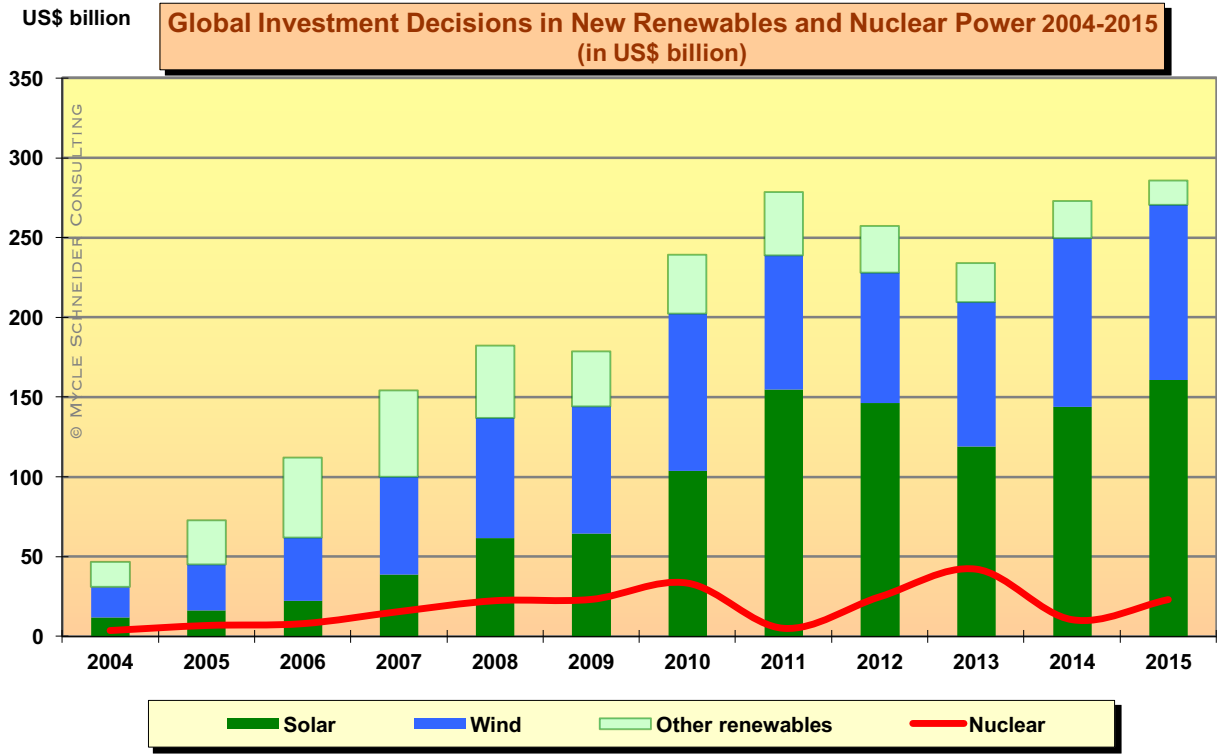
pathway, and one which few countries are pursuing. In contrast, some renewable energy sources, particularly wind and solar PV, are being deployed at rates significantly in excess of those forecasted even in recent years,³³⁹ entailing rapidly falling production and installation costs.

This section highlights the differences between the deployment rates of 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 33: Global Investment Decisions in Renewables and Nuclear Power 2004–15



Sources: FS-UNEP 2015 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\$285.9 billion in 2015, up from US\$273 billion in 2014 and exceeding the previous record of US\$278.5 billion achieved in 2011.³⁴⁰ Figure 33 compares the annual investment

³³⁹ Karel Beckman, “Renewables: does the IEA underestimate them?”, *Energy Post*, 6 October 2015, see <http://www.energypost.eu/renewables-iea-underestimate/>, accessed 30 June 2016.

³⁴⁰ FS-UNEP, “Global trends in renewable energy investment 2016”, Frankfurt School-UNEP collaboration Centre, Bloomberg New Energy Finance, March 2016.

decisions for the construction of new nuclear with renewable energy excluding large hydro since 2004. 2014 saw a sharp drop in new nuclear investment, with construction starting on only three units, which were the Barakah-3 in the UAE, Belarus-2 in Belarus and the Carem reactor in Argentina, but in 2015 eight new construction starts took place, with six of these were in China, with the other starts, the final unit, at the Barakah station in the UAE and K-2 in Pakistan, with a total investment cost of US\$28 billion. 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 these uncertainties, it is clear that over this period the investment in nuclear construction decisions is about an order of magnitude lower than that in renewable energy, with nearly five times more investment in solar and four times more in wind.

Table 14: Top 10 Countries for Renewable Energy Investment 2013–2015

	2015	2014	2013
	US\$ bn	US\$ bn	US\$ bn
China	102.9	81.0	54.2
United States	44.1	36.3	33.9
Japan	36.2	34.3	28.6
United Kingdom	22.2	13.9	12.1
India	10.2	7.1	6.0
Germany	8.5	11.4	9.9
Brazil	7.1	7.4	3.0
South Africa	4.5	5.5	4.9
Mexico	4.0	2.1	1.5
Chile	3.4	1.4	1.6

Source: FS-UNEP 2016, 2015, 2014

The past few years have seen the significant rise of investments into small (less than 1 MW) distributed generation and in 2015, they accounted for a quarter of all renewable energy investments, US\$67.4 billion, up 12 percent from the previous year, but still down from the record high of US\$79.3 billion in 2012. The fall in global investment is a result of slowing down of solar programs in Europe, and particularly Germany, as well as dramatically lower costs. Interesting to

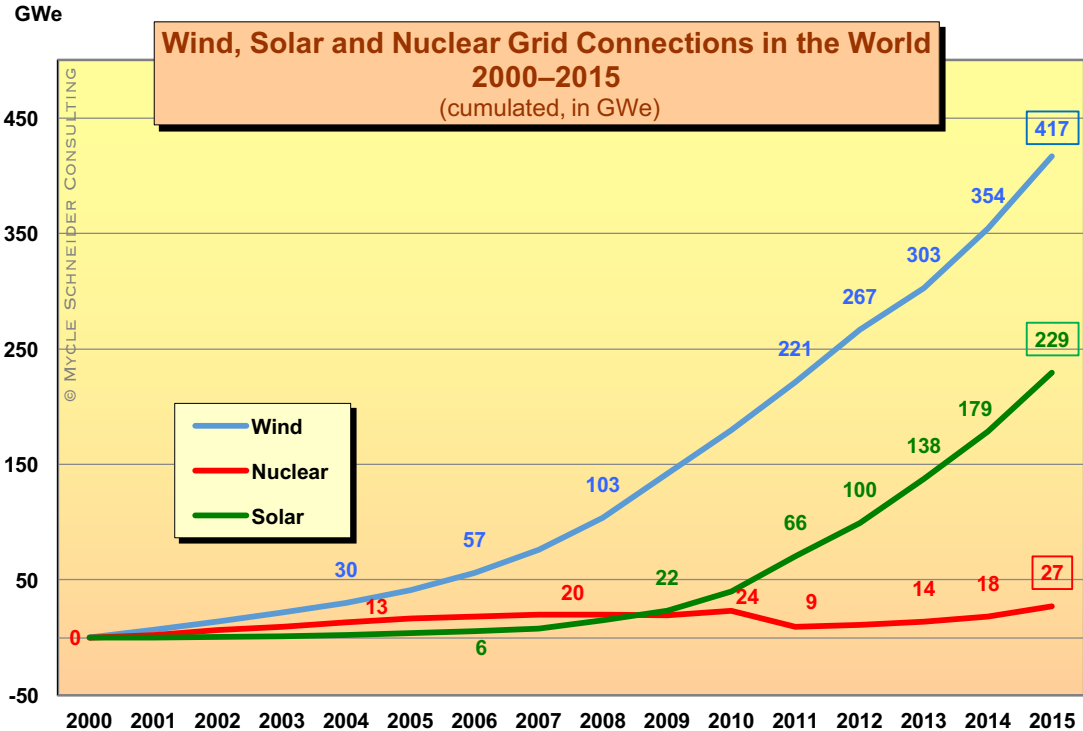
note is the rise of investment in Japan, US\$36.2 billion in 2015, up 0.1 percent.³⁴¹ The increased investment in solar, and its impact on lowering global prices, remains one of the underestimated global impacts of the Fukushima accident in 2011.

Globally, the importance of Europe for renewable energy investments is diminishing, with the rise of Asia, and in particular China and Japan. Ten years ago, in 2005, total investment in China was just US\$8.3 billion and is now an order of magnitude larger. Table 14 shows the top 10 countries for renewable energy investment in 2015 and how these have changed over the previous two years. The diversity of renewable energy development is now clear, and 2015 saw Mexico and Chile, entering the top 10 for the first time, with both countries having approximately doubled their annual renewable investment.

Installed Capacity

Globally, renewable energy continues to dominate new capacity additions. In total 147 GW of renewables capacity was added in 2015, according the REN 21, which was the largest increase ever.

Figure 34: Wind, Solar and Nuclear, Capacity Increases in the World 2000–2015



Sources: WNISR, BP Statistical Review 2016

In 2015, renewables accounted for an estimated more than 60 percent of net additions to global power generating capacity. Wind and solar PV both saw record additions for the second

³⁴¹ FS-UNEP, “Global trends in renewable energy investment 2016”, Frankfurt School-UNEP collaboration Centre, Bloomberg New Energy Finance, March 2016.

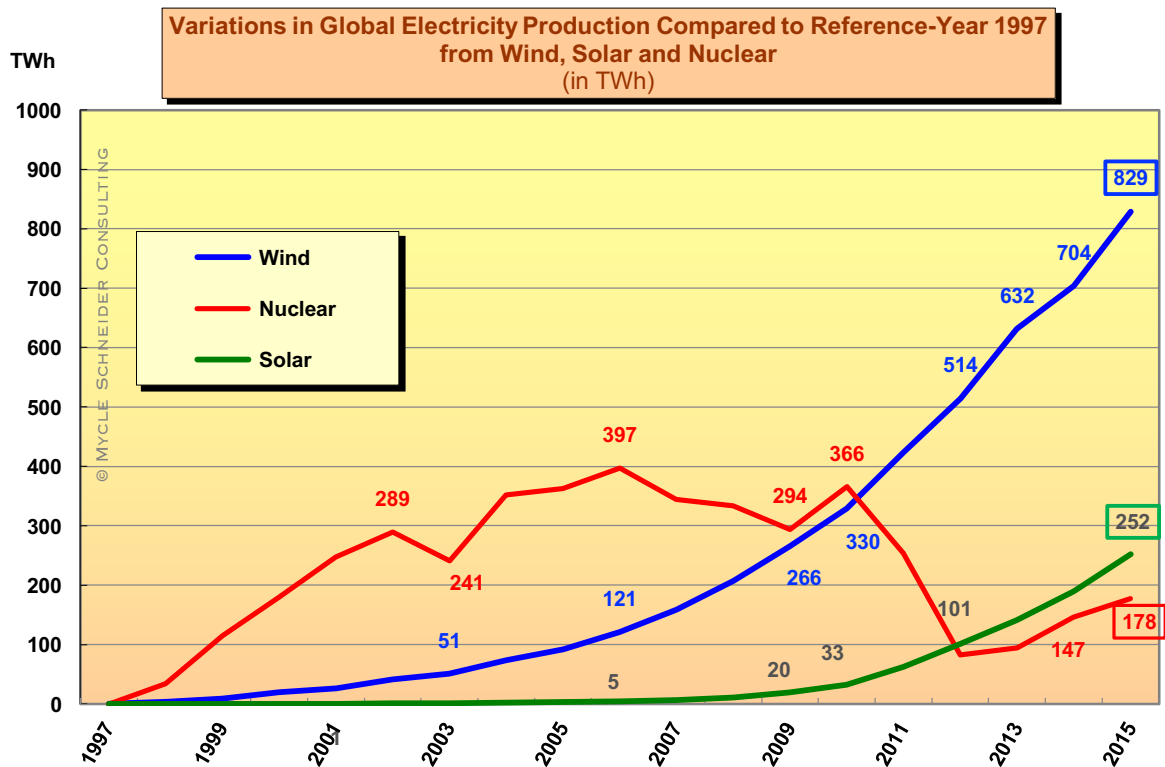
consecutive year, making up about 77 percent of all renewable power capacity added in 2015.³⁴² BP figures indicate an increase in 2015 over the previous year of 63 GW in wind power and 50 GW of solar,³⁴³ compared to a 6.5 GW increase for nuclear power.

Figure 34 illustrates the extent to which renewables have been deployed at scale since the new millennium, an increase in capacity of 417 GW for wind and of 229 GW for solar, compared to the stagnation of nuclear power capacity, which over this period increased by only 27 GW, including all reactors in LTO. Taking into account the fact that 35 GW of nuclear power are currently in LTO and not operating, the balance turns negative and 8 GW nuclear less are in operation than in 2000.

Electricity Generation

The characteristics of electricity generating technologies vary and different amounts of electricity are produced per installed unit of capacity. In general, over the year, nuclear power plants tend to produce more electricity per MW of installed capacity than renewables.

Figure 35: Global Electricity Production from Wind, Solar and Nuclear 1997-2015



Sources: BP, MSC, 2016

³⁴² REN 21, “Renewables 2016 Global Status Report”, Renewable Energy Policy Network for the 21st Century, June 2016.

³⁴³ BP, “Statistical Review of World Energy”, June 2016.

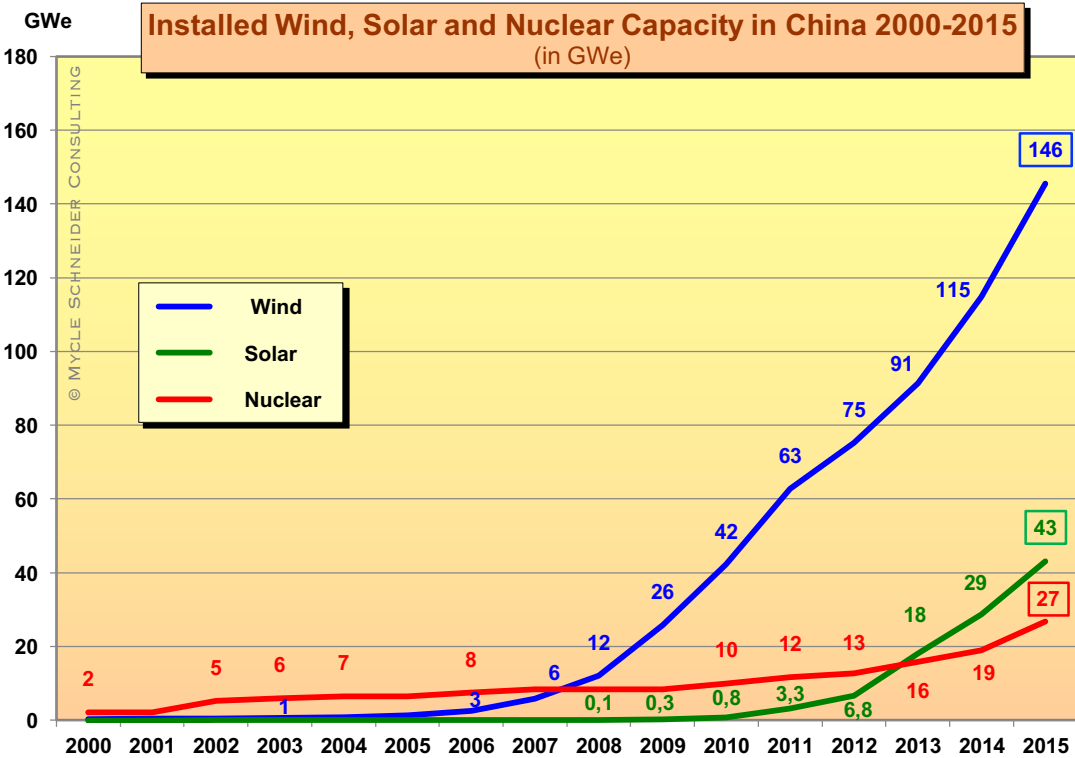
However, as can be seen, since 1997, the signing of the Kyoto Protocol, there has been an additional 829 TWh per year of wind power, 252 TWh more power from solar photovoltaics, and just an additional 185 TWh of nuclear electricity (see Figure 35).

In 2015, annual growth rates for the generation from wind power was over 17 percent globally, while it was over 33 percent for solar PV and 1.3 percent for nuclear power. In terms of actual production, nine of the 31 nuclear countries—Brazil, China, Germany, India, Japan, Mexico, Netherlands, Spain and U.K.—now all generate more electricity from non-hydro renewables than from nuclear power.

Status and Trends in China, the EU, India, and the U.S.

China continues to be a global leader for most energy technologies. In 2015, China installed more wind power and solar photovoltaics than any other country (see Figure 36), so worldwide, it now has the largest capacities of both, wind power and solar PV. In 2015, China has overtaken Germany in deployed PV capacity. Having started up eight of the world's ten reactors, China also installed more nuclear capacity in 2015 than any other country.

Figure 36: Installed Capacity in China from Wind, Solar and Nuclear 2000–2015



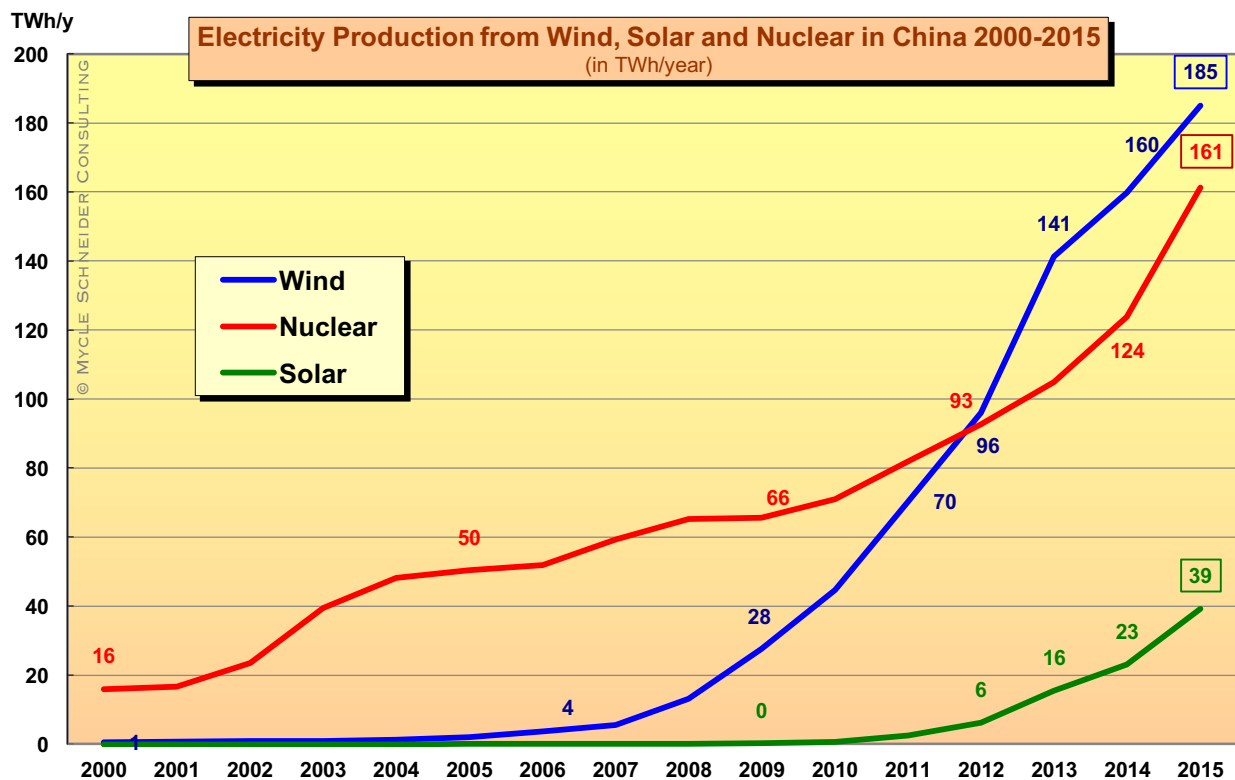
Sources: BP Statistical Review, IAEA PRIS 2016

Investment in renewables in China was by far the largest in the world with a total of just under US\$103 billion up from US\$83 billion the previous year. In 2015, investment in solar PV was

US\$43 billion and wind power was US\$42 billion,³⁴⁴ that compares to the start of construction on six new nuclear power plants, with Capex of an estimated, based on government figures, of around US\$18 billion.³⁴⁵

The 13th Five Year Plan (2015-2020) proposes new targets for energy efficiency, the reduction of carbon intensity as well as diversification away from fossil fuels, whereby non-fossil fuels are to provide 15 percent of primary energy consumption by 2020, up from 7.4 percent in 2005.³⁴⁶ Consequently, the explosive growth of renewables is expected to continue with a likely increase of installed capacity of approximately 19.5 GW of solar PV in 2016. Officials from China’s National Energy Administration (NEA) are considering raising the 2020 solar target from 100 GW to 150 GW, which would bring about 21 GW of annual installation between 2016 through to 2020.³⁴⁷

Figure 37: Electricity Production in China from Nuclear, Wind and Solar 2000-2015



Sources: BP Statistical Review, IAEA-PRIS 2016

³⁴⁴ FS-UNEP, “Global trends in renewable energy investment 2016”, Frankfurt School-UNEP collaboration Centre, Bloomberg New Energy Finance, March 2016.

³⁴⁵ WNA, “Nuclear Power in China”, 25 May 2016, see <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>, accessed 19 June 2016; and WNA, “Nuclear Power in China”, January 2015.

³⁴⁶ China Dialogue, “Climate, energy and China’s 13th Five-Year Plan in graphics”, 18 March 2016, see <https://www.chinadialogue.net/article/show/single/en/8734-Climate-energy-and-China-s-13th-Five-Year-Plan-in-graphics>, accessed 23 May 2016.

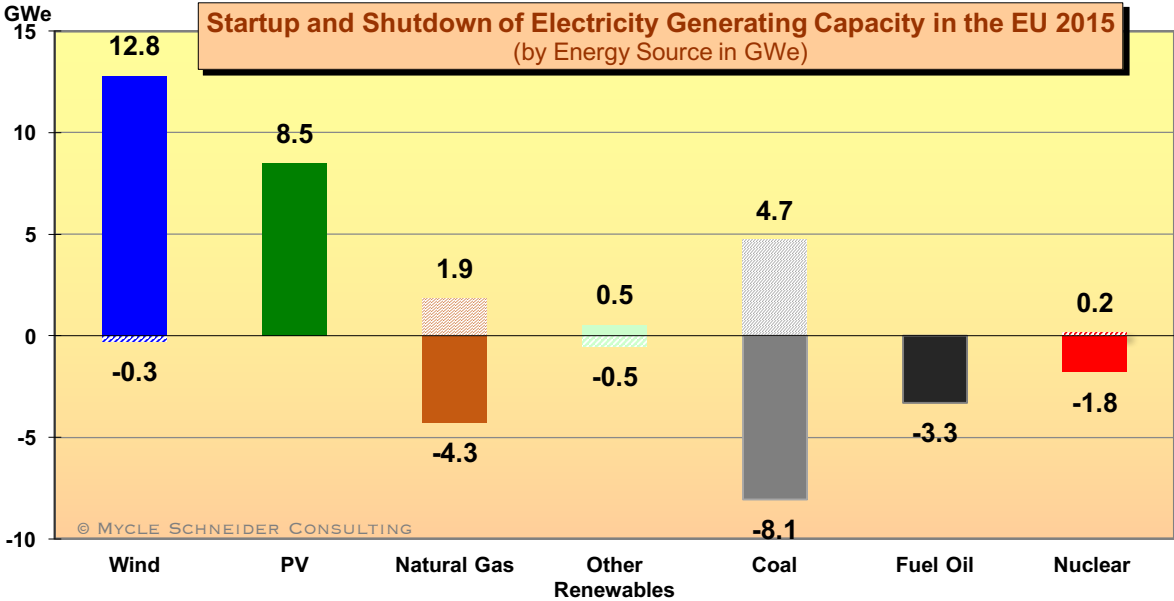
³⁴⁷ Junko Movellan, “The 2016 Global PV Outlook: US, Asian Markets Strengthened by Policies to Reduce CO₂”, 25 January 2016, see <http://www.renewableenergyworld.com/articles/2016/01/the-2016-global-pv-outlook-u-s-and-asian-markets-strengthened-by-policies-to-reduce-co2.html>, accessed 23 May 2016.

The 13th Five Year Plan is also proposing to increase the installed capacity of wind to 250 GW by 2020.³⁴⁸ Chinese officials envisage that there will be 58 GW of nuclear capacity in operation by 2020,³⁴⁹ up from 29.4 GW in mid-2016. However, the 21 units with 21.5 GW under construction will not be sufficient to reach the target. And the average construction time of the 25 units that China brought on line over the past decade was 5.7 years and many of the units under construction encounter significant delays. It appears therefore practically impossible for the country to reach its 2020 nuclear target.

While the power sector in China continues to be dominated by coal, the growth rate of non-fossil fuels is still impressive. This increase in electricity production is delivering changes in the power mix. While China's the nuclear buildup is fast—production increase by a factor of over three in 10 years, a factor of ten in 15 years—the renewable energy deployment has been breathtaking. In a decade Wind power increased generation from virtually nothing, that is less than 0.1 TWh in 2006 to 185 TWh in 2015. Solar PV went from less than 1 TWh in 2010 to 39 TWh in 2015 (see Figure 37).

In the **European Union**, between 2000 and 2015, the net changes in the capacity of power plants are estimated to be an increase of 129 GW in wind, 99 GW in natural gas and 96 GW in solar, while there have been decreases in nuclear by 14.8 GW, coal 28.3 GW and fuel oil by 28.2 GW.³⁵⁰

Figure 38: Startup and Shutdown of Electricity Generating Capacity in the EU in 2015



Source: European Wind Energy Association (EWEA) 2016³⁵¹

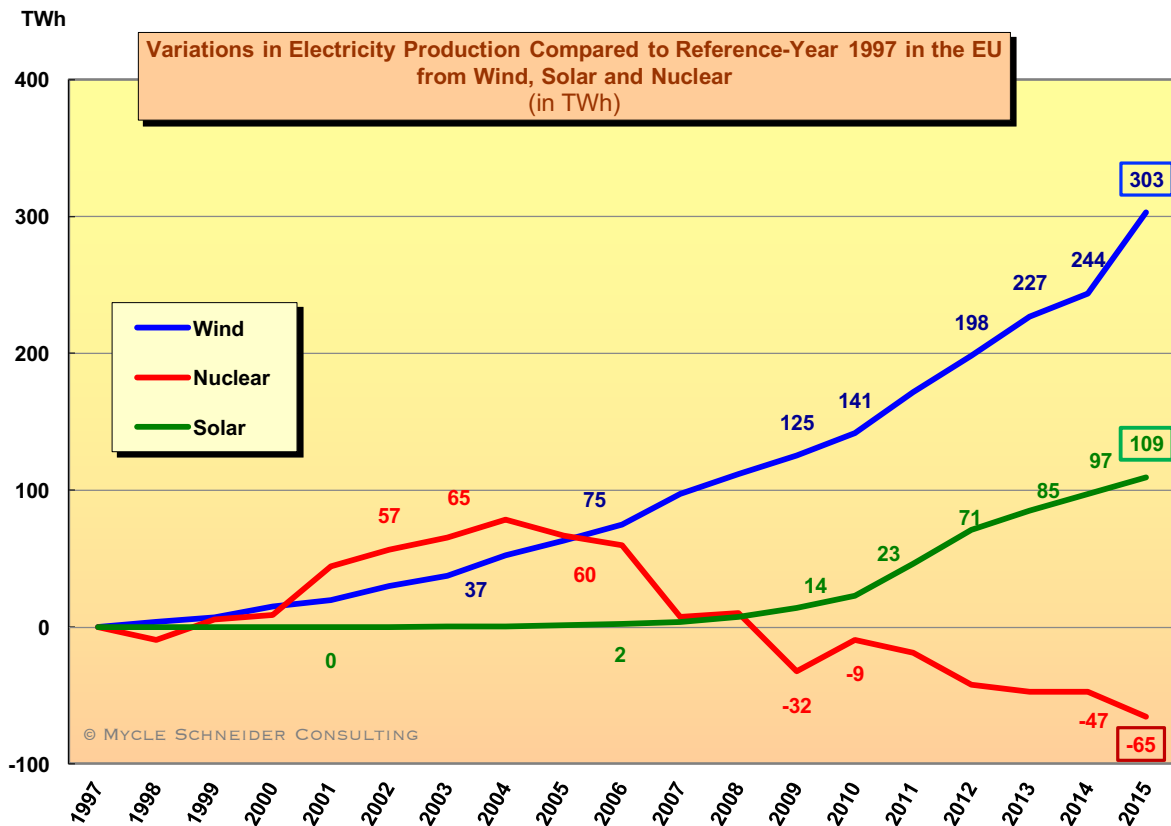
³⁴⁸ GWEC, “Global Wind Report, Annual Market Update 2015”, April 2016, see http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_22_04.pdf, accessed 30 June 2016.

³⁴⁹ Reuters, “China on course to meet 2020 nuclear capacity targets -official”, 27 January 2016, see <http://www.cnbc.com/2016/01/27/reuters-america-china-on-course-to-meet-2020-nuclear-capacity-targets-official.html>, accessed 23 May 2016.

³⁵⁰ European Wind Energy Association, “Wind in Power, 2015 European statistics”, February 2016.

³⁵¹ EWEA, “Wind in Power, 2015 European statistics”, February 2016.

Figure 39: Changes in EU Nuclear, Solar and Wind Power Production Since Signing of the Kyoto Protocol



Sources: BP Statistical Review³⁵², IAEA-PRIS 2016

EU 2015 renewable electricity production highlights included:

- In Germany, renewable energy sources – solar, wind, hydropower, and biomass – provided 30.1 percent of gross national electricity consumption.
- Denmark had another record year, with wind power providing a 42 percent of the Danes' electricity consumption.³⁵³
- In Spain, more electricity was produced by solar PV and wind power, than nuclear. While all renewables combined produced more electricity than the total from fossil fuels.³⁵⁴
- In the U.K., renewables' (including hydro) share of electricity generation increased to 24.7 percent, from 19.1 per cent in 2014. In total 83.3 TWh of power were produced by renewables, compared to 63.9 TWh for nuclear (18.9 percent).³⁵⁵

³⁵² Figures including data from: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden, U.K..

³⁵³ Energinet.dk, "New record-breaking year for Danish wind", 15 January 2016, see <http://energinet.dk/EN/EI/Nyheder/Sider/Dansk-vindstroem-slaar-igen-rekord-42-procent.aspx>, accessed 30 June 2016.

³⁵⁴ RedElectrica de Espana, "The Spanish Electricity System Preliminary Report, 2015", January 2016.

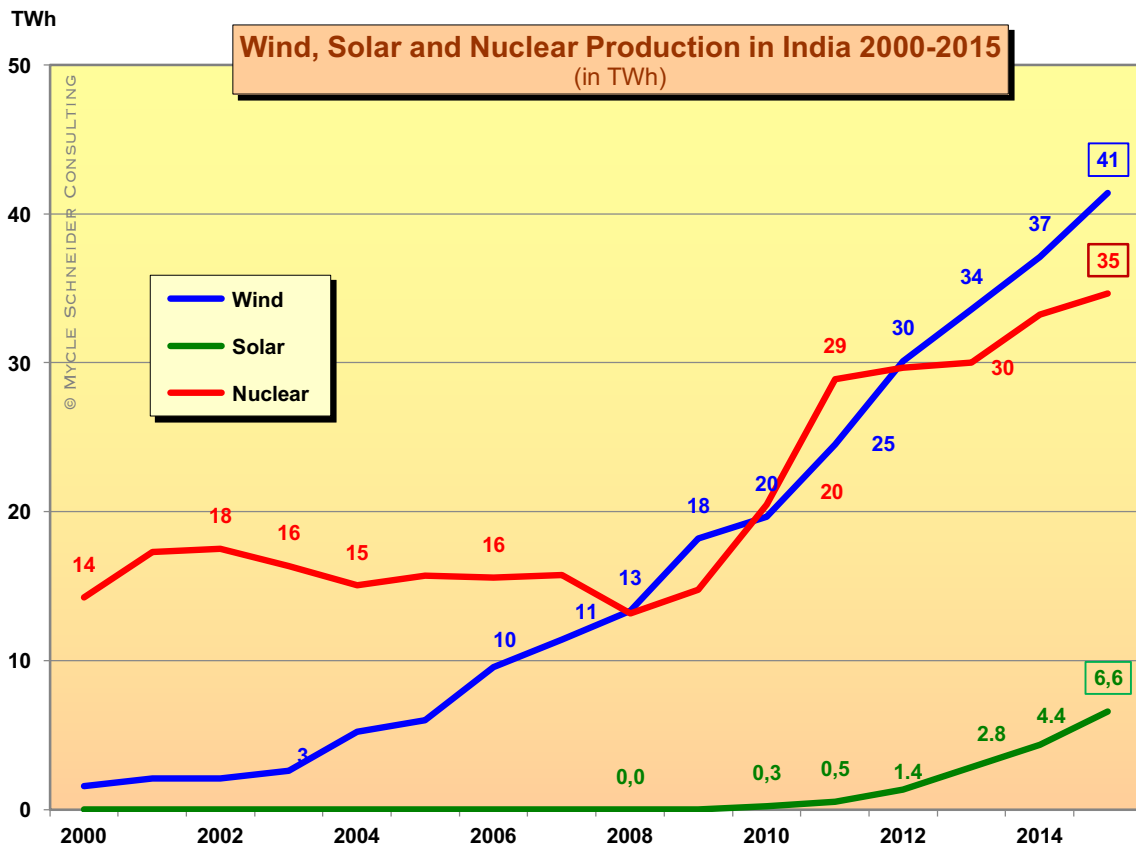
³⁵⁵ U.K. Government, "Energy Trends: renewables", 14 April 2016, see <https://www.gov.uk/government/statistics/energy-trends-section-6-renewables>, accessed 8 May 2016.

Compared to Kyoto Protocol Year 1997, in 2015 wind added 300 TWh and solar 108 TWh, while nuclear power generation declined by 80 TWh across the EU as can be seen in Figure 39.

This growth in installed renewables capacity 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 45 percent of power coming from renewables. This will require an escalation of the current rate of renewable electricity deployment. There is no EU-wide nuclear deployment target and the nuclear share has been shrinking for decades.

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)

Figure 40: Solar, Wind and Nuclear Production in India 2000-2015 (TWh)



Sources: BP Statistical Review, IAEA-PRIS 2016

This is in stark contrast to the more recent but steady development of the renewable energy sector. Figure 40 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. India has moved up the league of countries of global importance for renewable energy investment as a whole, with US\$10.2 billion in 2015. It is also on the 5th position for non-

hydro renewables power generation and the fourth most important for installed capacity for wind.³⁵⁶

Further increases in the growth in renewables are expected in the coming decade; in 2014 a 2022 target of 175 GW of renewable-based power capacity (excluding large hydropower) was announced. Of this total, 100 GW is to be solar (compared to 731 MW in 2014), 60 GW wind (compared to 22.4 GW in 2014), 10 GW biomass-based power, and 5 GW small hydropower projects.

In the **United States**, power demand remained largely static in 2015 as it has for the past decade, however underlying this are significant changes in the supply mix. In 2007, the historic peak for consumption, coal accounted for 48 percent of the power mix, but since coal's power production has fallen by nearly 500 TWh, to 1,356 TWh in 2015 or just 33 percent of the total. The largest part of this decline has been met by the increased use of natural gas—essentially shale gas—producing an additional 347 TWh compared to 2007 and equaling the share of coal for the first time in 2015. However, non-hydro renewables, have also grown considerably, increasing by 143 TWh, providing 2.7 percent in 2007 and 7.9 percent in 2015. Over the same period the output from the country's nuclear power plants remained approximately constant. With the current rate of increase of renewables and flat or falling production from nuclear power, by the early part of the next decade renewables, including hydro-power, are likely to exceed production from nuclear power.³⁵⁷

In 2015, a total of 16 GW of new renewable capacity was installed, of which 8.5 GW was wind and 7.3 GW was solar PV³⁵⁸, the majority of new installed capacity with little change in the nuclear sector. This trend is likely to continue as the U.S. Clean Power Plan will regulate the country's power sector, aiming to cut emissions by 32 percent relative to 2005 levels by 2030, accelerating the current trends of closure of coal and the installation of solar and wind and as we have seen in the country section, little new construction of nuclear and a likely acceleration of the closure rate of reactors in unregulated power markets.

³⁵⁶ REN 21, "Renewables 2016 Global Status Report", Renewable Energy Policy Network for the 21st Century, see www.ren21.net/GSR-2016-Report-Full-report-EN, accessed 30 June 2016.

³⁵⁷ US EIA, "Annual Energy Outlook 2016", US Energy Information Administration, 17 May 2016.

³⁵⁸ BNEF, "2016 Sustainable Energy in America Fact book", Business Council for Sustainable Energy, 2016.

Conclusion on Nuclear Power vs. Renewable Energies

The gulf between the development of new renewables, primarily wind and solar, and nuclear power is growing wider year by year. This can be measured, by the number of countries actively supporting the expansion of the technologies, for climate, energy access or economic reasons, or by the subsequent levels of investment, capacity increases or new generation put into the grid.

Furthermore, with rising nuclear construction costs contrasting rapidly decreasing prices for renewable technology this trend is likely to accelerate, in particular if decarbonization objectives agreed in Paris in December 2015 are adhered to. Nuclear power, even in countries that have or are considering to deploy it, will increasingly play a junior role to renewable energy which is already the case in many of the world's largest economies, such as Brazil, China, Germany, Japan and the U.K.. However, in the 163 U.N. Member States that don't use nuclear power, renewables are likely to flourish even faster in the coming decades, which will bring further technological and subsequent economic improvements, further marginalizing nuclear power.

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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 2016) 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 has two French (Framatome/AREVA)-built 31- and 32-year old 900 MW reactors. They are both located at the Koeberg site east of Cape Town and generated 11 TWh in 2015, a decline of 26 percent over the previous year, the largest drop worldwide. Nuclear power provided 4.7 percent of the country's electricity in 2015 (the historical maximum was 7.4 percent in 1989).

The Koeberg site hosts the only operating nuclear power plant on the African continent.

The Koeberg reactors are increasingly struggling with ageing issues. The decision to replace all six steam generators of the two units has been taken as early as 2010. The plant had been operating for many years at low temperatures in order to reduce the pace of corrosion in the steam generator tubes. Replacement work was to begin in 2018. But, since September 2014, a legal conflict between two competing supplier firms, French AREVA and Toshiba-owned Westinghouse, is delaying implementation. Both industrial groups are in financial troubles and badly need the 5 billion rand (US\$324 million) business. In addition, AREVA reportedly has already started working on steam generator fabrication at its Chinese subcontractor Shanghai Electric.³⁵⁹ 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 2016.³⁶⁰ The outcome is uncertain. Further delays could lead to missing the next scheduled refueling outage and prevent the plants to be back on line when power sources are most needed.

The state-owned South African utility and Koeberg operator Eskom has considered acquiring additional large Pressurized Water Reactors (PWR) 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. In February 2012 the Department of Energy (DOE) published a Revised Strategic Plan that still contained a 9.6 GW target, or six nuclear units, by 2030. Startup would be one unit every 18 months beginning in 2022.³⁶¹

³⁵⁹ *NIW*, "South African Court Upends Koeberg Steam Generator Contract", 11 December 2015.

³⁶⁰ 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.

³⁶¹ DOE, "Revised Strategic Plan – 2011/120-02015/16", February 2012.

The November 2013 edition of the Integrated Resource Plan for Electricity, which has not been updated since, concludes:

The nuclear decision can possibly be delayed. The revised demand projections suggest that no new nuclear base-load capacity is required until after 2025 (and for lower demand not until at earliest 2035) and that there are alternative options, such as regional hydro, that can fulfil the requirement and allow further exploration of the shale gas potential before prematurely committing to a technology that may be redundant if the electricity demand expectations do not materialise.³⁶²

However, DOE's Strategic Plan 2015–2020, released in April 2015, maintains the 2030 objective, but states that the investment in the 9.6 GWe Nuclear New Build Program "requires an innovative financing mechanism to provide a firm basis to launch procurement".³⁶³ A Nuclear Cooperation Agreement (NCA) signed with Russia in September 2014 allows for the delivery of VVER reactors "with total installed capacity of up to 9.6 GW", in other words potentially covering the entire program. This raised some concerns for the overall procurement process³⁶⁴ and in October 2015, environmental organization Earthlife Africa went to court against the entire new-build decision-making process, arguing that "the government is not complying with the constitution because they're doing this in a very secret, non-transparent, non-cost effective manner".³⁶⁵

Whatever the political and legal disputes, the main stumbling block remains finances. State utility Eskom withdrew the 2008 call-for-tender, because credit-rating agencies had "threatened" to downgrade the company, if it went ahead. In November 2014, Moody's downgraded Eskom nevertheless to "junk".³⁶⁶ In the latest rating action of May 2016, Moody's confirmed the Ba1-rating associated with a negative outlook.³⁶⁷ Eskom remains in critical condition as generating costs are increasing, consumption is falling, investment requirements are increasing and competitors are reportedly ferocious.³⁶⁸

The current new-build plan would see the government launching the procurement process. This in turn could threaten the credit-rating of the country. In its rationale to the latest credit-rating action in May 2016, Moody's confirmed South Africa Baa2 rating (outlook negative), just two notches off "junk", and stressed:

The authorities have also stated that expensive new projects such as the construction of massive nuclear power facilities and national health insurance will be developed only at the pace and scale that the budget allows.³⁶⁹

³⁶² DOE, "Integrated Resource Plan for Electricity (IRP) 2010-2030", Update Report 2013, 21 November 2013.

³⁶³ DOE, "Strategic Plan 2015–2020", April 2015, see <http://www.energy.gov.za/files/aboutus/DoE-Strategic-Plan-2015-2020.pdf>, accessed 15 May 2015.

³⁶⁴ *NIW*, "Russia Deal Unleashes Fury Over Procurement Process", 26 September 2014.

³⁶⁵ *NIW*, "South Africa – Battles Behind the 9.6 GW Newbuild", 19 February 2016.

³⁶⁶ Moody's, "Moody's downgrades Eskom to Ba1; outlook stable", 7 November 2014.

³⁶⁷ Moody's, "Moody's confirms Eskom's Ba1 ratings; negative outlook", 9 May 2016.

³⁶⁸ *EE Publishers*, "Eskom: from a crisis of capacity, to a crisis of rising prices, declining demand and funding", 15 November 2015, see <http://www.ee.co.za/article/eskom-crisis-capacity-crisis-rising-prices-declining-demand-funding.html>, accessed 4 June 2016.

³⁶⁹ Moody's, "Rating Action: Moody's confirms South Africa's sovereign rating at Baa2 and assigns a negative outlook", 6 May 2016, see https://www.moodys.com/research/Moodys-confirms-South-Africas-sovereign-rating-at-Baa2-and-assigns--PR_348291, accessed 16 June 2016.

An overwhelming majority of participants from government, banking sector, academia and independent expert community concluded during an NGO-convened March 2016 “Technical Workshop on the Economics of Nuclear Energy” in Johannesburg that there was no viable financing scheme for newbuild in sight.³⁷⁰ It is therefore difficult to conceive that the nuclear newbuild program would fit into South Africa’s strained budget for many years to come.

The five-year target as outlined in the Strategic Plan, is to have completed technology and vendor selection, the procurement process and to have begun construction of the first unit by 2020; with connection of the first unit to the grid by 2023 and the second one in 2024. This appears to be an overly ambitious timeline, by any standards.

The Americas

Argentina operates three nuclear reactors that in 2015 provided 6.5 TWh (a 24 percent increase over 2014, with Atucha-2 reaching 100 percent power in February 2015) or 4.8 percent of the country’s electricity (down from a maximum of 19.8 percent in 1990).

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). After close to 30 years of operation, 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 2013.³⁷¹ According to some reports, the refurbishment is planned to take about two years, with restart scheduled for March 2018.³⁷² However, *Nuclear Engineering International* estimated the 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.”³⁷³

Atucha-2 had been ordered in 1979 and was officially listed as “under construction” since 1981. Finally, on 3 June 2014, the 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 100 percent of

³⁷⁰ A summary of the workshop with links to the presentations can be found at Henrich Böll Foundation, Southern Africa, “Workshop Report: The Economics of Nuclear Energy in South Africa”, 9 May 2016, see <https://za.boell.org/2016/05/09/workshop-report-economics-nuclear-energy-south-africa>, accessed 1 July 2016.

³⁷¹ *Research and Markets*, “Nuclear Power Market in Argentina”, May 2012.

³⁷² SCN Lavalin, “Embalse Nuclear Generating Station Life Extension”, Undated, see <http://www.snclavalin.com/en/embalse-nuclear-generating-station-life-extension>, accessed 5 June 2016.

³⁷³ *NEI*, “Argentina—a possible return to new nuclear?”, 15 October 2013, see <http://www.neimagazine.com/opinion/opinionargentina-a-possible-return-to-new-nuclear/>, accessed 16 June 2016.

its rated power³⁷⁴ and until 26 May 2016 to enter commercial operation.³⁷⁵ The delays in the startup procedures echo the 33-year construction time.

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.³⁷⁶ Seven years later, work has not started. In February 2015, Argentina and China ratified an agreement to build an 800 MW CANDU-type reactor at the Atucha site. Construction is to take eight years, but it has not been announced, when work will start.³⁷⁷ In October 2014, *Nuclear Intelligence Weekly* noted that "while it's unclear when construction on Atucha-3 might start, the goal is to commission the reactor by July 2022". Atucha-3 is expected to cost US\$5.8 billion.³⁷⁸ In November 2015, a contract was signed between state-controlled Nucleoelectrica and 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 and Nucleoelectrica would act as designer, architect, engineer, builder and operator of the plant. This is quite a novel arrangement.

A framework agreement was also signed between the two companies for the construction of a Hualong One reactor, China's new, and as yet untested, Generation III design.³⁷⁹ A commercial contract was scheduled to be signed by the end of 2016.³⁸⁰ But in May 2015, as a result of delays in the Hualong One construction at Fuqing in China, it was reported that signature was likely to be pushed into 2017.³⁸¹

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 planned for 2018. The reactor is said to cost US\$450 million,³⁸² or about US\$17,000 per installed kWe, a record for reactors currently under construction in the world.

Brazil operates two nuclear reactors that provided the country with 13.9 TWh or 2.8 percent of its electricity in 2015 (down from a maximum of 4.3 percent in 2001).

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

³⁷⁴ 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 16 June 2016.

³⁷⁵ 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 June 2016.

³⁷⁶ *Marketwire.com*, "Argentina to Reinforce Nuclear Energy by Adding 700 MW and Building Fourth Nuclear Plant", 7 May 2009.

³⁷⁷ WNN, "Argentina and China plan fourth reactor", 3 February 2015, see <http://www.world-nuclear-news.org/NN-Argentina-and-China-plan-fourth-reactor-03021501.html>, accessed 16 May 2015.

³⁷⁸ 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 16 June 2016.

³⁷⁹ *NIW*, "Moving closer to Atucha-3 and HPR1000 Newbuilds", 6 November 2015.

³⁸⁰ WNN, "Hualong One selected for Argentina", 5 February 2015, see <http://www.world-nuclear-news.org/NN-Hualong-One-selected-for-Argentina-0502154.html>, accessed 16 May 2015.

³⁸¹ WNN, "Argentina-China talks on new nuclear plants", 8 May 2015, op.cit.

³⁸² *NIW*, "Cost Overruns Put Mobile Breeder Project in Quandary", 7 November 2014.

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, due to an ever-increasing debt burden and obvious interest in nuclear weapons by the Brazilian military, practically the entire program was abandoned. Only the first reactor, Angra-2, was finally connected to the grid in July 2000, 24 years after construction started.

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.³⁸³ 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.³⁸⁴ 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.³⁸⁵ Commissioning was previously planned for July 2016 but has been delayed to May 2018. No reasons were given for the new delays.³⁸⁶

The position on nuclear power of the incoming government under President Mauricio Macri remains unclear. The issue did not play any role in the December 2015 election.

Canada operates 19 reactors, all of which are CANDU (CANadian Deuterium Uranium), providing 95.6 TWh or 16.6 percent of the country's electricity in 2015 (down from a maximum of 19.1 percent in 1994), but 60 percent of the Province of Ontario's provincial power supply. However, in Ontario, the role of wind power is rapidly expanding and already represents 10 percent of the Province's installed capacity—versus 36 percent for nuclear—and has doubled its share in the generation mix from 3 to 6 percent in just two years.³⁸⁷

The Canadian CANDU reactor design typically requires extensive repair and upgrading work to operate beyond 25 years. This work—often referred to as re-tubing or refurbishment—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.

The estimated cost of extending the life of a CANDU reactor has tripled over the past fifteen years. In 2002, the cost of refurbishing New Brunswick's single unit Point Lepreau nuclear station was estimated at CAD840 million (US\$533 million).³⁸⁸ In 2012, Hydro-Quebec estimated the cost of

³⁸³ However, it is surprising to note that AREVA's 400-page Reference Document 2012 does not even contain the word "Angra".

³⁸⁴ *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 16 June 2016.

³⁸⁵ AREVA, Press Release, 29 April 2015.

³⁸⁶ *NIW*, "Briefs—Brazil", 9 January 2015.

³⁸⁷ IESO (Independent Electricity System Operator), "Supply Overview", see <http://www.ieso.ca/Pages/Power-Data/supply.aspx>, accessed 5 June 2016.

³⁸⁸ NB Power, "Project Execution Plan—Appendix A-4, Table 1-1", February 2002.

rebuilding its Gentilly-2 nuclear at over CAD3 billion (US\$3 billion). The company estimated the cost of electricity post life-extension would be 10.8 CAD cents/kWh. As result—also giving in to political pressure—Hydro-Quebec decided to close the Gentilly-2 reactor instead of rebuilding it.³⁸⁹

In 2010, Ontario Power Generation (OPG, formerly Ontario Hydro) announced it would not rebuild the four Pickering “B” reactors at the end of their design life. OPG estimated the cost of electricity post rebuilt at approximately 10 CAD cents/kWh.³⁹⁰ Previously, OPG had announced in 2005, it would permanently shut down two reactors at the Pickering “A” nuclear station due to “the costs and the risks” of restarting them.³⁹¹

In total, nine of Canada’s 22 CANDU Generation II reactors have been closed, or are set for closure, due to the high cost of CANDU life-extension.

The Ontario government’s 2013 Long Term Energy Plan (LTEP) committed to rebuilding and extending the lives of ten reactors at the Darlington and Bruce nuclear stations. The LTEP also stated the six operating Pickering units were “expected to be in service until 2020” but with an earlier shutdown “possible depending on projected demand going forward, the progress of the fleet refurbishment program, and the timely completion of the Clarington Transformer Station”.³⁹²

In December 2015, the Ontario government announced it had reached an agreement with Bruce Power, a private company that leases the Bruce nuclear site from state-owned OPG, to rebuild and extend the lives of six reactors at the Bruce Nuclear Generating Station (NGS).³⁹³ Commencement of work on the first reactor was delayed from 2016 to 2020 compared to the 2013 LTEP schedule. Bruce Power received a five-year licence for the Bruce A and B nuclear stations in 2015, but in making its decision the Canadian Nuclear Safety Commission (CNSC) noted: “Refurbishment was not considered in the context of this hearing. The Commission wishes to be clear that, in the event of an application for refurbishment at the Bruce NGS, this application will be considered at a public proceeding with public participation.”³⁹⁴

In January 2016, the Ontario government announced, it would allow OPG to proceed with the CAD12.8 billion (US\$18.5 billion) life-extension plan for the four Darlington units, with work to

³⁸⁹ Hydro-Québec, “Projet de réfection de la centrale nucléaire Gentilly-2”, 2 October 2012, see http://nouvelles.hydroquebec.com/media/filer_private/2012/12/17/etat_de_situation_1.pdf, accessed 9 June 2016.

³⁹⁰ OPG response to questions posed by Shawn-Patrick Stensil after a mediation held on 28 July 2010, in Freedom of Information request no. 100007, Energy Analyst, Greenpeace Canada. Information quoted in Pembina Foundation and Greenpeace Canada, “Renewable is Doable”, September 2013, see http://www.greenpeace.org/canada/Global/canada/report/2013/09/GPC_ENERGY_PLAN2013.pdf, accessed 6 July 2016.

³⁹¹ Ontario Power Generation, “Annual Report 2006”, p.22, see www.opg.com/about/finance/Documents/2006_Annual_Report.pdf, accessed 6 July 2016.

³⁹² Ministry of Energy, “Achieving Balance—Ontario’s Long-Term Energy Plan”, December 2013.

³⁹³ Government of Ontario, “Ontario Commits to Future in Nuclear Energy”, Ministry of Energy, Press Release, 3 December 2015, see <https://news.ontario.ca/mei/en/2015/12/ontario-commits-to-future-in-nuclear-energy.html>, accessed 16 June 2016.

³⁹⁴ CNSC, “Record of Proceedings, Including reasons for Decision in the Matter of Application to Renew the Power Reactor Operating Licences for Bruce A and Bruce B Nuclear Generating Stations”, 2015, p. 5, see <http://nuclearsafety.gc.ca/eng/the-commission/pdf/2015-04-14-CompleteDecision-BrucePower-edoc4798838.pdf>, accessed 9 June 2016.

start in October 2016.³⁹⁵ According to OPG’s schedule, rebuilding all four Darlington reactors will take over a decade.

Notably, the government of Ontario has required Bruce Power and OPG to plan “offramps”—a sort of Plan B—if life-extension work is delayed or goes over-budget. For the life-extension, the offramp allows “the government to assess Bruce Power’s cost estimates for each reactor prior to its refurbishment and stop the refurbishment, if the estimated cost exceeds a pre-defined amount.”³⁹⁶ The government, however, has not disclosed this “pre-defined amount”.

In 2016, the Ontario government announced, it will allow OPG to “pursue continued operation of the Pickering Generating Station beyond 2020 up to 2024.”³⁹⁷ In 2013, OPG applied to the CNSC to operate the Pickering reactors beyond its initial design life in 2014. The CNSC approved the application and issued a five-year licence to OPG, but put conditions on the licence including the distribution of information on nuclear emergency response to households in the Pickering area and a detailed risk improvement plan for the station.³⁹⁸

OPG estimates the cost of continuing to operate Pickering to 2024 at approximately CAD\$300 million (USD\$235 million), but that there is “a risk the station’s extended operation to 2024 may be determined to be uneconomical to pursue.”³⁹⁹ OPG’s license for the Pickering nuclear station expires in 2018.

The launch of a nuclear new-build program has not got beyond initial stages. In May 2012, the Government accepted the Environmental Impact Assessment report for the construction by OPG of up to four units at the Darlington site. On 17 August 2012, the CNSC issued a “Site Preparation License” for the Darlington project, “a first in over a quarter century”.⁴⁰⁰ But before the project proceeded, in October 2013, the Ontario Government pulled the plug and “decided against spending upwards of CAD10 billion [US\$7.8 billion] to buy two new nuclear reactors”.⁴⁰¹ Ontario’s

³⁹⁵ OPG, “OPG investing \$122 million into unit 4 Darlington Nuclear”, Press Release, 12 April 2016, see http://www.opg.com/news-and-media/news-releases/Documents/20160412_Unit4DarlingtonInvestment.pdf, accessed 9 July 2016.

³⁹⁶ Government of Ontario, “Ontario Commits to Future in Nuclear Energy”, Press Release, 3 December 2015, see <https://news.ontario.ca/mei/en/2015/12/ontario-commits-to-future-in-nuclear-energy.html>, accessed 16 June 2016.

³⁹⁷ Government of Ontario, “Ontario Moving Forward with Nuclear Refurbishment at Darlington and Pursuing Continued Operations at Pickering to 2024”, Press Release, 11 January 2016, see <https://news.ontario.ca/mei/en/2016/01/ontario-moving-forward-with-nuclear-refurbishment-at-darlington-and-pursuing-continued-operations-at.html>, accessed 9 June 2016.

³⁹⁸ CNSC, “Record of Decision, Application to Request a Removal of the Hold Point for the Pickering Nuclear Generating Station”, 2015, see <https://www.cnsccsn.gc.ca/eng/the-commission/pdf/2014-05-07-DecisionSummary-OPG-PickeringHoldPoint-e-Final-Edocs4448178.pdf>, accessed 9 June 2016.

³⁹⁹ QP Briefing, “Pickering nuke plant extension to cost \$307M, may prove ‘uneconomical’: OPG”, Queen’s Park Briefing, 20 May 2016, see <http://www.qpbriefing.com/2016/05/20/pickering-nuke-plant-extension-to-cost-307m-may-prove-uneconomical-opg/>, accessed 16 June 2016.

⁴⁰⁰ OPG, “Joint Review Panel issues Licence to Prepare Site”, 17 August 2012.

⁴⁰¹ *Globe and Mail*, “Ontario backs away from plans to buy new nuclear reactors”, 10 October 2013, see <http://www.theglobeandmail.com/news/politics/ontario-backs-away-from-plans-to-buy-new-nuclear-reactors/article14793803/>; and WNI SR, “The End of New Build in Canada?”, 11 October 2013, see <http://www.worldnuclearreport.org/The-End-of-New-Build-in-Canada.html>; both accessed 16 June 2016.

LTEP, released in December 2013, confirmed the decision: “Ontario will not proceed at this time with the construction of two new nuclear reactors at the Darlington Generating Station.”⁴⁰²

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 2015, nuclear power produced 11.2 TWh (up 20 percent), providing a record 6.8 percent of the country’s electricity, exceeding the 20-year old record of 6.5 percent in 1995. 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.”⁴⁰³ However, he did not indicate anything on timelines, technologies or costs involved.

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 2018.⁴⁰⁴ In March 2016, the Ministry organized the first power auction—inviting 15-year “clean energy” supply contracts and 20-year “clean energy” certificates—which had an unexpectedly large turnout with 103 preselected participants and more than 460 technical offers, of which 69 companies finally introduced 227 offers. Projects were mainly in the 10-100 MW range. Solar PV represented almost three quarters of the proposals.⁴⁰⁵

⁴⁰² Ministry of Energy, “Achieving Balance—Ontario’s Long-Term Energy Plan”, December 2013, see <http://www.energy.gov.on.ca/en/ltep/achieving-balance-ontarios-long-term-energy-plan/>, accessed 16 June 2016.

⁴⁰³ *Reuters*, “UPDATE 1-Mexico eyes construction of two new nuclear reactors -official”, 24 September 2015, see <http://www.reuters.com/article/mexico-nuclear-idUSL1N11U2WA20150924>, accessed 20 June 2016.

⁴⁰⁴ *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 16 June 2016.

⁴⁰⁵ *Argus*, “Solar looms large in Mexico's debut power auction”, 29 March 2016, see <https://www.argusmedia.com/news/article/?id=1212773>, accessed 6 June 2016.

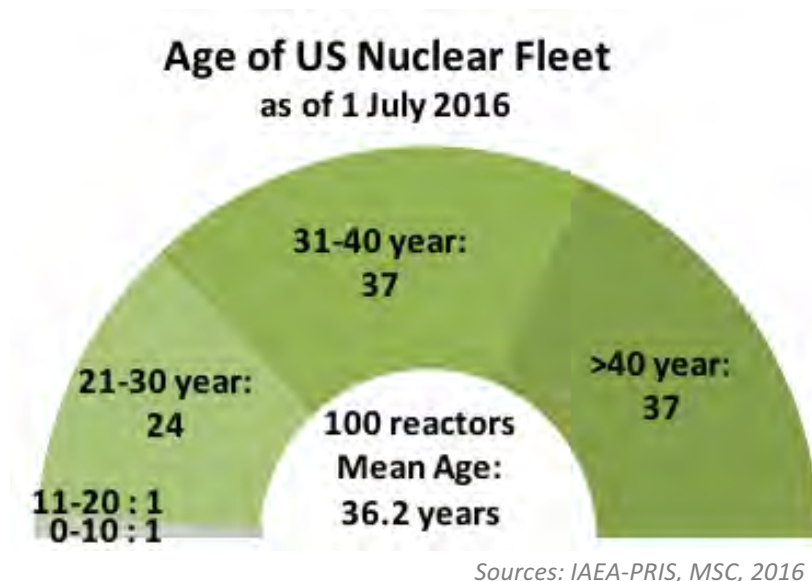
United States Focus

U.S. nuclear power plant operators are fighting a war on two fronts: Crashing prices for natural gas and accelerating market penetration of renewable energy have both contributed to dramatic drops in wholesale power price levels—in some states, they’ve fallen by more than two-thirds over the past decade. This has left nuclear power, whose operating costs are pretty much fixed, with few options other than surrender.

Peter Fairley, *IEEE Spectrum*, March 2016⁴⁰⁶

With a hundred commercial reactors officially currently operating, the United States possesses the largest nuclear fleet in the world. Four more reactors are under construction, but a number of reactors are due to be shutdown. The Nuclear Energy Institute, the advocacy organization for the U.S. nuclear industry, projects “15-to-20 plants at risk of shutdown over the next five-to-10 years”.⁴⁰⁷ Independent analysts think many more plants are at risk of being shut down.⁴⁰⁸ Therefore, the size of the U.S. nuclear fleet will decline in the foreseeable future.

Figure 41: Age of U.S. Nuclear Fleet



⁴⁰⁶ Peter Fairley, “Has U.S. Nuclear Power’s Death Spiral Begun?” *IEEE Spectrum*, 26 March 2016, see <http://spectrum.ieee.org/energy/nuclear/has-us-nuclear-powers-death-spiral-begun>, accessed 16 June 2016.

⁴⁰⁷ 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 16 June 2016.

⁴⁰⁸ 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 16 June 2016.

The U.S. reactor fleet provided 798 TWh in 2015, essentially the same as in 2014,⁴⁰⁹ but still below record year 2010 when it generated 807.1 TWh. Nuclear plants provided 19.5 percent of U.S. electricity in 2015, the same as 2014 and 3 percentage points below the highest nuclear share of 22.5 percent that was reached in 1995.

With only four reactors under construction and only one new reactor started up in 20 years, the U.S. reactor fleet continues to age, with a mid-2016 average of 36.2 years, amongst the oldest in the world: 37 units have operated for more than 40 years (see Figure 41).

In the past year, one new nuclear reactor was connected to the electric grid: Tennessee Valley Authority's (TVA) 1150 MW Watts Bar-2. The reactor went critical on 23 May 2016,⁴¹⁰ and was connected to the electric grid on 3 June 2016 (see box hereunder).⁴¹¹ But just a couple of days after, on 5 June, the unit shut down because of problems with its turbine system.⁴¹² On 21 June, the unit shut down a second time because of problems in its auxiliary feedwater system.⁴¹³

Watts Bar-2: Grid Connection 43 Years After Construction Start—Shutdown 2 Days Later

More than four decades after construction began, the Watts Bar-2 reactor was finally connected to the grid on 3 June 2016⁴¹⁴. However, two days later, while operating at 12.5 percent power, the reactor automatically shut down. According to the U.S. Nuclear Regulatory Commission (NRC), the reactor tripped when a high pressure turbine valve failed to open. On grid connection TVA reported that “it is rewarding to see TVA taking the lead on delivering the first new nuclear unit of the 21st century and providing safe, affordable and reliable electricity to those we serve.”⁴¹⁵

TVA filed the construction license application for Watts Bar on 18 May 1971. On 18 September 1972, TVA applied for the exceptional authorization of certain site preparation activities, although it had not transmitted the final environmental impact statement and the construction license was still pending.⁴¹⁶ TVA argued that startup of unit 1 by May 1977 “is vital in order to permit TVA to meet its summer 1977 peak loads” and beyond:

⁴⁰⁹ IAEA, “Nuclear Power Reactors in the World—2016 Edition”, Vienna, May 2016, see www-pub.iaea.org/MTCD/Publications/PDF/RDS_2-36_web.pdf, accessed 16 June 2016.

⁴¹⁰ *Nashville Public Radio*, “After Decades Under Construction, Watts Bar Unit 2 Finally Fires Up Its Nuclear Reactor”, 23 May 2016, see <http://nashvillepublicradio.org/post/after-decades-under-construction-watts-bar-unit-2-finally-fires-its-nuclear-reactor>, accessed 16 June 2016.

⁴¹¹ IAEA, “Power Reactor Information System (PRIS) Database”, 2016, see <http://www.iaea.org/programmes/a2/>, accessed 18 June 2016.

⁴¹² William Freebairn, “TVA’s Watts Bar-2 nuclear unit shuts soon after connecting to grid”, *Platts*, 6 June 2016, see <http://www.platts.com/latest-news/electric-power/washington/tvas-watts-bar-2-nuclear-unit-shuts-soon-after-21634906>, accessed 16 June 2016.

⁴¹³ *Times Free Press*, “Watts Bar nuclear plant shuts down for second time in three weeks”, 21 June 2016, see <http://www.timesfreepress.com/news/business/aroundregion/story/2016/jun/21/watts-bar-nuclear-plant-shuts-down-second-time-three-weeks/372227/>, accessed 22 June 2016.

⁴¹⁴ TVA, “Watts Bar Unit 2 Produces Electricity for the First Time”, 3 June 2016, see <https://www.tva.gov/Newsroom/Press-Releases/Watts-Bar-Unit-2-Produces-Electricity-for-the-First-Time>, accessed 22 June 2016.

⁴¹⁵ TVA, “Watts Bar Unit 2 Produces Electricity for the First Time”, 3 June 2016, see <https://www.tva.gov/Newsroom/Press-Releases/Watts-Bar-Unit-2-Produces-Electricity-for-the-First-Time>, accessed 22 June 2016.

⁴¹⁶ TVA, “Units 1 and 2, Watts Bar Nuclear Plant, Rhea County, Tennessee”, 18 September 1972, see <http://pbadupws.nrc.gov/docs/ML0734/ML073440321.pdf>, accessed 22 June 2016.

The present schedule for constructing the Watts Bar Nuclear Plant is predicated on beginning construction in October 1972. This schedule is extremely tight and failure to begin construction in October casts serious doubts on TVA's ability to meet its load commitments in the 1977-78 period.

TVA also insisted on costs to the ratepayer and environmental pollution of any delay:

6-month Delay: The total estimated monetary cost to the consumers of TVA power would be about \$58 million for a 6-month delay in operation of the Watts Bar Nuclear Plant. In addition to the monetary effects, TVA would be required to burn about 3.4 million additional tons of coal and about 36 million gallons of fuel oil in its plants with attendant atmospheric emissions which would not otherwise be required.

The construction license for the two 1,150-MW Pressurized Water Reactors (PWR) was issued in January 1973. The exact date of the pouring of the base slabs and thus the official construction starts remains unclear. TVA does not provide a specific date on its website. The IAEA recently modified in its online Power Reactor Information System (PRIS)⁴¹⁷ the construction-start date for Watts Bar-2 from 1 December 1972 to 1 September 1973.

The Watts Bar site is located in Rhea County, southeastern Tennessee approximately 50 miles northeast of Chattanooga. Construction delays and cost overruns plagued the reactor from the start. Construction was suspended in 1985 in part due to a decrease in electricity demand for TVA. In 2007, and based upon its projected increased energy demand, the TVA board approved a 5-year plan to complete the reactor. The completion cost also escalated from US\$2.5 billion in 2007 to US\$4.5 billion in 2013, to the final cost of the US\$4.7 billion assigned by TVA's board in February 2016. TVA is a corporate agency of the United States that provides electricity for business customers and local power distributors serving more than nine million people in parts of seven southeastern states.

Watts Bar units 1 and 2 are ice condenser designs, which makes them vulnerable to hydrogen buildup and containment failure. The Nuclear Regulatory Commission's (NRC) Near-Term Task Force on the Fukushima Daiichi March 2011 accident included requests for assessment of flood risk at U.S. nuclear power plants. In February 2013, the NRC censured TVA for using outdated and inaccurate calculations in estimating the maximum potential flood threat should upriver dams be breached, the end result of which could be loss of cooling function and reactor meltdown. In February 2016, the TVA board announced that flood prevention measures built at the plant to meet post Fukushima requirements, had risen to US\$300 million, compared to the US\$120 million estimated four years ago.⁴¹⁸

Watts Bar-2 is the first commercial reactor to be connected to the grid in the United States since 1996, when Watts Bar-1 started up, 23 years after its construction started.

Four nuclear plants were issued license renewals by the NRC in 2015: Sequoyah 1 & 2 (on 24 September 2015), Byron 1 & 2 (on 19 November 2015), Davis-Besse 1 (on 8 December 2015), and Braidwood 1 & 2 (on 27 January 2016).⁴¹⁹ Only one nuclear power plant applied for a license renewal (Waterford 3, on 23 March 2016). At the end of April 2016, 81 of the 100 operating U.S.

⁴¹⁷ IAEA, Power Reactor Information System (PRIS), see

<https://www.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=700>, accessed 22 June 2016.

⁴¹⁸ *Times Free Press*, "Cost of Watts Bar nuclear reactor rises by \$200 million to \$4.7 billion", 3 February 2016, see <http://www.timesfreepress.com/news/business/aroundregion/story/2016/feb/03/cost-watts-bar-reactor-rises-200-million-47-billion/348218/>, accessed 1 July 2016.

⁴¹⁹ NRC, "Status of License Renewal Applications and Industry Activities", Updated 14 April 2016, see <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>, accessed 16 June 2016.

units had received a license extension with a further eight applications under review. In December 2015, the NRC put out a draft document entitled “Generic Aging Lessons Learned for Subsequent License Renewal and Standard Review Plan for Subsequent License Renewal Applications for Nuclear Power Plants”, which describes “aging management programs” that might allow the NRC to allow old nuclear power plants to operate to “up to 80 years”.⁴²⁰

Struggling Reactors

The NRC’s exploration of a path to keeping nuclear reactors operating till 80 years and the license renewals for operations up to 60 years are in direct contradiction to the signals that the electricity market is sending to nuclear reactor operators, which has been to accelerate shutting down old reactors. For a long time now, 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, 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”.⁴²¹ 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 and generating electricity have been rising. In addition, falling 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 11 February 2016, the Nuclear Energy Institute (NEI), the most important lobbying organization for nuclear power in the U.S., reported that in 2014, evidently the last year for which it had data, annual expenditures at the average nuclear reactor (i.e., the various annual expenditures associated with running a nuclear reactor in the United States, averaged for the whole fleet) came to US\$36.27/MWh, with single unit plants averaging US\$44.14.⁴²² Note that these 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 (i.e., including the cost of recouping initial construction expenditures) of around US\$50/MWh, and even US\$40/MWh in some parts of the country.⁴²³

⁴²⁰ WNN, “NRC drafts guidance for 80-year lives”, 21 December 2015, see <http://www.world-nuclear-news.org/RS-NRC-drafts-guidance-for-80-year-lives-2112157.html>, accessed 16 June 2016.

⁴²¹ Ernest Moniz, “Why We Still Need Nuclear Power”, Energy Initiative, Massachusetts Institute of Technology, *Foreign Affairs*, November-December 2011 Issue, pp.83–94, see <https://www.foreignaffairs.com/articles/2011-10-17/why-we-still-need-nuclear-power>, accessed 16 June 2016.

⁴²² NEI, “Nuclear Energy 2016: Status and Outlook”, as presented at the Annual Briefing for the Financial Community, 2016, Slide 4, see <http://www.nei.org/Master-Document-Folder/Backgrounders/Presentations/Wall-Street-Briefing-2016-Slides>, accessed 10 June 2016.

⁴²³ Stephen Lacey, “Cheapest Solar Ever: Austin Energy Gets 1.2 Gigawatts of Solar Bids for Less Than 4 Cents”, *Greentech Media*, 30 June 2015, see <http://www.greentechmedia.com/articles/read/cheapest-solar-ever-austin-energy-gets-1.2-gigawatts-of-solar-bids-for-less>; and Mark Bolinger, Samantha Weaver, Jarett Zuboy, “Is \$50/MWh solar for real? Falling project prices and rising capacity factors drive utility-scale PV

NEI reports that “average generating costs have decreased from peak of US\$39.70/MWh in 2012 to US\$36.27/MWh in 2014”,⁴²⁴ but it is uncertain, if this slight 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 natural uranium and enrichment prices. As reported in *Nuclear Intelligence Weekly*, the spot market price of uranium in June 2012 was about US\$51 per pound of U₃O₈, whereas in June 2014, it was around US\$28 per pound of U₃O₈. Likewise, the spot price for uranium enrichment fell from around US\$140/SWU⁴²⁵ in early 2012 to around US\$95/SWU in early 2014. The other reason for the decrease in operational costs is that utilities have cut down on capital expenditures, but this cannot continue for long, as the age of the fleet is increasing. In the future, there may be a slight downward trend in the *average* operating cost because some of the older reactors, with highest operating costs, have been shut down or will be shut down soon. But this will be, partly or fully, counteracted by the increase in operating costs due to age.

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 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.⁴²⁶

The best example of how utilities have tried to obtain extra revenues to maintain profitability of their nuclear fleet has been in the state of Illinois. As far back as in November 2013, the utility Exelon, the largest nuclear operator in the U.S., had revealed that it was considering shutting down its twin-reactor Quad Cities power plant and single unit Clinton plant in Illinois because electricity prices had fallen so low that these reactors were proving unprofitable.⁴²⁷ Both of these units had been identified by independent analysts as being “at risk” even earlier.⁴²⁸

In the past few years, some of Exelon’s plants have failed to clear the capacity market auctions, especially in the PJM interconnection, 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. 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 a 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

toward economic competitiveness”, *Progress in Photovoltaics: Research and Applications*, see <http://onlinelibrary.wiley.com/doi/10.1002/pip.2630/abstract>, both accessed 16 June 2016.

⁴²⁴ NEI, “Nuclear Energy 2016: Status and Outlook” op.cit.

⁴²⁵ SWU=Separative Work Unit

⁴²⁶ 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 18 June 2016.

⁴²⁷ Steve Daniels, “What’s stronger than nuclear power? Falling electricity prices”, *Crain’s Chicago Business*, 16 November 2013, see

<http://www.chicagobusiness.com/article/20131116/ISSUE01/311169983/whats-stronger-than-nuclear-power-falling-electricity-prices>, accessed 16 June 2016.

⁴²⁸ 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 16 June 2016.

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 structure of capacity markets has often been manipulated by utilities to ensure greater profits.⁴²⁹

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 the NEI that "the market does not sufficiently recognize the significant value that nuclear plants provide in terms of reliability and environmental benefits".⁴³⁰ Subsequently, Exelon, along with PSE&G, another utility that operates nuclear plants, submitted comments to PJM arguing that the capacity market should be "redesigned to value high-availability capacity" and the failure of "over 4 GW of highly reliable nuclear capacity" to clear the markets only means that the "market signal (...) is clearly wrong and further demonstrates a need for changes to PJM's market design".⁴³¹ Likewise, Exelon also put forward proposals to MISO to allow it to get higher prices for their nuclear plants.⁴³²

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. The nuclear industry commended these changes, and NEI's Vice President for Policy Development and Planning Richard Myers announced: "This proposal should improve the economic advantage for the 33 nuclear power plants in PJM's operating area".⁴³³ The result of the changes was that there were "higher auction clearing prices" and the capacity cost was "almost 40 percent higher" than in 2014.⁴³⁴ Despite the 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".⁴³⁵ The company also announced that "a portion of the Byron nuclear plant's capacity did not clear the auction".⁴³⁶

⁴²⁹ David Cay Johnston, "How electricity auctions are rigged to favor industry", *Al Jazeera America*, 29 May 2014, see <http://america.aljazeera.com/opinions/2014/5/electricity-auctionpricespowerbillsconsumers.html>, accessed 12 June 2016.

⁴³⁰ NEI, "Exelon on the 2014 PJM Capacity Market Auction", 12 June 2014, see <http://www.nei.org/News-Media/News/News-Archives/Exelon-on-the-2014-PJM-Capacity-Market-Auction>, accessed 16 June 2016.

⁴³¹ PJM, "Supporting Comments of Calpine, Exelon, And PSEG Regarding PJM's Capacity Performance Proposal", 11 December 2014, see <http://www.pjm.com/~media/committees-groups/committees/elc/coalition-briefing-papers/coalition-paper-generation-coalition-3.ashx>, accessed 16 June 2016.

⁴³² *Energy Wire*, "Dynergy, Exelon propose capacity auction reforms in Illinois", *Midwest Energy News*, 24 February 2016, see <http://midwestenergynews.com/2016/02/24/dynergy-exelon-propose-capacity-auction-reforms-in-illinois/>, accessed 16 June 2016.

⁴³³ NEI, "FERC Approves PJM Plan to Keep Power On When Electricity Demand Peaks", 18 June 2015, see <http://www.nei.org/News-Media/News/News-Archives/FERC-Approves-PJM-Plan-to-Keep-Power-On-When-Elect>, accessed 16 June 2016.

⁴³⁴ Jeffrey Tomich, "PJM auction sees power prices soar under new reliability rules", *Environment & Energy Publishing*, 24 August 2015, see <http://www.eenews.net/stories/1060023802>, accessed 16 June 2016.

⁴³⁵ 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 1 July 2016.

⁴³⁶ 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 1 July 2016.

On 2 June 2016, Exelon announced that it would begin taking steps to permanently shut down its Quad Cities and Clinton nuclear power plants. Clinton is to close on 1 June 2017, and Quad Cities is to follow exactly one year later.⁴³⁷ Two weeks later, the company formally notified the Nuclear Regulatory Commission (NRC) of plans to retire the Clinton and Quad Cities nuclear stations in 2017 and 2018, respectively.⁴³⁸ 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.

Over the past two years, as Exelon's nuclear plants failed to clear capacity markets, the Corporation has been engaged in an effort to get the state of Illinois to offer it subsidies to continue operating its reactors.⁴³⁹ One approach was to push for a bill in the Illinois legislature that would have established a requirement that retail electric utilities procure 70 percent of their electricity from sources that do not emit carbon dioxide, specifically including nuclear power.⁴⁴⁰ The twist that would have allowed nuclear utilities to corner most of the profit was that renewables were allowed to participate only if they were not already participating in earlier state programs that offered incentives. The bill effectively would have funneled close to US\$300 million a year to Exelon's nuclear plants by imposing a surcharge on electric bills statewide.⁴⁴¹ But the bill did not clear the legislature.

In 2016, Exelon teamed up with subsidiary ComEd and proposed "a larger bill that would make sweeping changes to the state's energy system" and add "a surcharge onto electricity bills that would make the nuclear plants profitable".⁴⁴² Analysts estimate that the proposed "changes would amount to a total rate hike of US\$7.7 billion 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".⁴⁴³

One of the critics of the Exelon bill, Illinois Attorney General Lisa Madigan, explained clearly what is involved in the proposal: "Exelon's nuclear plants have benefitted from two rounds of Illinois

⁴³⁷ Aaron Larson, "Exelon Makes Good on Threat—Quad Cities and Clinton Nuclear Plants to Close", *POWER Magazine*, 2 June 2016, see <http://www.powermag.com/exelon-makes-good-on-threat-quad-cities-and-clinton-nuclear-plants-to-close/>, accessed 1 July 2016.

⁴³⁸ Exelon Corporation, "Exelon Notifies Nuclear Energy Regulator of Plans to Close Clinton and Quad Cities," 22 June 2016, see <http://www.exeloncorp.com/newsroom/nrc-retirement-notification-of-quad-cities-and-clinton>, accessed 1 July 2016.

⁴³⁹ Steve Daniels, "How Exelon lost its spark", *Crain's Chicago Business*, 21 June 2014, see <http://www.chicagobusiness.com/article/20140621/ISSUE01/306219983/how-exelon-lost-its-spark>; and Steve Daniels, "Exelon sees little hope of saving Quad Cities nuke", *Crain's Chicago Business*, 29 July 2015, see <http://www.chicagobusiness.com/article/20150729/NEWS11/150729783/exelon-sees-little-hope-of-saving-quad-cities-nuke>; both accessed 1 July 2016.

⁴⁴⁰ Special Committee on Nuclear in the States, "Nuclear in the States Toolkit Version 2.0—Policy Options for States Considering the Role of Nuclear Power in Their Energy Mix", American Nuclear Society, June 2016, see www.nuclearconnect.org/wp-content/uploads/2016/02/ANS-NIS-Toolkit-V2.pdf, accessed 22 June 2016.

⁴⁴¹ Steve Daniels, "Exelon Sees Little Hope of Saving Quad Cities Nuke", *Crain's Chicago Business*, 29 July 2015, see <http://www.chicagobusiness.com/article/20150729/NEWS11/150729783/exelon-sees-little-hope-of-saving-quad-cities-nuke>, accessed 1 July 2016.

⁴⁴² 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 16 June 2016.

⁴⁴³ Ibidem.

subsidies already. First, Illinois electricity ratepayers paid all of the construction costs for the Illinois nuclear plants. Illinois consumers then paid again when Exelon and others convinced Illinois lawmakers to create a competitive market for electricity and consumers were charged for additional costs associated with the transition to a deregulated supply market. Exelon's current bailout demand would amount to a third round of subsidies for these plants".⁴⁴⁴ Thus far, Exelon has been denied the further subsidies it is seeking from Illinois. One of the ironies involved is that while on the one hand, Exelon has been seeking subsidies from the government and the rate payers, on the other hand, it has been presenting itself as profitable to Wall Street companies.⁴⁴⁵

One state where the legislative approach seems to have nearly worked is Connecticut, where Dominion Energy instigated a special hearing by the state legislature's Energy and Technology Committee.⁴⁴⁶ At the hearing, officials from Dominion, as well as former Indiana Senator Evan Bayh, who has now become an active advocate for nuclear energy (partly through his position as the co-chairman of the nuclear lobby group Nuclear Matters), informed listeners that "the company's Millstone plant faces financial challenges and urged the state to consider measures to help avoid additional nuclear unit retirements".⁴⁴⁷ As a result, the Connecticut Senate passed legislation that changed the market structure in the state and would protect Dominion's Millstone plant. The legislation was widely criticized because it did not go through a public hearing, nor was it available for review until shortly before debate.⁴⁴⁸ However, the bill never came to the vote in Connecticut's House of Representatives.⁴⁴⁹ The nature of the Connecticut legislation was highlighted by the state's Consumer Counsel Elin Katz, who represents utility customers in the state, who noted that "in a deregulated market, the industry retains the benefits of the upswings and the risks of market downturns. If Connecticut consumers are going to be asked to backstop some of that risk, there should be a corresponding consideration of shared benefits".⁴⁵⁰

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

⁴⁴⁴ Rich Miller, "Environmental group rails at AG Madigan, environmentalists", *Capitol Fax*, 10 June 2016, see <http://capitolfax.com/2016/06/10/environmental-group-rails-at-ag-madigan-environmentalists/>, accessed 16 June 2016.

⁴⁴⁵ 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 16 June 2016.

⁴⁴⁶ Mark Pazniokas, "Nuclear power's future in Connecticut is on the table", *The CT Mirror*, 23 March 2016, see <http://ctmirror.org/2016/03/23/nuclear-powers-future-in-connecticut-is-on-the-table/>, accessed 16 June 2016.

⁴⁴⁷ *NW*, "Dominion urges Connecticut to support Millstone", *Platts*, Volume 57, Number 13, 31 March 2016

⁴⁴⁸ Mark Pazniokas, "CT Senate passes bill to stabilize revenues in nuclear industry", *The CT Mirror*, 30 April 2016, see <http://ctmirror.org/2016/04/30/ct-senate-passes-bill-to-stabilize-revenues-in-nuclear-industry/>, accessed 16 June 2016.

⁴⁴⁹ Judy Benson, "Bill that would have protected Millstone from energy market dips dies in House", *The Day*, 5 May 2016, see <http://www.theday.com/article/20160505/NWS01/160509539>, accessed 16 June 2016.

⁴⁵⁰ Housley Carr, "Dominion Urges Connecticut to Support Millstone", *NW*, Volume 57—Number 13, 31 March 2016.

Pilgrim would not be part of the next electricity auction.⁴⁵¹ Subsequently, in April 2016, Entergy announced the closing date of the plant as 31 May 2019.⁴⁵²

The inability of nuclear power to compete on the electricity marketplace was apparent in New York state too, where Entergy announced in November 2015 that “market conditions require us to... close the FitzPatrick nuclear plant.”⁴⁵³ 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 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”,⁴⁵⁴ did not change Entergy’s decision. In February 2016, Entergy announced that the plant will be closed on 27 January 2017.⁴⁵⁵ Exelon, which also operates nuclear plants in New York, has taken 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”.⁴⁵⁶

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 costs 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.⁴⁵⁷ While Entergy has declared that it is exempt from needing the coastal zone management certification, New York state has asserted that it does and the two are battling it out in the Court of Appeals.⁴⁵⁸ On the clean water permit, Entergy is appealing “a decision by the New York Department of Environmental

⁴⁵¹ 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 16 June 2016.

⁴⁵² 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 16 June 2016.

⁴⁵³ Entergy, “Entergy to Close James A. FitzPatrick Nuclear Power Plant in Central New York”, Press Release, 2 November 2015, see <http://www.entergynewsroom.com/latest-news/entergy-close-jamesfitzpatrick-nuclear-power-plant-central-new-york/>, accessed 16 June 2016.

⁴⁵⁴ Andrew Cuomo, “Governor Cuomo Directs Department of Public Service to Begin Process to Enact Clean Energy Standard”, New York State Governor, 2 December 2015, see <https://www.governor.ny.gov/news/governor-cuomo-directs-department-public-service-begin-process-enact-clean-energy-standard>, accessed 16 June 2016.

⁴⁵⁵ Tim Knauss, “Entergy announces date when FitzPatrick nuclear plant will close”, *syracuse.com*, 18 February 2016, see http://www.syracuse.com/news/index.ssf/2016/02/entergy_announces_date_when_fitzpatrick_nuclear_plant_will_close.html, accessed 16 June 2016.

⁴⁵⁶ Jim Ostroff, “Exelon to shut Nine Mile Point-1, Ginna reactors if New York fails to OK compensation plan,” *Platts*, 14 June 2016, see <http://www.platts.com/latest-news/electric-power/washington/exelon-to-shut-nine-mile-point-1-ginna-reactors-21708658>, accessed 15 June 2016.

⁴⁵⁷ Frans Koster, “Could Indian Point Fall Victim to Economics?”, *NIW*, 10 June 2016.

⁴⁵⁸ 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 16 June 2016.

Conservation (DEC) to deny the plant a clean water permit” and a decision is expected in the fall of 2016.⁴⁵⁹ These environmental problems add to the outages of the plant, likely due to aging, making Indian Point less profitable to Entergy. Indeed, Moody’s vice president and senior analyst, Ryan Wobbrock argued that “Indian Point is becoming increasingly expensive to operate; not only are there declining prices for power but the costs of the actual facility are increasing because of the extended outages and various problems the plant had over the past years,” leading to the possibility that the reactor might ultimately be shut down for economic rather than environmental or legal reasons.

In neighboring New Jersey, the state Department of Environmental Protection has 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, a step environmentalists had long advocated as a way to avoid decimating the estuary’s fish population, by issuing permits allowing the units to withdraw billions of gallons of water from the Delaware Bay.⁴⁶⁰

Another nuclear plant that just became the latest victim of eroded competitiveness is Fort Calhoun Station. 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 Omaha Public Power District (OPPD)—the plant’s owner—told its Board that its continued operation was not financially sustainable.⁴⁶¹ The reason offered for its shutdown reveal the problems confronting nuclear power plants in the United States. 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”.⁴⁶² Separately, Moody’s Investors Service’s evaluation suggested that the price for electricity in the SPP has been “well below the operating cost of Fort Calhoun” because of low natural gas prices and expanding wind generation in SPP; Moody’s calculated Fort Calhoun’s 2015 operating and maintenance expenses at US\$32.39/MWh, 65 percent above SPP South’s average price of US\$19.59/MWh.⁴⁶³ 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”.⁴⁶⁴

⁴⁵⁹ Frank Koster, “Could Indian Point Fall Victim to Economics?”, *NIW*, 10 June 2016.

⁴⁶⁰ 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 13 June 2016.

⁴⁶¹ 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 16 June 2016.

⁴⁶² 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.

⁴⁶³ 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 16 June 2016.

⁴⁶⁴ Cole Epley, “‘Simply an Economic Decision’: OPPD to Close Fort Calhoun Nuclear Plant by End of 2016,” *Omaha.com*, 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 1 July 2016.

Another plant that is reportedly under financial stress is the Davis Besse nuclear plant in Ohio. It had been identified as being at risk of shutdown due to economic factors.⁴⁶⁵ Its operator FirstEnergy proposed a power-purchase agreement with the Public Utilities Commission of Ohio, which approved a special eight-year arrangement in March 2016.⁴⁶⁶ 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.⁴⁶⁷ FirstEnergy is now trying to put together a revised power purchase plan.⁴⁶⁸ In the meanwhile, FirstEnergy has not publicly announced what happened to Davis Besse and the coal power plants in the Pacific Gas & Electric Co (PG&E) capacity auction.⁴⁶⁹

Perhaps the most dramatic decision to shut down a nuclear power plant has been that of PG&E in June 2016 to close the two units of Diablo Canyon, the last nuclear power plant in California, by 2024 and 2025, and replace the lost electrical capacity with “investment in a greenhouse-gas-free portfolio of energy efficiency, renewables and energy storage”.⁴⁷⁰ The deliberate and well-planned way in which the plant is being replaced is due to extensive negotiations between PG&E and the International Brotherhood of Electrical Workers Local 1245, the Coalition of California Utility Employees, the Natural Resources Defense Council, Environment California, Friends of the Earth and the Alliance for Nuclear Responsibility. What is also noteworthy is PG&E Chief Executive Tony Earley’s acknowledgment that as California makes the transition towards a grid based on energy efficiency, renewables and storage, “Diablo Canyon’s full output will no longer be required” and that would eventually make the nuclear plant too expensive to operate. As other U.S. states, and indeed other countries, move to electrical power systems that use renewables and energy efficiency more extensively, it is quite likely that they will come to the same realization.

In all, therefore, over the last three years, electrical utilities have decided to shut down 14 nuclear reactors because of their lack of economic competitiveness. As of now, the list of reactors includes Crystal River 3 in Florida, San Onofre 2 and 3 in California, Kewaunee in Wisconsin, Vermont Yankee in Vermont, Fort Calhoun in Nebraska, Fitzpatrick in New York, Clinton and Quad Cities 1

⁴⁶⁵ 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, see [http://www-assets.vermontlaw.edu/Assets/iee/Power Shift Mark Cooper June 2015.PDF](http://www-assets.vermontlaw.edu/Assets/iee/Power%20Shift%20Mark%20Cooper%20June%202015.PDF), accessed 16 June 2016.

⁴⁶⁶ 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 16 June 2016.

⁴⁶⁷ 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.

⁴⁶⁸ Jon Chavez, “FirstEnergy rate plan gets retooled”, *The Blade*, 22 May 2016, see <http://www.toledoblade.com/Energy/2016/05/22/Controversial-rate-plan-gets-retooled.html>, accessed 16 June 2016.

⁴⁶⁹ John Funk, “FirstEnergy mum on fate of two old Ohio power plants in regional auction”, *Cleveland.com*, 25 May 2016 see http://www.cleveland.com/business/index.ssf/2016/05/firstenergy_mum_on_fate_of_two.html, accessed 13 June 2016.

⁴⁷⁰ Ivan Penn, Samantha Masunaga, “PG&E to Close Diablo Canyon, California’s Last Nuclear Power Plant”, *Los Angeles Times*, 21 June 2016, see <http://www.latimes.com/business/la-fi-diablo-canyon-nuclear-20160621-snap-story.html>, accessed 24 June 2016.

& 2 in Illinois, Pilgrim in Massachusetts, Oyster Creek in New Jersey, and Diablo Canyon 1 & 2 in California. The number is likely to grow further. A June 2016 report from UBS Securities warns that even nuclear plants with long-term power purchase agreements might be at risk of early closure, and listed Xcel Energy Inc.'s Prairie Island plant in Minnesota and Entergy Corp.'s Palisades plant in Michigan as two examples of nuclear facilities that could close early.⁴⁷¹

New Reactor Projects—Delayed, Suspended, Cancelled

Construction of four AP1000 reactors, Vogtle-3 and -4 in Georgia and VC Summer-2 and -3 in South Carolina has continued. In an effort to speed up construction of these already delayed reactors, Westinghouse settled ongoing legal cases with the owners of these plants and purchased the nuclear construction unit Stone & Webster from Chicago Bridge & Iron.⁴⁷² Westinghouse Chief Executive Danny Roderick was confident that the acquisition would lead to shorter construction times, claiming: “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”.⁴⁷³ So far, there has been no significant change in the pace of construction of these four units.

An illustration of the continuing construction problems is at the Vogtle site where units-3 and -4 are falling further behind schedule. According to testimony before the Georgia Public Service Commission (GPSC) in December 2015, efforts to catch up haven’t been successful and delays have become worse.⁴⁷⁴ The Vogtle units are now officially delayed by 39 months, and if a US\$1.1 billion tax bill is added, the current cost for Georgia Power, which owns 45.7 percent of the project, is US\$9.5 billion, much higher than the US\$6.1 billion the GPSC originally certified for Georgia Power; assuming that the other share of the project has experienced similar cost increases, the total costs for the project are estimated to be approximately US\$21 billion.⁴⁷⁵ A June 2016 assessment by the GPSC concluded that current scheduled commercial operation dates of June 2019 for unit 3 and June 2020 for unit 4 are unlikely to be met: “It is our opinion that there exists a strong likelihood of further delayed operation dates for both units”.⁴⁷⁶

The latest cost increase at the time of writing was South California Electric & Gas (SCE&G), which sought and received approval from state regulators for a US\$852 million increase in the projected cost of VC Summer-2 and -3.⁴⁷⁷ The company terms its contract a fixed one; according to a spokesperson: “The fixed-price option provides substantial value to our customers, investors and our company by limiting the risk of future cost increases”. Others did not agree with this

⁴⁷¹ Matthew Bandyk, “UBS Analysts: Longterm Contracted Nuclear Plants Also at Risk of Shutdown.” *SNL Financial*, 24 June 2016.

⁴⁷² Westinghouse, “Westinghouse Acquires CB&I Stone & Webster, Inc.”, Westinghouse Electric Company, 27 October 2015, see <http://www.westinghousenuclear.com/About/News/View/Westinghouse-Acquires-CB-I-Stone-Webster-Inc>, accessed 16 June 2016.

⁴⁷³ Phil Chaffee, “Westinghouse’s Strategy in CB&I Stone & Webster Acquisition”, *NIW*, 2015,3.

⁴⁷⁴ Walter C. Jones, “More delays for Plant Vogtle”, *Savannah Morning News*, 11 December 2015, see <http://savannahnow.com/news-latest-news/2015-12-11/more-delays-plant-vogtle>, accessed 15 June 2016.

⁴⁷⁵ *NIW*, “Vogtle Costs May Have Reached \$21 Billion”, 11 Decemer 2015.

⁴⁷⁶ *SNL Interactive*, “Ga. PSC staff expects additional delays in Vogtle nuke construction project”, 30 June 2016.

⁴⁷⁷ Roddie Burris, “SCE&G asking for \$852 million more to finish Summer nuclear plants”, *The State*, 13 June 2016, see <http://www.thestate.com/news/business/article83609292.html>, accessed 15 June 2016.

characterization; even the South Carolina Office of Regulatory Staff, which represents the public's interest in utility regulation, was openly skeptical, with the agency's executive director putting it bluntly: "This is not a fixed-price contract (...). [This proposal's] got some aspects of a fixed price, but there's stuff in there that's not fixed and we are going through that now".⁴⁷⁸ Including this cost increase, according to the filing made by SCE&G, "the capital cost estimate (...) is US\$6.8 billion in 2007 dollars and US\$7.7 billion with escalation." SCE&G is currently a 55 percent owner of the project, with Santee Cooper owning the other 45 percent (set to go down to 40 percent), which means that the overall cost of the project is now around US\$14 billion.⁴⁷⁹ In June 2016, SCE&G filed a request with the Public Service Commission of South Carolina and the South Carolina Office of Regulatory Staff to increase to its approved electric rates under provisions of a state law known as the Base Load Review Act, which allows the state's regulated utilities to adjust rates annually during construction of nuclear power plants to recover related financing costs.⁴⁸⁰ At this point, over 18 percent of the electricity bill of residential consumers is estimated to be attributable to the construction of the two nuclear reactors.

In February 2016, Tennessee Valley Authority (TVA) abandoned plans "to build two AP1000 pressurized water reactors at the Bellefonte site in Alabama and notified federal authorities it is withdrawing its application for two combined construction permits and operating licenses at the site".⁴⁸¹ Explaining the decision, a TVA spokesperson said: "It doesn't make sense to keep the licenses since it will be decades before we need the new generation". TVA already has two partially constructed nuclear plants at the Bellefonte site and it has decided to leave them "in preservation status and continue to spend a minimum yearly amount for their maintenance and security".⁴⁸²

The poor experience with the construction of the AP1000s at Vogtle and VC Summer has been hard for Toshiba, the owner of Westinghouse. As one commentator put it, the "design changes and construction delays at both Vogtle and Summer added hundreds of millions of dollars in additional costs, turning the promise of newbuild into something of a nightmare for Toshiba".⁴⁸³ No one expects any new AP1000s to be ordered in the United States—a significant drop from the expectation in the mid-2000s when Toshiba acquired Westinghouse in the expectation that there would be at least 14 AP1000s constructed in the United States.⁴⁸⁴

⁴⁷⁸ Ibidem.

⁴⁷⁹ Tom Clements, "SCE&G Requests \$852 Million Increase in Cost of VC Summer Nuclear Construction Project", Savannah River Site Watch, 2 June 2016, see http://www.srswatch.org/uploads/2/7/5/8/27584045/news_srs_watch_on_sceg_nuclear_cost_increase_june_2_2016.pdf, accessed 16 June 2016.

⁴⁸⁰ *Yahoo Finance*, "SCE&G Files for Rate Adjustment Under Base Load Review Act," 27 June 2016, see <http://finance.yahoo.com/news/sce-g-files-rate-adjustment-210500545.html>, accessed 1 July 2016.

⁴⁸¹ Mary Powers, "TVA puts Bellefonte nuclear power units on hold, while other utilities move forward", *Platts*, 16 February 2016, see <http://www.platts.com/latest-news/electric-power/birmingham-alabama/tva-puts-bellefonte-nuclear-power-units-on-hold-21942467>, accessed 16 June 2016.

⁴⁸² Ibidem.

⁴⁸³ Daye Kim, "Toshiba-Westinghouse — A Dream Deal Gone Sour?", *NIW*, 2015,6–7.

⁴⁸⁴ Ibidem.

Pending Combined Operating License Applications (COLA)

As of May 2016, the NRC had received 18 Combined Operating License Applications (COLA) for a total of 28 reactors. All were submitted between July 2007 and June 2009. Ten of the 18 COLAs were subsequently withdrawn or the application has been suspended.

In February 2016, NRC issued a combined license to the South Texas Project Nuclear Operating Company to construct two Advanced Boiling Water Reactors.⁴⁸⁵ However, at that time, the CEO of the company stated: “Having these licenses puts us in a position to move the project forward *when economic conditions support construction* [emphasis added] (...) current sustained low natural gas prices and Texas electric market conditions do not support starting construction at this time”.⁴⁸⁶

The United States operates the world’s largest nuclear fleet. Including the most recent unit Watts Bar-2, there are 100 operating reactors, but the future seems to be only downhill. In the long run, 2016 might not be remembered as the year that Watts Bar-2 came online, but as the last year that the country’s nuclear fleet numbered three digits. The rate of decline in the number of operating reactors might be reduced through bailouts or other government interventions, but it looks like governmental and other officials are quickly becoming aware of the unsustainable nature of most nuclear plants.

Asia

China Focus

Although China embarked on nuclear power relatively late in comparison with other countries with large nuclear generation capacities, it has been constructing reactors at a rapid pace. As of mid-2016, there are 34 operating reactors with a total net capacity of 29.4 GW. Eight new units were connected to the grid in 2015, 80 percent of the world total of 10 startups. A further 21 reactors, with a total capacity of 21.5 GW, are under construction. Nuclear power contributed 161.2 TWh—a 30 percent increase over 2014—which constituted 3 percent of all electricity generated in China in 2015, up from 2.4 percent in 2014.⁴⁸⁷ In comparison, wind energy contributed 186.3 TWh in 2015, an increase of 22 percent.⁴⁸⁸ Solar energy’s output went up even more, by 55.6 percent over the previous year, to contribute 39.2 TWh in 2015.⁴⁸⁹ Although the share of nuclear power in overall electricity generation has increased, the average utilization

⁴⁸⁵ NRC, “Combined License Holders for New Reactors”, U.S. Nuclear Regulatory Commission, Updated 24 February 2016, see <http://www.nrc.gov/reactors/new-reactors/col-holder.html>, accessed 16 June 2016.

⁴⁸⁶ Ryan West, “NRC green lights STP licenses for Units 3 & 4: Construction on hold until market conditions improve”, *Palacios Beacon*, 17 February 2016, see www.palaciosbeacon.com/02-17-16.pdf, accessed 16 June 2016.

⁴⁸⁷ IAEA, “Nuclear Power Reactors in the World—2016 Edition”, Vienna, May 2016, see www-pub.iaea.org/MTCD/Publications/PDF/RDS_2-36_web.pdf, accessed 16 June 2016.

⁴⁸⁸ GWEC, “Global Wind Report—Annual Market Update 2015”, April 2016, see www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_22_04.pdf, accessed 16 June 2016.

⁴⁸⁹ Kimfeng Wong, “Coal Loses More Market Share to Nuclear, Renewables”, *NIW*, 19 February 2016.

factor of nuclear plants (their operating hours per year) has declined; in 2015, it was 84 percent, down from 89 percent in 2014.⁴⁹⁰

China has also long made ambitious plans for nuclear expansion. According to the 13th Five Year Plan announced earlier this year, the target for nuclear power in 2020 remains 58 GW, with another 30 GW under construction. To meet this target, nuclear capacity would have to double within the next four years, which appears now technically impossible, even given China's rapid pace of construction. The average construction time of the 25 units brought online over the past decade was 5.7 years, which also corresponds to the construction time of the latest unit to come online, Changjiang-2, connected to the grid on 20 June 2016. At the most, the 21 units currently under construction and scheduled for startup before 2021 could be added to the operating capacity, which would bring the total to a maximum of just under 51 GW rather than 58 GW by 2020.

The target of 58 GW by 2020 was first set in 2012.⁴⁹¹ This constancy is in distinct contrast to the pre-Fukushima period when targets grew rapidly. The increases started in 2002 when the draft short- and medium-term plan for nuclear expansion was released, which called for China to build 20 GW nuclear power generation capacity by 2010 and 40 GW by 2020.⁴⁹² By the end of the decade, that target figure had increased to 70 GW by 2020.⁴⁹³ The expectation then was that the target would be easily met and even more ambitious targets could be set; for example, the director of science and technology at the China National Nuclear Corporation (CNNC)—one of the major state-owned enterprises involved in constructing and operating nuclear power plants—stating in 2009, “reaching 70GW before 2020 will not be a big problem”.⁴⁹⁴ The current target of 58 GW by 2020 evidently represents a significant decline in the 2020 target.

Even the slower expansion plans have raised widespread concerns about nuclear safety.⁴⁹⁵ There is some evidence that this concern extends to Chinese policy makers, one reason for their refusal so far to allow construction of reactors in inland areas. Prior to the Fukushima accident, China had plans constructing nuclear power stations, not only at coastal sites where reactors had

⁴⁹⁰ Ibidem.

⁴⁹¹ *Xinhua*, “Information Office of the State Council, “Full Text: China’s Energy Policy 2012”, 24 October 2012, see http://news.xinhuanet.com/english/china/2012-10/24/c_131927649.htm, 16 June 2016.

⁴⁹² Yi-Chong Xu, “Nuclear energy in China: Contested regimes”, *Energy*, Volume 33, Issue 8, August 2008.

⁴⁹³ Sonal Patel, “China: A World Powerhouse”, *Power Magazine*, 1 July 2010, see <http://www.powermag.com/china-a-world-powerhouse/>, accessed 24 August 2015.

⁴⁹⁴ David Stanway, “China struggles to fuel its nuclear energy boom”, *Reuters*, 10 December 2009, see <http://www.reuters.com/article/2009/12/10/uranium-china-nuclear-idUSPEK20761020091210>, accessed 16 June 2016.

⁴⁹⁵ Emily Rauhala, “China has an awful safety record—and wants to run 110 nuclear reactors by 2030”, *Washington Post*, 4 December 2015, see <https://www.washingtonpost.com/news/worldviews/wp/2015/12/04/china-has-an-awful-safety-record-and-wants-to-run-110-nuclear-reactors-by-2030/>; and Emma Graham-Harrison, “China warned over ‘insane’ plans for new nuclear power plants”, *The Guardian*, 25 May 2015, see <http://www.theguardian.com/world/2015/may/25/china-nuclear-power-plants-expansion-he-zuoxiu>; and Stephen Chen, “China admits nuclear emergency response ‘inadequate’ as safety fears delay construction of two Guangdong reactors”, *South China Morning Post*, 27 January 2016, see <http://www.scmp.com/news/china/policies-politics/article/1906287/china-admits-nuclear-emergency-response-inadequate>, all accessed 16 June 2016.

traditionally been sited, but also at new inland sites.⁴⁹⁶ But this was suspended after Fukushima. In 2014, a State Council circular discussing the State Council's Energy Development Strategy Action Plan (2014-2020) indicated that inland nuclear power still required further research and proof of safety.⁴⁹⁷ The safety rationale for the restriction of construction in inland areas relates to two different aspects of safety: prevention of severe accidents, and mitigation of the consequences of a severe accident, should one occur. The public, naturally, is concerned about the potential for accidents, especially in the areas close to sites selected for reactor construction.⁴⁹⁸ There is also concern about China's growing water stress and increasing water demand from the power sector. The resulting debate over the siting of reactors away from the coast has pushed back plans; the current expectation is that inland nuclear construction will not start before at least 2020.⁴⁹⁹

The other significant decision made by policy makers in the aftermath of Fukushima was that China would build only Generation III or III+ reactors. The initial assumption was that this stipulation would lead to the adoption of AP1000 technology. In 2011, a general manager in the China Power Investment Corporation pointed out that the "reactors in the Japanese nuclear power plants, which have been affected by the massive quake, are Generation II reactors and have to rely on back-up electricity to power their cooling system in times of emergency", whereas the "AP1000 nuclear power reactors, currently under construction in China's coastal areas and set to be promoted in its vast hinterland, are Generation III reactors and have built in safety features to overcome such a problem".⁵⁰⁰

However, China's experience in building the imported AP1000 and EPR designs has been fairly troubled, with significant delays and cost escalations.⁵⁰¹ The EPR units being built at Taishan were originally scheduled to "be commissioned at the end of 2013 and in autumn 2014 respectively, and France's AREVA had hoped "to have started work on more reactors" by then.⁵⁰² None of that

⁴⁹⁶ Fenglei Du, "Site Selection for Nuclear Power Plants in China", IAEA, as presented at the Technical Meeting on Common Challenges On Site Selection For Nuclear Power Plants, Vienna (Austria), 6-9 July 2010.

⁴⁹⁷ CNEA, "Guowuyuan bangongting guanyu yinfa nengyuan fazhan zhanlue xingdong jihua (2014nian-2020nian) de tongzhi, State Council General Office Circular concerning the publication of the Energy Development Strategy Action Plan (2014-2020)", China National Energy Administration, 2014, see http://www.nea.gov.cn/2014-12/03/c_133830458.htm, accessed 2 March 2015.

⁴⁹⁸ Chris Buckley, "China's Nuclear Vision Collides With Villagers' Fears", *New York Times*, 21 November 2015, see <http://www.nytimes.com/2015/11/22/world/asia/chinas-nuclear-vision-collides-with-villagers-fears.html>, accessed 16 June 2016.

⁴⁹⁹ C. F. Yu, "Construction on Inland Plants Unlikely Before 2020", *NIW*, 1 April 2016..

⁵⁰⁰ *WantChinaTimes.com*, "China to promote nuclear power despite explosion in Japan", 13 March 2011, see <http://www.wantchinatimes.com/news-subclass-cnt.aspx?id=20110313000104&cid=1102>, accessed 24 March 2015.

⁵⁰¹ Chuin-Wei Yap, Brian Spegele, "China's First Advanced Nuclear Reactor Faces More Delays", *Wall Street Journal*, 15 January 2015, see <http://www.wsj.com/articles/chinas-first-advanced-nuclear-reactor-faces-more-delays-1421297393>, accessed 23 March 2015; David Stanway, Kathy Chen, "China's debut Westinghouse reactor delayed until June 2017: exec", *Reuters*, 9 March 2016, see <http://www.reuters.com/article/us-china-parliament-nuclear-idUSKCN0WB09F>; and Wong Lok-to, "Safety Fears Cause Concern Amid Delays to China's Taishan Nuclear Plant", *Radio Free Asia*, 7 March 2016, see <http://www.rfa.org/english/news/china/safety-03072016114147.html>, both accessed 1 July 2016.

⁵⁰² Harold Thibault, "Construction schedule on Chinese third-generation nuclear plants races ahead of European models", *The Guardian*, 28 December 2010, see <https://www.theguardian.com/environment/2010/dec/28/china-areva-taishan-nuclear-thibault>, accessed 16 June 2016.

has happened. In January 2016, Taishan-1 underwent its cold functional test,⁵⁰³ a pre-operational stage that is carried out before any fuel is loaded on the reactor. As of March of this year, China General Nuclear (CGN) officials were projecting that Taishan-1 will start up next year.⁵⁰⁴ However, there are additional uncertainties over the safety of the reactor pressure vessels, which are subject to the same carbon content issue as the French Flamanville EPR that do not meet technical specifications (see France Focus). Media reports suggest that there are differences of opinion between French engineers working on the EPR construction in Flamanville in France and CGN officials with the former arguing that the Taishan reactors will only come online in 2018, and the latter pushing for a 2017 start date for both units. CGN's chief executive officer is quoted as saying that "while France suspended work on the nuclear technology to renew the technical standards, it was not reasonable to measure the old units by new standards".⁵⁰⁵

In the case of the four AP1000 reactors, the main source of problems, although not the only one, has been the reactor coolant pumps (RCPs) that were supplied by US manufacturer Curtiss-Wright Corporation. Problems with RCPs could have serious safety consequences and Chinese nuclear officials have expressed concern in the past about these problems. In 2013, for example, Yulun Li, former vice-minister for nuclear energy and former vice-president of CNNC complained to *South China Morning Post*: "Our state leaders have put a high priority on [nuclear safety] but companies executing projects do not seem to have the same level of understanding".⁵⁰⁶ After a long series of delays (see previous WNISRs), the first two of four RCPs for unit 1 of the Sanmen plant arrived at the construction site on 30 December 2015.⁵⁰⁷ According to Sun Qin, the chairman of the China National Nuclear Corporation, "if everything goes smoothly, the first unit will go into operation in June 2017, and the second unit at the end of 2017".⁵⁰⁸ That is four years after the reactors were supposed to have come online.

The poor experience at Sanmen and Haiyang did not stop Westinghouse Chief Executive Officer Daniel Roderick from claiming: "The AP1000 is going to be able to compete against anybody or anything... The next wave of AP1000s will be built between 36 and 40 months".⁵⁰⁹ Roderick offered this confident assessment as part of an effort to get China to buy more AP1000 units, but prospects for this seem to be dim. An article published by the Chinese Nuclear Energy Society written by a retired CNNC official suggested "that the State Council should approve future AP1000

⁵⁰³ CGN, "Taishan Unit 1 CFT Completed Successfully", Press Release, 28 January 2016, see <http://en.cgnpc.com.cn/n1017152/n1017227/c1235676/content.html>, accessed 25 May 2016.

⁵⁰⁴ Phil Chaffee, "EDF Faces British Frustrations on Hinkley", *NIW*, 24 March 2016.

⁵⁰⁵ Celia Chen, "CGN Power says Taishan nuclear reactors pose no safety risks," *South China Morning Post*, 30 May 2016, see <http://www.scmp.com/business/companies/article/1959199/cgn-power-says-taishan-nuclear-reactors-pose-no-safety-risks>, accessed 16 June 2016.

⁵⁰⁶ *South China Morning Post*, "China nuclear plant delay raises safety concern", 7 October 2013, see <http://www.scmp.com/business/china-business/article/1325973/china-nuclear-plant-delay-raises-safety-concern>, accessed 17 June 2016.

⁵⁰⁷ *WNN*, "Final module installed at Sanmen 2", 4 January 2016, see <http://www.world-nuclear-news.org/NN-Final-module-installed-at-Sanmen-2-0401165.html>, accessed 1 July 2016.

⁵⁰⁸ David Stanway, Kathy Chen, "China's debut Westinghouse reactor delayed until June 2017: exec", *Reuters*, 9 March 2016, see <http://www.reuters.com/article/us-china-parliament-nuclear-idUSKCNOWB09E>, accessed 1 July 2016.

⁵⁰⁹ Stephen Stapczynski, "Westinghouse Races China for \$1 Trillion Nuclear Power Prize", *Bloomberg*, 9 December 2015, see <http://www.bloomberg.com/news/articles/2015-12-09/westinghouse-races-china-for-1-trillion-nuclear-power-prize>, accessed 1 July 2016.

projects only after Sanmen-1 ‘successfully completes the first fuel reload’ and is hooked to the grid.”⁵¹⁰

Efforts by Westinghouse to paint the delays at Sanmen and Haiyang as due to first-of-a-kind challenges has come under question due to the pattern of cost and time overruns at the follow-on AP1000 units being constructed in the United States.⁵¹¹ As Lin Boqiang, director at the China Center for Energy Economics Research at Xiamen University told *Bloomberg News*: “The only way Westinghouse can win contracts in China is to demonstrate they can build reactors quicker and cheaper than anyone else in China’s market and win hearts with actions, not words...Westinghouse so far hasn’t demonstrated such abilities”.⁵¹²

The Sanmen project is also the likely cause of the resignation of more than half a dozen executives and board members, including the CEO, from Toshiba Corporation.⁵¹³ An investigation into accounting practices at the company revealed that it had under-booked losses at a Westinghouse project (whose name was not revealed but a comparison of the construction start and projected generation start dates matches that of Sanmen). Specifically, the budget overruns of US\$385 million and US\$401 million during the second and third quarters of 2013 were booked by Toshiba at US\$69 million and US\$293 million respectively.

The CAP1400 design, a larger capacity version of the AP1000, is still not complete and there remain significant questions about its future. Construction of the first reactor with this design has been delayed and in May 2016, a member of the Expert Committee of China’s State Nuclear Power Technology Corporation revealed that “the detailed design can only support 12 months of continuous construction” after first pour of concrete.⁵¹⁴ In other words, the design is not yet ready for construction. One factor that has held up the finalization of the CAP1400 design is the reactor cooling pump, the same problem that has afflicted the parent AP1000 design.⁵¹⁵ Reportedly, the decision over whether the CAP1400 will be exclusively for exports also “is in flux”.⁵¹⁶

Meanwhile, CGN and CNNC started developing their own Generation-III designs. In November 2011, CGN announced that it had developed and held “full intellectual property rights”—a key requirement for exports—over the newly designed ACPR1000, a reactor, which it stated had incorporated the lessons of Fukushima in “meeting the standards of international third-generation nuclear power technology”⁵¹⁷. A few months later, at the 3rd Asia Nuclear Power Summit in January 2012, CNNC unveiled its own ACP1000 reactor⁵¹⁸. Subsequently, after being

⁵¹⁰ C. F. Yu, “Nine Projects Top Priority List”, *NIW*, 6 May 2016.

⁵¹¹ Anya Litvak, “Toshiba downplayed Westinghouse losses”, *Pittsburgh Post-Gazette*, 28 July 2015, see <http://powersource.post-gazette.com/powersource/companies/2015/07/28/Toshiba-downplayed-Westinghouse-cost-overruns/stories/201507280057>, accessed 16 June 2016.

⁵¹² Stephen Stapczynski, “Westinghouse Races China for \$1 Trillion Nuclear Power Prize”, *Bloomberg*, 9 December 2015, see <http://www.bloomberg.com/news/articles/2015-12-09/westinghouse-races-china-for-1-trillion-nuclear-power-prize>, accessed 1 July 2016.

⁵¹³ Anya Litvak, “Toshiba downplayed Westinghouse losses”, *Pittsburgh Post-Gazette*, 28 July 2015.

⁵¹⁴ *NIW*, “Weekly Roundup”, 20 May 2016.

⁵¹⁵ C. F. Yu, “Nine Projects Top Priority List”, *NIW*, 6 May 2016.

⁵¹⁶ *NIW*, “Weekly Roundup”, 20 May 2016.

⁵¹⁷ *People’s Daily Online*, “China rolls out new homegrown nuclear reactor”, 18 November 2011.

⁵¹⁸ Yun Zhou, “China’s Nuclear Energy Industry, One Year After Fukushima”, *Technology&Policy*, 5 March 2012, see <http://www.technologyandpolicy.org/2012/03/05/chinas-nuclear-energy-industry-one-year-after-fukushima/#.VRBnnSk-Dw4>, accessed 16 June 2016.

directed by government planners to do so, the two organizations jointly developed the Hualong One, which was certified by the National Nuclear Safety Administration in 2014.⁵¹⁹ However, CNNC and CGN are apparently promoting two slightly different designs, with separate supply chains, under the same name. In March 2016, the two companies set up a 50-50 joint venture to promote this design in overseas markets.⁵²⁰

Construction of the Hualong design started domestically in China with units 5 and 6 of the Fuqing plant in May and December 2015, as well as unit 3 of Fangchenggang in December 2015. The first of these units “is expected to be completed by around June 2020”.⁵²¹ However, as these projects proceed, construction of the Hualong at the Fuqing plant might be delayed, again because the RCPs to be used in the design are already “falling behind schedule for (sic!) five months”.⁵²² Unlike the AP1000 project that sourced its RCPs from the Curtiss-Wright company, for the Hualong design, CNNC signed a supply contract with China’s Harbin Electric Power Equipment Corporation and the Austrian manufacturer Andritz, who in turn have subcontracted with firms such as Italy’s Foriatura to supply key components.⁵²³ Other construction starts since July 2015, when the last WNISR was published, include Tianwan-5, Hongyanhe-6, and Changjiang-2.

All these reactor construction starts and targets should be viewed in the context of a slowdown of energy demand growth in China. According to data from the China Electricity Council, the 2015 power-generation level of 5,604.5 TWh was only 0.6 percent more than the figure for 2014.⁵²⁴

Looking further out, in its 2016 Energy Outlook, the oil and gas firm ExxonMobil “lowered its forecast for China’s annual energy demand growth to 2.2 percent through 2025. The report predicted that the country’s energy demand would plateau around 2030”.⁵²⁵ The slowdown of energy demand, in turn, is a result of falling rate of increase of the Gross Domestic Product (GDP), increased energy efficiency, and a change in the relative distribution of different sectors of the economy, in particular a decline in the share of industry.⁵²⁶ China also has a significant overcapacity of coal-fired power plants, with average annual operating hours and capacity factors declining steadily over the past five years.⁵²⁷ One effect of this decline in demand and coal plant overcapacity on the nuclear sector might be the 10 percent stake sold to Thailand’s Ratchaburi Electricity Generating Holding Public Co. by CGN for its first Hualong project at Fangchenggang II,

⁵¹⁹ WNN, “China’s new nuclear baby”, 2 September 2014, see <http://www.world-nuclear-news.org/E-Chinas-new-nuclear-baby-0209141.html>, accessed 24 June 2016.

⁵²⁰ WNN, “Hualong One joint venture officially launched”, 17 March 2016, see <http://www.world-nuclear-news.org/C-Hualong-One-joint-venture-officially-launched-1703164.html>, accessed 1 July 2016.

⁵²¹ Reuters, “China’s debut Westinghouse reactor delayed until June 2017: exec”, Reuters, 9 March 2016, see <http://www.reuters.com/article/us-china-parliament-nuclear-idUSKCN0WB09F>, accessed 16 June 2016.

⁵²² C. F. Yu, “RCPs Pose Problems Again—This Time for Hualong”, *NIW*, 2016.

⁵²³ Ibidem.

⁵²⁴ China Electricity Council, Press Release, 3 February 2016, see <http://www.cec.org.cn/yaowenkuaidi/2016-02-03/148763.html>, accessed 2 June 2016.

⁵²⁵ Claire Groden, “Exxon Cuts China Energy Demand Growth forecast”, *Fortune*, 26 January 2016, see <http://fortune.com/2016/01/26/china-energy-demand/>, accessed 16 June 2016.

⁵²⁶ Fergus Green, Nicholas Stern, “China’s changing economy: implications for its carbon dioxide emissions”, *Climate Policy*, 7 March 2016.

⁵²⁷ Fredrich Kahrl, “Coal-Fired Generation Overcapacity in China”, Regulatory Assistance Project, Beijing (China), February 2016, see <http://www.raponline.org/document/download/id/8038>, accessed 9 July 2016.

geographically the nuclear plant that is closest to Southeast Asia.⁵²⁸ While documents from Ratchaburi list 236 MW of capacity from Fangchenggang II coming on in 2021, it is unclear, if this is going to result in an actual delivery of electricity or this represents merely a financial asset.⁵²⁹

India operates 20 nuclear power reactors, with a total capacity of 5.2 GW. In 2015, nuclear power provided a record 34.6 TWh, but that only constituted 3.5 percent (down from 3.7 percent in 2011) of the total electricity generated in the country. The nuclear share has remained stable since 2013, while nuclear power generation increased by 15.4 percent over the same period. 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 the WNISR criteria, was moved to the LTO category in 2014. In September 2014, the chairman of the Atomic Energy Commission stated that Rajasthan-1 (or RAPS-1) would not be restarted⁵³⁰ and WNISR moved it from LTO to closure.

Six reactors are under construction with a total capacity of 3.9 GW. These include the second VVER from Russia at Kudankulam that has been under construction since July 2002, the Prototype Fast Breeder Reactor (PFBR) whose construction started in October 2004, and four PHWRs whose construction started in 2010 and 2011. All of these are delayed. Kudankulam-2 was to have been commissioned in December 2008.⁵³¹ However, its commissioning has been repeatedly postponed due to various causes. The latest problem to be publicly revealed has been with the reactor coolant pump, whose design had to be modified and components replaced after a round of tests carried out prior to commissioning the reactor.⁵³² As of May 2016, the reactor had been loaded with fuel and was expected to become critical by “mid-2016”.⁵³³ The cost of the two Kudankulam units has gone up by over 70 percent.⁵³⁴ The PFBR was supposed to be commissioned in 2010.⁵³⁵ In December 2015, the Chairman and Managing Director of the State Owned Corporation that is constructing the PFBR pronounced that the project “shall generate power by September next

⁵²⁸ Phil Chaffee, “Thailand: Beyond the Fangchenggang Stake”, *NIW*, 8 January 2016.

⁵²⁹ Ratchaburi Electricity Generating Holding Public Co, “Analyst Meeting, 2015 Year End Results”, 26 February 2016, see <http://ratch.listedcompany.com/misc/PRESN/20160302-ratch-analystmeeting-4q2015-01.pdf>, accessed 31 May 2016.

⁵³⁰ *Deccan Herald*, “End of the road for RAPS 1”, 6 September 2014, see <http://www.deccanherald.com/content/429550/end-road-raps-1.html>, accessed 16 June 2016.

⁵³¹ Infrastructure & Project Monitoring Division, “Project Implementation Status Report on Central Sector Projects (Costing Rs.20 Crores & Above)—January-March 2004”, Ministry of Statistics & Programme Implementation (MoSPI), New Delhi, 2004, see http://mospi.nic.in/pi_status_report_csp.pdf, accessed 2 July 2016.

⁵³² Department-related Parliamentary Standing Committee on Science & Technology, Environment & Forests, “Two Hundred Eighty Second Report on—Demands for Grants (2016-2017) of the Department of Atomic Energy (Demand No. 4)”, May 2016, New Delhi.

⁵³³ IANS, “Kudankulam unit 2 reactor fuel loading complete”, *Business Standard*, 19 May 2016, see http://www.business-standard.com/article/news-ians/kudankulam-unit-2-reactor-fuel-loading-complete-116051900856_1.html, accessed 17 June 2016.

⁵³⁴ MoSPI, “78th Report On Mega Projects (Rs. 1000 Crore and Above)”, November 2015.

⁵³⁵ T. S. Subramanian, “A milestone at Kalpakkam”, *Frontline*, Volume 21, Issue 23, 6-19 November 2004, see <http://www.frontline.in/static/html/fl2123/stories/20041119003210200.htm>, accessed 2 July 2016.

year”.⁵³⁶ But by April 2016, scientists involved with the project told *Indian Express* that “it is unlikely that the project could be completed by the end of this year”.⁵³⁷ The PFBR’s cost estimate has gone up by over 62 percent.⁵³⁸ And finally, the start date projected for the first of the PHWRs to start generating power by the director of the project is end-2016 or early-2017, which would be about two years past the initial projections.⁵³⁹ However, other official reports suggest that the four PHWRs will only be commissioned in 2018/19.⁵⁴⁰

The experience with recently commissioned reactors has been poor. Although Kudankulam-1 reached criticality in July 2013, it took over 17 months to being declared commercial on 31 December 2014. Since commercial operation started, Kudankulam-1 has only operated for 4,212 hours in 2014 and 3,993 hours in 2015;⁵⁴¹ in other words, in both years, it has been shut down for longer than it has been online. A good fraction of those operations evidently involved the reactor generating less than its rated power capacity because its reported load factor in 2015 was only 40 percent. The Indian Department of Atomic Energy describes this dismal performance as “teething problems”,⁵⁴² but it remains to be seen if the reactor, will eventually grow out of these problems.⁵⁴³

Despite this poor performance, the Nuclear Power Corporation of India Ltd. (NPCIL) has gone ahead with the early stages of construction of the third and fourth units at the Kudankulam site; excavation of the site started in February 2016.⁵⁴⁴ The first pour of concrete is expected to take place in 2017. A General Framework Agreement to construct the two units was signed in April 2014.⁵⁴⁵ Cost estimates for these two units have been reported to be as high as Rs. 398 billion

⁵³⁶ Dennis S. Jesudasan, “Industry supplies delay PFBR commissioning”, *The Hindu*, 13 December 2015, see <http://www.thehindu.com/news/cities/chennai/industry-supplies-delay-pfbr-commissioning/article7982156.ece>, accessed 2 July 2016.

⁵³⁷ C. Shivakumar, “AERB Rules Slowing Reactor Project?”, *Indian Express*, 30 April 2016.

⁵³⁸ MoSPI, “78th Report On Mega Projects (Rs. 1000 Crore and Above)”, November 2015.

⁵³⁹ IANS, “Third atomic reactor at Kakrapar reaches a milestone”, *Business Standard*, 30 October 2015, see http://www.business-standard.com/article/news-ians/third-atomic-reactor-at-kakrapar-reaches-a-milestone-115103001777_1.html, accessed 17 June 2016.

⁵⁴⁰ Department-related Parliamentary Standing Committee on Science & Technology, Environment & Forests, “Two Hundred Eighty Second Report—Demands for Grants (2016-2017) of the Department of Atomic Energy (Demand No. 4)”, May 2016.

⁵⁴¹ IAEA, “Power Reactor Information System (PRIS) Database”.

⁵⁴² Meera Mohanty, “Kudankulam delays are on ‘teething problems’, says AEC chairman”, *The Economic Times*, 15 November 2015, see <http://economictimes.indiatimes.com//articleshow/49793357.cms>, accessed 2 July 2016.

⁵⁴³ M. V. Ramana, “‘Teething Troubles’ at Kudankulam: India Biting More Nuclear Than it Can Chew”, *The Wire*, 8 March 2016, see <http://thewire.in/2016/03/08/the-nuclear-powers-persistence-with-kudankulam-barely-masks-a-crumbling-project-24114/>, accessed 17 June 2016.

⁵⁴⁴ *The Hindu*, “Site excavation for 3rd, 4th reactors begins at KKNPP”, 18 February 2016, see <http://www.thehindu.com/news/national/tamil-nadu/site-excavation-for-3rd-4th-reactors-begins-at-kknpp/article8250518.ece>, accessed 2 July 2016.

⁵⁴⁵ *The Times of India*, “India, Russia finally sign agreement on Kudankulam 3, 4 units”, 11 April 2014, see <http://timesofindia.indiatimes.com/india/India-Russia-finally-sign-agreement-on-Kudankulam-3-4-units/articleshow/33623262.cms>, accessed 2 July 2016.

(US\$6.6 billion),⁵⁴⁶ to as low as Rs. 330 billion (US\$5.5 billion).⁵⁴⁷ However, in light of the experience so far, these costs are likely to go up significantly. Even without accounting for such escalations, these estimates are already much higher than the Rs. 225 billion currently estimated for the first two units at Kudankulam.⁵⁴⁸

The reason for the cost increase is said to be the Indian nuclear liability law.⁵⁴⁹ A section in that law offers NPCIL the “right of recourse”, i.e., the right to claim compensation from suppliers up to a maximum of Rs. 15 billion (US\$240 million) in the event of an accident involving a nuclear reactor supplied by a multinational supplier. The amount under question is tiny in comparison with the cost of, say, the Fukushima accident or the total cost of a nuclear reactor. The latter rather creates a “moral hazard” for reactor suppliers.⁵⁵⁰ Despite the small size of the potential amount to be paid to NPCIL in the event of an accident, reactor vendors, especially U.S. based companies like General Electric and Westinghouse, have been opposed to taking on any liability. Successive administrations in India have been under pressure to find a way to let these vendors avoid liability and have modified the rules for implementation of the legislation in various ways.⁵⁵¹ Over the course of 2015, the government set up a domestic insurance pool that would provide coverage in the event of a nuclear accident.⁵⁵² In February 2016, the Indian government ratified the Convention on Supplementary Compensation for Nuclear Damage, also known as the CSC, but even that has not satisfied companies like Westinghouse and GE.⁵⁵³

The liability concern has been one factor that has slowed down plans to import reactors from AREVA & EDF for the Jaitapur site, and from Westinghouse and GE for the Mithi Viridi and Kovvada sites respectively. GE, in particular, had earlier ruled out selling a nuclear reactor to India as long as the liability legislation remains.⁵⁵⁴ However, on the Indian side, the prospects for high costs of power from imported reactors have also been a significant concern.

⁵⁴⁶ *The Hindu*, “Kudankulam units 3, 4 cost more than doubles over liability issues”, 3 December 2014, see <http://www.thehindu.com/news/national/kudankulam-units-3-4-cost-more-than-doubles-over-liability-issues/article6658451.ece>, accessed 2 July 2016.

⁵⁴⁷ *The Times of India*, “India, Russia Finally Sign Agreement on Kudankulam 3, 4 Units”, 11 April 2014.

⁵⁴⁸ MoSPI, “78th Report On Mega Projects (Rs. 1000 Crore and Above)”, November 2015.

⁵⁴⁹ *The Hindu*, “Kudankulam units 3, 4 cost more than doubles over liability issues”, 3 December 2014, see <http://www.thehindu.com/news/national/kudankulam-units-3-4-cost-more-than-doubles-over-liability-issues/article6658451.ece>, accessed 2 July 2016.

⁵⁵⁰ Suvrat Raju, M. V. Ramana, “Moral hazard of indemnifying suppliers”, *The Hindu*, 20 August 2010.

⁵⁵¹ Suvrat Raju, M. V. Ramana, “Strange Love”, *OPEN Magazine*, 14 May 2011, see <http://www.openthemagazine.com/article/india/strange-love>; and M. V. Ramana, Suvrat Raju, “The strange love for nuclear energy”, *The Hindu*, 17 December 2015, see <http://www.thehindu.com/opinion/lead/on-the-indiajapan-civil-nuclear-deal/article7996972.ece?homepage=true>, both accessed 2 July 2016.

⁵⁵² *Business Standard*, “Indian nuclear insurance pool still in unclear waters (News Analysis)”, 15 December 2015, see http://www.business-standard.com/article/news-ians/indian-nuclear-insurance-pool-still-in-unclear-waters-news-analysis-115121500415_1.html, accessed 2 July 2016.

⁵⁵³ Stephen Stapczynski, Rajesh Kumar Singh, Natalie Obiko Pearson, “Nuclear Liability Concern Lingers Despite India Signing Treaty”, *Bloomberg*, 25 February 2016, see <http://www.bloomberg.com/news/articles/2016-02-25/nuclear-liability-concern-lingers-despite-india-signing-treaty>, accessed 17 June 2016.

⁵⁵⁴ Frank Jack Daniel, “GE’s Immelt rules out India nuclear investment under current law”, *Reuters*, 21 September 2015, see <http://www.reuters.com/article/us-ge-exim-idUSKCN0RLOX220150921>, accessed 17 June 2016.

The Jaitapur site was promised in 2007 to France as part of negotiations over India receiving a waiver from the Nuclear Suppliers Group (the so-called U.S.-India nuclear deal).⁵⁵⁵ NPCIL and AREVA then signed a formal Memorandum of Understanding to work on the setting up of two to six EPR units in February 2009.⁵⁵⁶ From that point, it took over six years for AREVA to sign a Pre-engineering Agreement (PEA) contract with NPCIL and a Memorandum of Understanding with Larsen & Toubro, an engineering conglomerate based in India, to potentially carry out some of the production locally.⁵⁵⁷ Then in January 2016, following a state visit by France's President Hollande to India, all that Prime Minister Modi and President Hollande could say in their joint statement was that they wanted to "encourage" their nuclear firms to conclude techno-commercial negotiations by the end of the year.⁵⁵⁸ Thus progress on the project has been slow at best and there are still major differences in the price expectations of AREVA/EDF and NPCIL.⁵⁵⁹

The Mithi Viridi site, where Westinghouse's AP1000 reactors are proposed, was approved in 2008,⁵⁶⁰ although there was a period after the Fukushima accidents, when the local state government was unsure of proceeding with the reactor.⁵⁶¹ India's setting up of an insurance pool in combination with a paucity of reactor sales elsewhere appears to have persuaded Westinghouse to continue pursuing the deal. Although initially Westinghouse CEO Daniel Roderick had not been optimistic and was still looking for "a break",⁵⁶² by January 2016 he was hoping to make a "commercially significant announcement" by March 2016.⁵⁶³ In June 2016, following a meeting between Indian Prime Minister Narendra Modi and U.S. President Barack Obama, the joint statement released said that the two "leaders welcomed the start of preparatory

⁵⁵⁵ *The Sunday Guardian*, "Jaitapur will go to the French, Kakodkar disclosed", 11 September 2011, see <http://www.sunday-guardian.com/investigation/jaitapur-will-go-to-the-french-kakodkar-disclosed>, accessed 27 May 2016.

⁵⁵⁶ Areva, "Areva pursues its development in India", Press Release, 10 July 2009, see <http://www.areva.com/EN/news-6874/areva-pursues-its-development-in-india.html>, accessed 17 June 2016.

⁵⁵⁷ Areva, "India: AREVA signs agreements for the development of the Jaitapur nuclear power plant project", 10 April 2015, see <http://www.areva.com/EN/news-10497/india-areva-signs-agreements-for-the-development-of-the-jaitapur-nuclear-power-plant-project.html>, accessed 17 June 2016.

⁵⁵⁸ Charu Sudan Kasturi, "Rafale and nuke deals in price tangle", *The Telegraph*, 26 January 2016, see http://www.telegraphindia.com/1160126/jsp/nation/story_65959.jsp, accessed 17 June 2016.

⁵⁵⁹ Sanjay Jog, "Sanjay Jog: Jaitapur's nuclear discontent", *Business Standard*, 10 October 2015, see http://www.business-standard.com/article/opinion/sanjay-jog-jaitapur-s-nuclear-discontent-115101000884_1.html; and Anil Sasi, "Jaitapur nuclear project: Renewed push, amid lingering concerns", *The Indian Express*, 27 January 2016, see <http://indianexpress.com/article/business/business-others/jaitapur-nuclear-project-renewed-push-amid-lingering-concerns/>, both accessed 17 June 2016.

⁵⁶⁰ Rajiv Shah, "N-plant site in Gujarat approved", *Times of India*, 23 August 2008, see <http://timesofindia.indiatimes.com/city/ahmedabad/N-plant-site-in-Gujarat-approved/articleshow/3395046.cms>, accessed 17 June 2016.

⁵⁶¹ *The Times of India*, "State does a rethink on Mithivirdi N-plant", 3 May 2011, see <http://timesofindia.indiatimes.com/city/ahmedabad/State-does-a-rethink-on-Mithivirdi-N-plant/articleshow/8147498.cms>, accessed 17 June 2016.

⁵⁶² Anya Litvak, "Westinghouse needs break in India nuclear stalemate", *Pittsburgh Post-Gazette*, 25 January 2015, see <http://powersource.post-gazette.com/powersource/policy-powersource/2015/01/25/Westinghouse-waiting-for-progress-in-India-nuclear-stalemate/stories/201501250086>, accessed 17 June 2016.

⁵⁶³ *Reuters*, "Westinghouse eyes India reactor deal by March-end", *Business Standard India*, 16 January 2016, see http://www.business-standard.com/article/primer-friendly-version?article_id=116011600016_1, accessed 18 January 2016.

work on site in India for six AP1000 reactors to be built by Westinghouse and noted the intention of India and the U.S. Export-Import Bank to work together toward a competitive financing package for the project (...). Both sides welcomed the announcement by the Nuclear Power Corporation of India Ltd, and Westinghouse that engineering and site design work will begin immediately and the two sides will work toward finalizing the contractual arrangements by June 2017".⁵⁶⁴

The relatively vague statement did not excite most financial analysts. Chris Gadomski, a leading nuclear analyst at Bloomberg New Energy Finance in New York, for example was blunt: "To be frank, I'll believe it when the check clears (...). There's so many of these deals that, you have to wait until the pie is completely cooked".⁵⁶⁵ In India, questions have been raised about the cost competitiveness of these reactors.⁵⁶⁶ A recent assessment of the economics of AP1000 reactors by the Institute for Energy Economics and Financial Analysis found that the costs of generating electricity at the proposed AP1000 reactors would be at least three and possibly six times the corresponding cost of setting up solar photovoltaic plants.⁵⁶⁷

Japan Focus

For the first time in nearly two years, commercial nuclear reactors began operation in Japan during 2015. The Sendai-1 reactor restarted on 14 August⁵⁶⁸ with Sendai-2 restarting 21 October.⁵⁶⁹ In the following months, both reactors generated a total 3 TWh of electricity, or 0.5 percent of the nation's annual output. This compares with a nuclear share of 1.7 percent of total electricity in 2013, 2 percent in 2012, 18 percent in 2011, 29 percent in 2010, and the historic maximum of 36 percent in 1998. The restarts of Sendai were the first reactor operations since 15 September 2013, when Ohi Unit-4 was shut down.⁵⁷⁰ Efforts to follow restart of the Sendai plant, with operation of the Takahama-3 reactor⁵⁷¹ in January 2016, proved short-lived due to an

⁵⁶⁴ The White House, "Joint Statement: The United States and India: Enduring Global Partners in the 21st Century", Press Release, 7 June 2016, see <https://www.whitehouse.gov/the-press-office/2016/06/07/joint-statement-united-states-and-india-enduring-global-partners-21st>, accessed 2 July 2016.

⁵⁶⁵ *Tribune-Review*, "Westinghouse to Build 6 Nuclear Reactors in India", 7 June 2016, see <http://triblive.com/business/headlines/10595279-74/deal-india-westinghouse>, accessed 2 July 2016.

⁵⁶⁶ Suvrat Raju, "The Cost of Nuclear Diplomacy," *The Hindu*, 20 June 2016, see <http://www.thehindu.com/opinion/op-ed/the-cost-of-nuclear-diplomacy/article8748864.ece>, accessed 22 June 2016.

⁵⁶⁷ David A. Schlissel, "Bad Choice: The Risks, Costs and Viability of Proposed U.S. Nuclear Reactors in India", Institute for Energy Economics and Financial Analysis, March 2016, see <http://ieefa.org/wp-content/uploads/2016/03/Bad-Choice-The-Risks-Costs-and-Viability-of-Proposed-US-Nuclear-Reactors-in-India-March-2016.pdf>, accessed 2 July 2016.

⁵⁶⁸ WNISR, "32-Year-Old Reactor First to Generate Power in Japan in Nearly Two Years", 14 August 2015, see <http://www.worldnuclearreport.org/32-Year-Old-Reactor-First-to-Generate-Power-in-Japan-in-Nearly-Two-Years.html>, accessed 17 June 2016.

⁵⁶⁹ WNISR, "Second Reactor Restarts in Japan", 22 October 2015, see <http://www.worldnuclearreport.org/Second-Reactor-Restarts-in-Japan.html>, accessed 17 June 2016.

⁵⁷⁰ WNISR, "Japan Nuclear Free, Last Operating Reactor Shut Down", 16 September 2013, see <http://www.worldnuclearreport.org/Japan-Nuclear-Free-Last-Operating.html>, accessed 2 July 2016.

⁵⁷¹ JAIF, "Kansai EP Starts Up Takahama-3 NPP", 29 January 2016, see <http://www.jaif.or.jp/en/kansai-ep-starts-up-takahama-3-npp/>, accessed 17 June 2016.

unprecedented court ruling on 9 March 2016 forcing the immediate closure of the reactor.⁵⁷² The Otsu District Court ruling also required the continued shutdown of Takahama-4 which had earlier suffered a technical failure on 29 February when plant operator Kansai Electric Power Company was attempting grid connection.⁵⁷³

As a result of the Otsu court ruling the two Sendai reactors, owned by Kyushu Electric and located in Kagoshima prefecture in southern Japan, is the only nuclear power plant operating as of 1 July 2016, highlighting the failure of the industry to recover from the progressive shutdown of all reactors in the period after 11 March 2011. As a result, all but three of Japan’s nuclear reactors are in the WNISR category of Long Term Outage (LTO).⁵⁷⁴ (See Annex 2 for a detailed overview of the Japanese Reactor Program.)

Figure 42: Age Distribution of the Japanese Nuclear Fleet

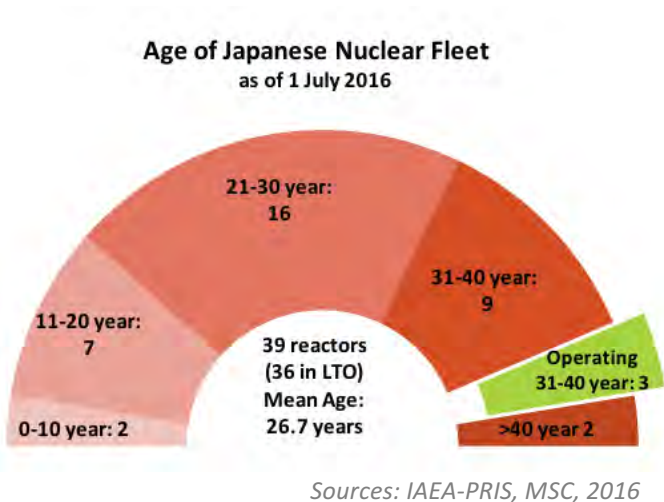


Figure 6 shows the collapse of nuclear electricity generation in Japan from 287 TWh to 9.7 TWh in 2015. While the most dramatic decline has been since the 2011 Fukushima Daiichi accident, in fact it has been 17 years since Japan’s nuclear output peaked at 313 TWh in 1998. The noticeably sharp decline during 2002-2003, amounting to a reduction of almost 30 percent, was due to the temporary shutdown of all 17 of Tokyo Electric Power Company’s (TEPCO) reactors—seven at Kashiwazaki Kariwa and six at Fukushima Daiichi and four at Fukushima Daini.⁵⁷⁵ The shutdown was following an admission from TEPCO that its staff had deliberately falsified data for inclusion

⁵⁷² *Nikkei Asian Review*, “Japan court orders shutdown of nuclear reactors”, 10 March 2016, see <http://asia.nikkei.com/Business/Companies/Japan-court-orders-shutdown-of-nuclear-reactors>, accessed 2 July 2016.

⁵⁷³ WNISR, “Takahama-4 Reactor Fails Grid Connection in Japan”, 2 March 2016, see <http://www.worldnuclearreport.org/Takahama-4-Reactor-Fails-Grid-Connection-in-Japan.html>, accessed 17 June 2016.

⁵⁷⁴ M. Schneider, A. Froggatt, et. al., “WNISR 2014”, 18 August 2014, see <http://www.worldnuclearreport.org/WNISR2014.html>, accessed 17 June 2016.

⁵⁷⁵ Daiichi means “Number One” and Daini means “Number Two”, each referring to a multi-reactor generating complex.

in regulatory safety inspections reports.⁵⁷⁶ 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, with a total installed capacity of 8 GWe, following the Niigata Chuetsu-oki earthquake in 2007.⁵⁷⁷ TEPCO was struggling to restart the Kashiwazaki Kariwa units, when the Fukushima earthquake occurred.

The Fukushima-Daiichi accident, which began on 11 March 2011 (see Fukushima Status Report), led to the shutdown of all 50 nuclear reactors in addition to the destruction of four of the six units at the Fukushima-Daiichi site. Five years on, the consequences of the accident continue to define the future prospects for nuclear energy in Japan. The number of reactors theoretically available to resume operation declined further with five reactors declared for permanent closure in March 2015⁵⁷⁸ and the confirmation of the permanent closure of the 39-year-old Ikata-1 reactor on 25 March 2016.⁵⁷⁹ WNISR considers the day of the last electricity generation as the closure date and accordingly modifies the statistics retroactively.

Table 15: Japanese Reactors Officially Closed

Owner	Unit	Capacity	Grid Connection	Last Production	Age ⁵⁸⁰
Kansai Electric	PWR Mihama Unit 1	340 MW	1970	2010	40 years
	PWR Mihama Unit 2	500 MW	1972	2011	40 years
Kyushu Electric	PWR Genkai Unit 1	559 MW	1975	2011	37 years
Shikoku	PWR Ikata Unit 1	538 MW	1977	2011	35 years
JAPC	BWR Tsuruga Unit 1	357 MW	1969	2011	41 years
Chugoku Electric	PWR Shimane Unit 1	460 MW	1974	2010	37 years

Sources: IAEA-PRIS, MSC, 2016

While the nuclear industry has failed to resume operation of nuclear power plants, a consistent majority of Japanese citizens, when polled, continue to oppose the continued reliance on nuclear

⁵⁷⁶ Hiroyuki Kuroda, "Lesson Learned from TEPCO Nuclear Power Scandal", Manager Corporate, Communications Department, TEPCO, 24 March 2004, see <http://www.tepco.co.jp/en/news/presen/pdf-1/040325-s-e.pdf>, accessed 17 June 2016.

⁵⁷⁷ 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 www.tepco.co.jp/en/news/presen/pdf-1/0709-e.pdf, accessed 2 July 2016.

⁵⁷⁸ WNISR, "Japanese Utilities Confirm Closure of Five Reactors", 21 March 2015, see <http://www.worldnuclearreport.org/Japanese-Utilities-Confirm-Closure.html>, accessed 2 July 2016.

⁵⁷⁹ 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 2 July 2016.

⁵⁸⁰ Note that WNISR considers the age from first grid connection to last production.

power, support its early phase-out, and remain opposed to the restart of reactors—with latest polling in February 2016 indicating about 60 percent opposed to reactor operations.⁵⁸¹

The polling came prior to Japan's largest earthquake since 2011, which struck the island of Kyushu in mid-April 2016.⁵⁸² The two major earthquakes on 14 and 16 April and hundreds of aftershocks did not cause damage to the Sendai nuclear plant, located around 150km from the epicentres, or at the Genkai and Ikata nuclear plants, which are also in relative proximity to the seismic events.⁵⁸³ However, 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 Japan's Nuclear Regulation Authority (NRA).⁵⁸⁴ 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).⁵⁸⁵ The effect of this has been to further sensitize Japanese public opinion to the earthquake risks to nuclear power in Japan.

The government of Prime Minister Abe, elected in December 2012, confirmed in 2014 a new Strategic Energy Plan. It reversed the previous government's position, announced in September 2012, that called for a zero nuclear power future by the 2030s.⁵⁸⁶ In April 2015, the Long-term Energy Supply and Demand Outlook was proposed, which set the percentage of energy the nation aims to generate from different sources by the year 2030.⁵⁸⁷ Adopted in July 2015, it was decided that a nuclear share of 20-22 percent, renewable energy of 22-24 percent, and fossil fuels 56 percent would be achieved by 2030.⁵⁸⁸ The proposed nuclear share is below the pre-Fukushima projection within the Ministry of Economics, Trade and Industry's (METI)

⁵⁸¹ Nikkei, "Opposition to nuclear power plant re-running 60 percent headquarters poll", 29 February 2016, (in Japanese), see http://www.nikkei.com/article/DGXXKASF528H1F_Y6A220C1PE8001/, accessed 12 May 2016.

⁵⁸² *Bloomberg*, "Japan's Worst Quake Since 2011 Seen Delaying Nuclear Starts", 26 April 2016, see <http://www.bloomberg.com/news/articles/2016-04-26/japan-s-worst-quake-since-fukushima-seen-delaying-nuclear-starts>, accessed 2 July 2016.

⁵⁸³ NRA, "Situation of Nuclear Facilities following the 2016 Kumamoto Earthquake", News Release, 18 April 2016, see <https://www.nsr.go.jp/data/000147663.pdf>, accessed 17 June 2016.

⁵⁸⁴ *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 2 July 2016.

⁵⁸⁵ *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 2 July 2016.

⁵⁸⁶ The Energy and Environment Council, "Innovative Strategy for Energy and the Environment", Government of Japan, 14 September 2012.

⁵⁸⁷ METI, "Long-term Energy Supply and Demand Outlook", (Provisional Translation), July 2015, see http://www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf, accessed 17 June 2016.

⁵⁸⁸ Kenji Kaneko, "Japan Announces Energy Mix Plan for 2030", Clean Tech Institute, *Solar Power Plant Business*, 1 May 2015, see http://techon.nikkeibp.co.jp/english/NEWS_EN/20150501/416800/?ST=msbe, accessed 17 June 2016.

2010 Strategic Energy Plan, which had planned for 50 percent by 2030,⁵⁸⁹ and also below the actual pre-Fukushima Daiichi accident level of 29 percent in March 2011.

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.⁵⁹⁰ In response, the then Industry Minister, Yoichi Miyazawa, stated that high energy costs from renewables would require a nuclear share of at least 20-22 percent.⁵⁹¹ To attain that nuclear share, all 26 reactors that have applied for NRA review would have to be operating, plus most of those yet to be reviewed, a prospect that in reality is unattainable. Miyazawa stated that achieving this percentage would require the operation of 35 reactors by 2030, a target that does not reflect the reality of the many challenges facing Japan's aging nuclear reactor fleet⁵⁹² (see also Figure 42).

If anything, the prospects for attaining the current 2030 nuclear share have worsened during the past year. The Otsu District Court in Shiga prefecture, in issuing the injunction sought by 29 citizens living within 30-70km of the Takahama reactors⁵⁹³, signaled to Japan's utilities and government that even with reactors approved for restart and operating, there is a possibility of future injunctions forcing the shutdown of reactors. As with the Otsu judgement, this could include a court located in neighboring prefectures outside the immediate area of the location of the nuclear power plant. It remains unclear what the final legal outcome will be in the Takahama-3 and -4 dispute, however, Kansai Electric is clearly determined to use all legal means to try to overturn the specific judgement⁵⁹⁴. The significance and medium to long term impact of the Otsu judgement is difficult to overstate, given the uncertainty as to which reactor could be next. The fact that Kansai Electric were not prepared for the ruling and its shock impact (its share price dropped by 15 percent, the largest plunge since October 1987) was highlighted by the reaction of the vice chair of the Kansai Economic Federation: "Why is a single district court judge allowed to trip up the government's energy policy?"⁵⁹⁵

Within the utility industry, it is acknowledged that it will be a challenge to reach the government target and that 15 percent by 2030 is more realistic. And even attaining this figure looks

⁵⁸⁹ METI, "The Strategic Energy Plan of Japan—Meeting global challenges and securing energy futures", Revised June 2010.

⁵⁹⁰ *Asahi Shimbun*, "Nuclear power crucial as renewable energy too costly, ministry says", 27 May 2015.

⁵⁹¹ *Ibidem*.

⁵⁹² *Asahi Shimbun*, "Japan needs 35 nuclear reactors operating by 2030, says industry minister", 11 June 2015.

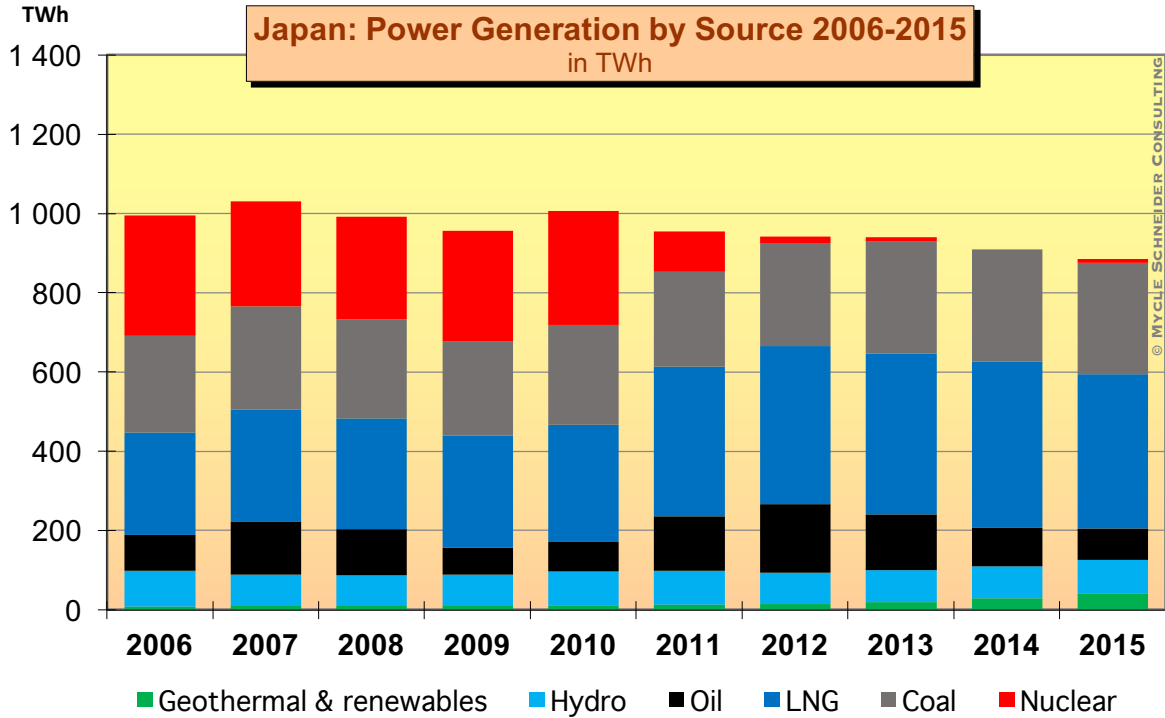
⁵⁹³ Kansai Electric Power Company, "Decision of a provisional disposition preventing the operation of Units 3 and 4 of Takahama Nuclear Power Station", 9 March 2016, see http://www.kepco.co.jp/english/corporate/pr/2016/_icsFiles/afieldfile/2016/03/09/2016_mar9_2.pdf, accessed 17 June 2016.

⁵⁹⁴ Kansai Electric Power Company, "Appeal of an Objection to the Provisional Disposition to Suspend Operation of Takahama Units 3 and 4", 14 March 2016, see http://www.kepco.co.jp/english/corporate/pr/2016/_icsFiles/afieldfile/2016/03/14/2016_mar14_1.pdf, accessed 17 June 2016.

⁵⁹⁵ *Asahi Shimbun*, "Editorial: nuclear power proponents still scoffing at public safety concerns", 28 March 2016, see <http://www.asahi.com/ajw/articles/aj201603280014.html>, accessed 12 May 2016.

uncertain.⁵⁹⁶ Wider corporate Japan is increasingly skeptical of the prospects for attaining a high share.⁵⁹⁷ Several scenarios indicating a share of less than 10 percent were published during 2015.⁵⁹⁸ In May 2016, indications emerged that this lower target may be adopted in a revised energy plan. Reflecting the unrealistic prospects for nuclear reactor restarts and continuing strong public opposition, unnamed sources suggested that an updated energy plan to be released in 2017 would revise downwards the nuclear share to between 10 and 15 percent.⁵⁹⁹

Figure 43: Electricity Generation in Japan by Source 2006-2015



Source: FEPC, 2016⁶⁰⁰

⁵⁹⁶ Shigeru Muraki, “Plenary Discussion: Managing Global Risks—Markets, Geopolitics and Climate”, Tokyo Gas, Columbia Global Energy Summit, 28 April 2015, see <http://energypolicy.columbia.edu/events-calendar/2015-columbia-global-energy-summit>, accessed 2 July 2016.

⁵⁹⁷ Reuters, “Japan Inc not as keen as Abe government on nuclear power—Reuters poll”, 24 May 2015, see <http://www.reuters.com/article/2015/05/24/japan-companies-nuclear-idUSL3NOYB2PR20150524?feedType=RSS&feedName=utilitiesSector>, accessed 2 July 2016.

⁵⁹⁸ Shaun Burnie, “Reality Check: Energy Mix 2030 and Japan’s Collapse in Nuclear Power Generation”, Greenpeace Germany, Published 24 April 2015, Updated June 2015, see <http://www.greenpeace.org/japan/Global/japan/pdf/20150428-briefing-energy-mix.pdf>, accessed 2 July 2016; and BNEF, “Japan’s likely 2030 energy mix: more gas and solar”, 2 June 2015, see <http://about.bnef.com/white-papers/japans-likely-2030-energy-mix-gas-solar/>, accessed 12 May 2016.

⁵⁹⁹ Reuters, “Japan to cut emphasis on nuclear in next energy plan: sources”, 26 May 2016, see <http://www.reuters.com/article/us-japan-nuclear-idUSKCN0YI06Z>, accessed 25 June 2016.

⁶⁰⁰ FEPC, “Summary of Press Conference Comments Made by Makoto Yagi, FEPC Chairman”, 20 May 2016, see https://www.fepec.or.jp/english/news/conference/_icsFiles/afieldfile/2016/05/24/kaiken_e_20160520.pdf, accessed 5 July 2016.

The options for how such targets would be attained are of course dependent upon multiple factors, in particular installed capacity per reactor. Taking into account the major uncertainties, one scenario for a 10 percent target would require the operation of 13 of the reactors currently under NRA review, including start up and operation of the two Advanced Boiling Water Reactors (ABWR) under construction at Shimane and Ohma. 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. Specifically, the uncertainties in the prospects for reactor restart mean that, no matter what target percentage is set, the Japanese Government and utilities simply do not know, how many of Japan's 36 remaining reactors will be restarted, nor when.

People often wonder, how Japan could handle the loss of close to 30 percent of the electricity generating capacity following the 3/11 events without any major blackouts. As Figure 43 illustrates, there were two key components, savings/energy efficiency and increased fossil fuel use. Compared to 2010, consumption dropped nationwide by 5 percent in 2011. One remarkable aspect is that consumption did not pick up again, on the contrary, continued to fall: In 2015, national power consumption was 12 percent below the 2010 level. The fuel shift between 2010 and 2015 shows an increase of 5 percentage points for both, natural gas and coal, while the oil consumption, after a brief surge, fell back to its pre-3/11 levels. Renewables pick up only slowly and contribute now about 5 percent to the mix compared to 1 percent in 2010.

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 Mixed Oxide (MOX) fuel into 16-18 light water reactors.⁶⁰¹ The plans to use MOX fuel have for the past two decades been the justification used for Japan's accumulation of plutonium through reprocessing. The Takahama-3 reactor, operated between 29 January and 10 March with MOX fuel, and the MOX-fueled reactor Takahama-4, are now shutdown. The first reactor to resume operation with MOX fuel will likely be Ikata-3 scheduled for summer 2016. The 22nd delay in beginning the commercial operation of the Rokkasho-mura reprocessing plant, intended to produce plutonium for use in MOX fuel, was announced in November 2015.⁶⁰² Originally scheduled to begin operation in 1997, construction of the plant began in 1993.⁶⁰³

⁶⁰¹ NW, "Japan postpones plans to use MOX fuel", 26 November 2015.

⁶⁰² JNFL, "Extraordinary Press Conference—Schedule Change of Completion of Rokkasho Reprocessing Plant and MOX Fuel Fabrication Plant", 16 November 2015, see <http://www.jnfl.co.jp/en/release/president-talk/2015/20151116.html>, accessed 17 June 2016.

⁶⁰³ 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*, Volume 14, Issue 5, 1 March 2016, see <http://apjif.org/-Shaun-Burnie--Frank-Barnaby--Tom-Clements--Aileen-Mioko-Smith--Kendra-Ulrich/4860/article.pdf>, accessed 17 June 2016.

NRA Nuclear Safety Review

As of 1 July 2016, eleven power companies that own nuclear reactors have applied to Japan's regulator NRA for safety assessments of a total of 26 nuclear reactors (see Annex 2 for details), with seven reactors having completed all stages of the review (Sendai-1 and -2, Takahama-3 and -4⁶⁰⁴, Ikata-3⁶⁰⁵), as well as Takahama-1 and -2 that, on 20 June 2016, became the first units to be granted a lifetime extension to 60 years under the new regulations. The NRA is expected to complete pre-operational inspections for Ikata-3 in July 2016. Compliance with the NRA guidelines, which came into force in July 2013⁶⁰⁶, is a requirement for utilities in their plans for reactor restart, along with “securing local public understanding” and approval from the prefectural government and local town mayors. 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;⁶⁰⁷ fire protection; the management of the reactor in the event of a loss of offsite electrical power, cooling function, and accident management,⁶⁰⁸ 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 would 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 Pressurized Water Reactors (PWR) based on the regulator's analysis that it is easier to secure them against seismic events than it is for Boiling Water Reactors (BWR). 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.

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.⁶⁰⁹ However, there has been an ongoing dispute since 2012 between the NRA and JAPCO over the nature of a

⁶⁰⁴ NRA, “Completion of the 3-step conformity review on the New Regulatory Requirements for Takahama NPS Units 3 and 4”, News Release, 9 October 2015, see <https://www.nsr.go.jp/data/000125853.pdf>, accessed 17 June 2016.

⁶⁰⁵ NRA, “Completion of the 3-step conformity review on the New Regulatory Requirements for Ikata Power Station Unit 3” News Release, 20 April 2016, see <https://www.nsr.go.jp/data/000147907.pdf>, accessed 17 June 2016.

⁶⁰⁶ NRA, “New Regulatory Requirements for Light-Water Nuclear Power Plants—Outline—August 2013”, see <https://www.iaea.org/sites/default/files/requirements160913.pdf>, accessed 17 June 2016.

⁶⁰⁷ NRA, “Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Earthquakes and Tsunamis)”, 3 April 2013.

⁶⁰⁸ NRA, “Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Severe Accident Measures)”, 3 April 2013.

⁶⁰⁹ 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 17 June 2016.

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,⁶¹⁰ and in May 2013 the evaluation report of the NRA determined that the D-1 fracture zone lying directly under Tsuruga-2 was active.⁶¹¹ The JAPCO, and a team of international experts have claimed ever since that the fault line is not active.⁶¹² Despite counter arguments from JAPCO, in March 2015, the NRA Commissioners agreed with the final evaluation that the fault was active.⁶¹³ 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.

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.⁶¹⁴ The older Shika unit is not under NRA review and it is almost certain that it will be decommissioned. 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.⁶¹⁵ The NRA commissioners have yet to make a final determination on this issue, requesting more information from the utility. 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.

In August 2015, the NRA 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

⁶¹⁰ *Japan Times*, “Detecting Active Faults Near Reactors”, Editorial, 14 December 2012, see <http://www.japantimes.co.jp/opinion/2012/12/14/editorials/detecting-active-faults-near-reactors/>, accessed 17 June 2016.

⁶¹¹ 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 17 June 2016.

⁶¹² JAPCO, “Evaluation of shatter zones at Tsuruga NPP site—Interim Report of the Joint International Experts’ Meeting (TRM/IRG)”, 21 May 2013, see http://www.japc.co.jp/english/shatter_zones/pdf/130521/250521_2.pdf, accessed 2 July 2016.

⁶¹³ JAIF, “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 2 July 2016.

⁶¹⁴ 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 2 July 2016.

⁶¹⁵ *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 May 2016.

of ten, to advance through the review process.⁶¹⁶ However, there are no prospects for restart of the reactors in the coming year, not least due to multiple outstanding issues including seismic risks, and the opposition to restart from the Niigata prefectural governor.⁶¹⁷ On 30 November 2015, TEPCO admitted to the NRA multiple safety failures at the Kashiwazaki Kariwa plant—this followed a warning from the NRA that safety standards under the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors had been broken during safety-related construction at the plant. TEPCO confirmed that at all seven Kashiwazaki-Kariwa reactors they had identified 1,745 electric cables found to have problems, including no separation between safety and non-safety cabling.⁶¹⁸ TEPCO also admitted that in hundreds of construction projects at the Kashiwazaki Kariwa plant there had been inadequate supervision.

The decision of the NRA to focus on the ABWRs at Kashiwazaki also means 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—will be pushed back.⁶¹⁹

The credibility and effectiveness of the NRA during the past year has been significantly challenged.

IAEA Integrated Regulatory Review Service (IRRS)

In addition to court rulings that have questioned in particular the effectiveness of seismic assessments of the NRA, in January 2016, the regulator was reviewed by the IAEA Integrated Regulatory Review Service (IRRS). In the final report, presented to the NRA on 23 April 2016⁶²⁰, the IAEA praised the establishment of the NRA and acknowledged that it has sought to improve independence and transparency since it was set up in 2012, it also noted however significant areas of weakness. These included that the NRA is currently conducting its work outside the recommendations and guidelines of the IAEA General Safety Requirements (REV 1) and the inadequacy of NRA inspections of nuclear facilities including nuclear plants—this includes poor training, limited inspections rights, and extended periods between inspections. In its report the IAEA concluded:

The unnecessary complexity of the legal framework with respect to inspections was also recognized during the IRRS mission to Japan in 2007. However, the IRRS team noted that the approach remains essentially the same 9 years later. During the preparations for the IRRS mission the NRA also recognized the unnecessary complexity of the legal framework for performing inspections and has already foreshadowed improvements towards simplification. Such improvements will require changes in the laws, which will likely take considerable time (...).

⁶¹⁶ 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 2 July 2016.

⁶¹⁷ Bloomberg, “Tepco Niigata Atomic Plant Safe to Restart in 2016, Adviser Says”, 20 November 2015, see <http://www.bloomberg.com/news/articles/2015-11-20/tepc0-niigata-atomic-plant-safe-to-restart-in-2016-adviser-says>, accessed 2 July 2016.

⁶¹⁸ The Mainichi, “TEPCO reports 2,000 incorrectly installed cables at 2 nuclear complexes”, 1 December 2015, see <http://mainichi.jp/english/articles/20151201/p2a/00m/0na/013000c>, accessed 2 July 2016.

⁶¹⁹ NW, “Japan’s NRA prioritizing Kashiwazaki-Kariwa review: commissioner”, 20 August 2015.

⁶²⁰ Department of Nuclear Safety and Security, “Integrated Regulatory Review Service (IRRS) Mission to Japan”, IAEA, Tokyo (Japan), 10-22 January 2016, see <https://www.nsr.go.jp/data/000148261.pdf>, accessed 17 June 2016.

The IRRS team concluded that the NRA inspection program needs significant improvement in certain areas (...):

In particular the legal framework for inspection is prescriptive in nature and allows very little freedom to NRA to decide on the scope, frequency and content of inspections taking into account risk significance of issues.⁶²¹

The weakness of NRA inspections was highlighted in December 2015, when it was confirmed that the NRA had failed to conduct on-site inspections for fire related cable installation at reactors, where it had completed and approved pre operational inspection.⁶²²

Even before the release of the IAEA IRRS report the NRA Commissioners unanimously approved on 16 March 2016 a proposal to try to implement recommendations from the IRRS report.⁶²³ The NRA will also seek an amendment of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, to specifically revise inspection procedures to the Diet at some point in 2016.⁶²⁴ 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.”⁶²⁵

Critical Ageing 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 2016, a total of six reactors (see Table 15) have been declared to be decommissioned, not including Fukushima. This is a significant departure from the position of utilities prior to the Fukushima Daiichi nuclear accident, when they and METI were proposing operation of nuclear reactors beyond 60 years.⁶²⁶ The decision to permanently shut down these reactors highlights the ageing issues confronting Japan’s nuclear power utilities.

Before the March 2011 nuclear accident at Fukushima Daiichi, Japan had 54 commercial nuclear reactors. As a result of the accident, all 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. TEPCO has yet to announce the permanent closure of its four Fukushima

⁶²¹ Ibidem.

⁶²² *Japan Times*, “NRA fails to conduct on-site checks for nuclear-plant cables”, 6 December 2015, see <http://www.japantimes.co.jp/news/2015/12/06/national/nra-fails-to-conduct-on-site-checks-for-nuclear-plant-cables/#.Vz7j-yMrK2w>, accessed 17 June 2016.

⁶²³ *Platts*, “Japan’s regulator sets March 2020 target to implement IAEA recommendations” Nuclear News Flashes, 20 March 2016.

⁶²⁴ *Platts*, “Japan’s NRA forms team to implement IAEA inspection recommendations”, 11 May 2016.

⁶²⁵ JAIF, “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 17 June 2016.

⁶²⁶ 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, Japan, 2002, as published in the Proceedings of a symposium held in Budapest on Nuclear Power Plant Life Management by the IAEA, 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 http://wwwpub.iaea.org/MTCD/publications/PDF/csp_021c/PDF/contents.pdf, accessed 19 May 2016.

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.⁶²⁷ 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 estimated at ¥200 billion (\$1.77 billion).⁶²⁸ 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 2.7GW, equal to 5.6 percent of Japan's nuclear capacity as of March 2011. Together with the ten Fukushima, the total rises to 16 nuclear 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 likely future nuclear generating capacity of Japan, and in particular the operation of reactors beyond 40 years, will in part be determined during 2016 with decisions made by Kansai Electric on reactors Takahama-1 and 2 and Mihama-3. The 780 MW PWR Mihama-3 is 40 years old, while Takahama units 1 and 2 are 42 and 41 years old respectively. On 14 November 2014, the NRA had granted a ten-year life extension for Takahama-1, and on 8 April 2015 for Takahama-2.⁶²⁹ 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, Kansai Electric applied for a 20-year life extension for the two Takahama reactors,⁶³⁰ which was granted on 20 June 2016⁶³¹.

NRA requirements set 7 July 2016 as a deadline for approval of life extension for the Takahama units, and November 2016 for Mihama. The NRA on 24 February 2016 announced that the Takahama units were compatible with the 2013 safety guidelines;⁶³² and on 20 June 2016, the NRA, and for the first time, approved the 20-year extension for the two Takahama reactors as

⁶²⁷ Mitsuru Obe, "Tepco May Scrap Second Nuclear Plant", *WSJ*, 4 July 2012, see <http://www.wsj.com/articles/SB10001424052702304141204577506531300365556>, accessed 17 June 2015.

⁶²⁸ 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 17 June 2016.

⁶²⁹ *Japan Times*, "Kepco asks for permission to run 40-year-old reactors for 20 more years", 1 May 2015, see <http://www.japantimes.co.jp/news/2015/05/01/national/kepco-applies-extend-operating-life-two-aging-reactors-fukui-20-years/#.VWthYyiaH6h>, accessed 18 June 2016.

⁶³⁰ *Ibidem*.

⁶³¹ *WNN*, "Takahama units cleared for extended operation", 20 June 2016, see <http://www.world-nuclear-news.org/RS-Takahama-units-cleared-for-extended-operation-2006165.html>, accessed 2 July 2016.

⁶³² 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 7 July 2016.

meeting the new regulatory guidelines.⁶³³ On 14 April 2016 citizens filed an administrative lawsuit in Nagoya District Court, against the NRA approval of extending operation of the Takahama reactors.⁶³⁴ Kansai Electric does not expect the two Takahama units to resume operations before November 2019, at the earliest, because extensive retrofits will need to be implemented before restarting them.

Kansai Electric already opted to decommission the Mihama-1 and -2 reactors in 2015, and there are doubts that it will proceed with plans to operate Mihama-3. In March 2016, Kansai Electric 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).⁶³⁵ A significant part of this cost relates to seismic resistance measures required to meet the higher Design Basis Ground Motion. While the NRA is expected to approve Mihama-3 as in compliance with the revised guidelines, it remains unclear whether Kansai Electric will meet the 30 November 2016 deadline for approval of a 20-year extension, which requires assessing the aging plant. As with the decision to shut down the Ikata-1 reactor, there is every likelihood that Kansai Electric will determine that it makes no economic sense to attempt a restart of Mihama-3 given the investment costs required.

Restart Prospects

As of 1 July 2016, 36 commercial reactors in Japan remain in Long Term Outage, with 19 reactors under review for restart by the NRA. Restart of the Ikata-3 reactor is planned for summer 2016, following completion of NRA pre-operating inspections. That will bring to three the number of operating reactors in Japan. Whether or not the Takahama-3 and 4 reactors are restarted before the end of 2016 is dependent upon the appeal proceedings initiated by Kansai Electric against the Otsu court ruling. The next in line for possible restart are the Genkai-3 and 4 reactors owned by Kyushu Electric, and Tomari-3 owned by Hokkaido Electric Power Company. It is unlikely that any of these will resume operation before 2017, and failure to overturn the legal decision on Takahama-3 and 4, will mean as few as three reactors will be operating by December 2016.

At the same time, pressure to resume operations to generate electricity and income is clearly mounting. Despite the setbacks, 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;

⁶³³ 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 24 June 2016.

⁶³⁴ 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 May 2016.

⁶³⁵ *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 May 2016.

- Local political and public opposition;
- Impact of electricity deregulation and intensified market competition.

At the same time, however, Japanese utilities are insisting on, 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 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 19 reactors 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 3-4 reactors each year from 2016 onwards remains a possibility but also a challenge, with the major uncertainty that even restarted reactors will be shut down through the courts.

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 in Shimane-3 and Ohma-1 plants, but there was little sign of any resumption of work. Officially, construction “partially resumed” at Ohma in October 2012⁶³⁶ and Shimane-3 has remained “under construction”, according to the Japan Atomic Industrial Forum (JAIF)⁶³⁷ and IAEA statistics. In the case of Shimane-3, it was 94 percent complete by March 2011⁶³⁸. 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.⁶³⁹ The utility began work to install filtered vents during 2014-2015, and other modifications “pursuant to the new regulatory requirements”.⁶⁴⁰ No startup date has been

⁶³⁶ J-Power, “2014 Annual Report”, August 2014, see <http://www.jpowers.co.jp/english/ir/pdf/2014.pdf>, accessed 11 June 2015.

⁶³⁷ JAIF, “Nuclear Power Plants in Japan”, 22 May 2013.

⁶³⁸ 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 2 July 2016.

⁶³⁹ NEI, “New-build now. Part 2: Asia”, 9 July 2014, see <http://www.neimagazine.com/features/featurenew-build-now-part-2-asia-4313945/>, accessed 2 July 2016.

⁶⁴⁰ 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 2 July 2016.

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 2016, 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. The construction works for these measures was scheduled to begin in November 2015 and to be completed in December 2020.⁶⁴¹ The budget for construction of the additional safety features is some JPY130 billion (\$1.1 billion). J-Power applied to the NRA on 16 December 2014 for review of the Ohma reactor.⁶⁴² Ohma is planned to operate with a 100 percent plutonium MOX core.⁶⁴³ 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. Hakodate is challenging both the central government and J-Power in the first such lawsuit in Japan.⁶⁴⁴

Although there remain major obstacles for both reactors, with little public information on the exact status and advancement of construction, even though no planned grid connection date has been communicated, considering that *some* construction work is reportedly ongoing, for the time being, WNISR reintegrates Shimane-3 and Ohma in its listing of reactors under construction.

Pakistan operates three reactors (two Pressurized Water Reactors from China and one Pressurized Heavy Water Reactor from Canada) that have a net capacity of 690 MW and provided 4.3 TWh in 2015, down from 4.58 TWh in 2014;⁶⁴⁵ nuclear power contributed 4.4 percent of the country's electricity in 2015, 0.9 percent below the historic maximum of 5.3 percent in 2012.

In the city of Karachi, construction of the first of two reactor units purchased from China started in August 2015, with Prime Minister Nawaz Sharif presiding over the event.⁶⁴⁶ Reportedly, this is likely to be China's first export of Hualong reactor design.⁶⁴⁷ There has been widespread civil

⁶⁴¹ 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 2 July 2016.

⁶⁴² 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 2 July 2016.

⁶⁴³ 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*, Volume 14, Issue 5, Number 2, 1 March 2016, see <http://apjif.org/2016/05/Burnie.html>, accessed 2 July 2016.

⁶⁴⁴ *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 2 July 2016.

⁶⁴⁵ IAEA, "Nuclear Power Reactors in the World—2016 Edition", see [www-pub.iaea.org/MTCD/Publications/PDF/RDS_2-36_web.pdf](http://www.pub.iaea.org/MTCD/Publications/PDF/RDS_2-36_web.pdf), accessed 17 June 2016.

⁶⁴⁶ Imtiaz Ali, Shahid Ghazali, "PM Nawaz inaugurates K-2 power plant at Kanupp", *Dawn*, Updated 21 August 2015, see <http://www.dawn.com/news/1201662>, accessed 18 June 2016.

⁶⁴⁷ WNN, "Hualong One Joint Venture Officially Launched", 17 March 2016, see <http://www.world-nuclear-news.org/C-Hualong-One-joint-venture-officially-launched-1703164.html>, accessed 18 June 2016.

society opposition to the construction of these reactors next to the crowded city of Karachi, with the environmental impact assessment being a particular target of criticism.⁶⁴⁸

Pakistan has been seeking permission from the Nuclear Suppliers Group (NSG) to import nuclear technology, just as India has been permitted since 2008, but has so far not succeeded. In this effort, it has been aided by China, which has pushed a “criteria-based approach” to membership to the NSG as a way of allowing Pakistan also to be considered for the same.⁶⁴⁹ This is being considered by diplomats at the NSG, but it is not likely to be adopted soon. Pakistan also continues to produce highly enriched uranium and plutonium for nuclear weapons.⁶⁵⁰

On the Korean Peninsula, the **South Korea** (Republic of Korea) operates 25 reactors, one more than by mid-2015. Nuclear power provided a record 157.23 TWh or 31.7 percent of the country’s electricity share in 2015, up from 30.4 percent in 2014, and down from a maximum of 53.3 percent in 1987. Three additional reactors are under construction.

In 2014, five reactors were listed as under construction, of which three were scheduled for startup that year, but none achieved it. Shin-Wolsong-2 was finally connected to the grid in February 2015. Construction began on Shin-Wolsong-2 in 2008 and was completed in 2013, but planned operation was suspended following disclosure of falsified quality-control certificates (see below).⁶⁵¹ In a first for the nuclear program of South Korea, on 12 June 2015, the Ministry of Trade, Industry and Energy announced that it would request the closure of the Kori unit 1 reactor by 18 June 2017, when the reactor will be 40 years old.⁶⁵² Four days later the plant operator, Korea Hydro and Nuclear Power Co (KHNP) part of the Korea Electric Power Corporation (KEPCO) group, announced it would not apply for a life extension and the reactor would be shut down.⁶⁵³ The reactor has been at the center of civic resistance to its continued operation, including from the nearby city of Busan, and is scheduled to end operations in June 2017.⁶⁵⁴

Less than a month after 3/11, the 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.⁶⁵⁵

⁶⁴⁸ *The News International, Pakistan*, “A nuclear Karachi?”, 25 August 2015, see <http://www.thenews.com.pk/print/58443-a-nuclear-karachi>, accessed 18 June 2016.

⁶⁴⁹ Rakesh Sharma, Stephanie Cooke, “NSG Weighs Criteria-Based Approach for Membership”, *NIW*, 2016.

⁶⁵⁰ IPFM, “Global Fissile Material Report 2015—Nuclear Weapon and Fissile Material Stockpiles and production”, Princeton University, December 2015, see fissilematerials.org/library/gfmr15.pdf, accessed 18 June 2016.

⁶⁵¹ WNISR, “South Korea: Shin-Wolsong-2 Grid Connected / Wolsong-1 Lifetime Extension”, 1 March 2015, see <http://www.worldnuclearreport.org/South-Korea-Shin-Wolsong-2-Grid.html>, accessed 18 June 2016.

⁶⁵² *Korea Herald*, “South Korea to shut down oldest nuke reactor: Kori-1 will become the nation’s 1st nuclear reactor to permanently close down”, Updated 13 June 2015, see <http://www.koreaherald.com/view.php?ud=20150612000846>, accessed 18 June 2016.

⁶⁵³ *Yonhap*, “S. Korea to shut down oldest reactor in 2017”, 16 June 2015, see <http://english.yonhapnews.co.kr/business/2015/06/16/0501000000AEN20150616008100320.html>, accessed 18 June 2016.

⁶⁵⁴ NSSC, “The NSSC Launched Safety Examination in Preparation of Permanent Shutdown of Kori Unit 1”, 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 4 July 2016.

⁶⁵⁵ Ki Hak Kim, “Fueling the Sustainable Future”, 6 April 2011.

However, observers saw a “dramatic political shift against nuclear power in the year since Fukushima”.⁶⁵⁶ In 2012, for example, 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 reactor. 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. After his overwhelming re-election in June 2014, Mayor Park is also a prime candidate for the next presidential election in 2018. 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.⁶⁵⁷

In the past three years, the Korean nuclear industry has moved to recover from major equipment falsification scandals and resultant forced shutdown of multiple reactor units.⁶⁵⁸ The disclosures beginning in December 2012 and subsequent investigations by the Nuclear Safety and Security Commission (NSSC), together with the impact of the Fukushima Daiichi accident, severely eroded public support for nuclear power. The ten-year-long falsification of thousands of quality control certificates for equipment installed in KHNP reactors widened in May 2013, when the NSSC, following information from an anonymous whistleblower, confirmed that test reports had been forged and that the test in fact failed under Loss-Of-Coolant-Accident (LOCA) conditions. The NSSC investigation found that safety-related control-command cabling with forged documentation had been installed at four of KHNP’s reactors: Shin-Kori units 1 and 2 and Shin-Wolsong units 1 and 2.⁶⁵⁹ In May 2013, the four reactors were ordered to be shut down as a result of the falsification and, according to the NSCC, their failure to pass the LOCA test.⁶⁶⁰ Shin-Wolsong-2 was authorized for restart on 25 June 2013,⁶⁶¹ while the other three remained shut down for most of 2013 (reflecting the reduced electricity share) and were approved for restart in early January 2014.⁶⁶² Shin-Kori-3 and -4, as well as Shin-Wolsong-2, then all under construction, also had falsified quality-control documents and needed to replace the affected cables.⁶⁶³ 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. Relatively light penalties for falsifying nuclear safety documents or for corrupt revolving-door hiring were

⁶⁵⁶ *NIW*, “South Korea: Growing Nuclear Skepticism”, 23 March 2012.

⁶⁵⁷ For a list of SIEAC Members and background see <http://www.ieac.info/Seoul-International-Energy-Advisory-Council>, accessed 18 June 2016. SIEAC is coordinated by Mycle Schneider.

⁶⁵⁸ KINS, “CFSI (Counterfeit, Fraudulent, Suspect Item) Investigation”, Korean Institute of Nuclear Safety, see <http://www.kins.re.kr/en/ourwork/cfsi.jsp>, accessed 18 June 2016.

⁶⁵⁹ *WNN*, “Reactor restart allays Korean power concerns”, 10 June 2013, see http://www.world-nuclear-news.org/RS-Reactor_restart_allays_Korean_power_concerns-1006134.html, accessed 18 June 2016.

⁶⁶⁰ NSCC, “NSSC Approved The Resumption of Shinkori Unit 1.2 and Shinwolsong Unit 1”, 2 January 2014.

⁶⁶¹ *WNN*, “Another Korean reactor cleared for restart”, *WNA*, 27 June 2013, see http://www.world-nuclear-news.org/RS-Another_Korean_reactor_cleared_for_restart-2706135.html, accessed 18 June 2016.

⁶⁶² *Reuters*, “South Korea cuts future reliance on nuclear power, but new plants likely”, 13 January 2014, see <http://www.reuters.com/article/2014/01/14/us-nuclear-korea-idUSBREA0D06G20140114>, accessed 18 June 2016.

⁶⁶³ NSSC, “NSSC Confirms Fake Test Reports of Safety-Class Control Cables”, 29 May 2013.

strengthened from 1 July 2015—though with a six-month phase-in period, when first offenders will get just a warning.⁶⁶⁴

On 15 January 2016, the Shin Kori-3, located at Gori in the city district of Busan in the south east of the Republic of Korea, was connected to the grid, two years later than planned.⁶⁶⁵ The KHNP owned reactor is the first APR1400 (Advanced Pressurized Reactor) design to begin operation and the nation's 25th commercial reactor. KHNP applied for an operational license for Shin Kori-3 in 2011, with construction completed in 2013. However, the plant was caught up in the safety scandals at that time. In April 2015, the NSSC postponed a decision on granting a license, following notification by General Electric that it would recall valve components installed in Shin Kori-3 and -4. NSSC found that nine valves were installed in both Shin Kori-3 and -4, which did not comply with the technical specifications. The operational license was only granted by the NSSC on 29 October 2015. Shin Kori-4 is planned for operation in 2017. On 23 June 2016, the NSSC approved by majority the construction permits for the AP1400 reactors Shinkori-5 and -6.⁶⁶⁶ Construction is scheduled to commence for unit 5 in September 2016 and one year later for unit 6. Operation is planned for 2021 and 2022 respectively.

On 27 February 2015, the NSSC voted in favor of plant life extension for the 32-year-old Wolsung-1 pressurized heavy water reactor.⁶⁶⁷ Two of the nine commissioners abstained from voting. In two previous meetings, the NSSC had failed to reach agreement on granting approval. 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.⁶⁶⁸ The reactor restarted in June 2015.

Operation of Wolsung-1 has been a major controversy over recent years, in particular following the Fukushima Daiichi accident, with uncertainty as to whether it would have its license extended. Over the 30 years since the reactor started operating in 1983, the nuclear plant was shut down 39 times due to malfunctions.⁶⁶⁹ The main political opposition party 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.⁶⁷⁰

⁶⁶⁴ *NIW*, "South Korea", 3 July 2015.

⁶⁶⁵ WNISR, "Shin Kori-3 Connected to the South Korean Grid", 20 January 2016, see <http://www.worldnuclearreport.org/Shin-Kori-3-Connected-to-the-South-Korean-Grid.html>, accessed 10 July 2016.

⁶⁶⁶ NSSC, "The 57th Meeting Grants Construction Permit for Shinkori Units 5 and 6, 23 June 2016", see http://www.nssc.go.kr/nssc/english/release/list.jsp?mode=view&article_no=36864, accessed 1 July 2016.

⁶⁶⁷ NSSC, "The Commissioners Decided to Approve Continued Operation of Wolsong Unit 1 in the 35th Meeting", 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 18 June 2016.

⁶⁶⁸ *Korea Herald*, "Restart of aging nuclear reactor sparks controversy", 27 February 2015, see <http://www.koreaherald.com/view.php?ud=20150227000740>, accessed 4 June 2015.

⁶⁶⁹ *Ibidem*.

⁶⁷⁰ *Yonhap New Agency*, "(3rd LD) Nuclear watchdog extends operation of 32-year-old reactor", 27 February 2015, see

Despite the government's commitment to continuing nuclear power growth, public and political opposition has continued to challenge nuclear operations. For example, all political candidates in the June 2014 elections in Busan, the closest major city to the Kori nuclear plant, called for the closure of unit 1, which has been plagued with safety issues, and whose license expires in 2017.⁶⁷¹ The operating license of unit 2 expires in 2023.⁶⁷² The Kori plant remains controversial.

The political consequences of the multiple scandals surrounding the nuclear sector led to a government-appointed study group's recommending in October 2013 a reduction in projected nuclear electricity share to 22–29 percent by 2035.⁶⁷³ The head of the study group reported that “the implementation of energy policy doesn't just involve the government now, it's become an increasingly important and extremely sensitive issue for each and every citizen. Our suggestion is to set the direction in the policy for social consent, as there are huge social conflicts.”⁶⁷⁴

In the end, the government's draft energy paper released in December 2013 opted for the higher 29 percent option by 2035, below both the 30 percent achieved in 2012 and the 41 percent long-term goal set in the previous long-term plan of 2008.⁶⁷⁵ In July 2015 the government's released Seventh Basic Long-term Power Development Plan of electricity supply and demand covering the period of 2015 to 2029, with a nuclear generation target of 28.5 percent—based on the operation of ten nuclear reactors.⁶⁷⁶ The nuclear plans are premised on an annual electricity demand growth of 2.2 percent through 2029, when demand increased 0.5 percent in 2014. The Government plan for nuclear expansion was criticized by both civil society groups and political opposition parties. The defeat of the ruling Saenuri party in parliamentary elections in April 2015,⁶⁷⁷ and presidential elections in 2017, there is a prospect that implementation of the energy will prove less than straightforward.

After five years of negotiation, in April 2015, it was announced that the United States and South Korea had reached a provisional agreement for the extension of peaceful nuclear cooperation

<http://english.yonhapnews.co.kr/national/2015/02/27/52/0302000000AEN20150227000453315F.html>, accessed 18 June 2016.

⁶⁷¹ *Shanghai Daily*, “S.Korean activists warn of nuclear disaster from oldest reactor”, 2 June 2014, see http://www.shanghaidaily.com/article/article_xinhua.aspx?id=221967, accessed 18 June 2016.

⁶⁷² *Hankyoreh*, “Smoke at Kori reactor the latest case of danger at a nuclear plant”, 30 May 2015, see http://english.hani.co.kr/arti/english_edition/e_national/693529.html, accessed 18 June 2016.

⁶⁷³ *Bloomberg News* and *Reuters*, “South Korea pours cold water on nuclear fuel”, 13 October 2013, see <http://www.thenational.ae/business/energy/south-korea-pours-cold-water-on-nuclear-fuel>, accessed 18 June 2016.

⁶⁷⁴ *Ibidem*.

⁶⁷⁵ *Reuters*, “South Korea cuts future reliance on nuclear power, but new plants likely”, 13 January 2014, see <http://www.reuters.com/article/2014/01/14/us-nuclear-korea-idUSBREA0D06G20140114>, accessed 5 June 2015.

⁶⁷⁶ *Korea Herald*, “Korea to build two new nuclear reactors by 2029”, 8 June 2015, see <http://www.koreaherald.com/view.php?ud=20150608000946>, accessed 1 July 2016.

⁶⁷⁷ *Yonhap*, “(6th LD) Ruling party fails to win parliamentary majority”, 14 April 2016, see <http://english.yonhapnews.co.kr/national/2016/04/13/2/0301000000AEN20160413005457315F.html>, accessed 1 July 2016.

between the two nations.⁶⁷⁸ The new pact, signed on 25 June 2015,⁶⁷⁹ called the “123 Agreement” after Section 123 of the U.S. Atomic Energy Act (AEA), replaces the existing 1974 agreement, which was due to expire in 2014, but was extended, while negotiations continued. Major obstacles to reaching agreement related to South Korean efforts to secure the right to develop the entire fuel chain, in particular uranium enrichment and spent fuel reprocessing, both excluded from the previous agreement. The agreement, does not include the right of South Korea to indigenous development of enrichment or reprocessing, however, in a major concession, it does give the right to export spent fuel for reprocessing, and specifically to France, under advance programmatic approval.⁶⁸⁰ The return of plutonium Mixed Oxide Fuel (MOX) would require case by case U.S. approval.⁶⁸¹ Such a concession brings the agreement between the two nations on to a level with the U.S. agreement with Japan prior to 1988. The new agreement, entered into force on 25 November 2015.⁶⁸²

Taiwan operates three twin units at Chinshan (also spelled Jinshan), Kuosheng and Maanshan, all owned by Taipower, the state-owned utility monopoly. Only five of the reactors were connected to the grid in 2015 and generated 35.1 TWh, providing 16.3 percent of the country’s electricity (compared with its maximum share of 41 percent in 1988).

The Chinshan-1 reactor failed to operate during the entire year 2015, and has therefore entered 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 Atrium-10 fuel assembly. A safety evaluation report conducted by Taipower and AREVA was posted in June 2015 by the Atomic Energy Council (AEC), which approved the reactor for restart, but lawmakers required the issue to be addressed by the national parliament prior to restart.⁶⁸³ As of 1 July 2016, the unit remains offline.

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. Their construction had been delayed multiple times. According to the Atomic Energy Council, as of the

⁶⁷⁸ *WSJ*, “U.S., South Korea Reach Revised Nuclear Deal The agreement stops short of allowing Seoul to enrich uranium or reprocess spent nuclear fuel”, 22 April 2015, see <http://www.wsj.com/articles/u-s-south-korea-reach-revised-nuclear-deal-1429705290>, accessed 4 June 2015.

⁶⁷⁹ *Korea Herald*, “S. Korea, U.S. formally sign civil nuclear energy cooperation pact”, 16 June 2015, see http://www.koreatimes.co.kr/www/news/nation/2015/06/116_180943.html, accessed 30 June 2015

⁶⁸⁰ Mark Fitzpatrick, “South Korea nuclear cooperation deal not as simple as 123”, International Institute for Strategic Studies (IISS), 23 April 2015, see <https://www.iiss.org/en/politics%20and%20strategy/blogsections/2015-932e/april-ea11/south-korea-nuclear-cooperation-deal-not-as-simple-as-123-a371>, accessed 7 July 2016.

⁶⁸¹ International Panel on Fissile Materials (IPFM), “United States grants advance consents rights to Korea for overseas reprocessing”, 25 June 2015, see http://fissilematerials.org/blog/2015/06/united_states_grants_adva.html, accessed 9 July 2015.

⁶⁸² Paul K. Kerr, Mary Beth D. Nikitin, “Nuclear Cooperation with Other Countries: A Primer”, Congressional Research Service, 3 December 2015 see <https://www.fas.org/sgp/crs/nuke/RS22937.pdf>, accessed 1 July 2016.

⁶⁸³ *NW*, “Chinshan-1 might not restart until after September: lawmakers”, 2 July 2015.

end of March 2014, unit 1 of Lungmen construction was 97.7 percent complete,⁶⁸⁴ while unit 2 was 91 percent complete. The plant is estimated to have cost US\$9–9.9 billion so far.⁶⁸⁵ After multiple delays, rising costs, and large-scale public and political opposition, on 28 April 2014, 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.

As a result of failure to negotiate payment for work completed on the Lungmen plant, in December 2015 Taipower announced that General Electric (GE) had filed for arbitration with the Hong Kong branch of the International Chamber of Commerce (ICC) Court of Arbitration.⁶⁸⁶ No financial details have been disclosed.

The Presidential election victory of Tsai Ing-wen on 12 March 2016 could be 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 accident. 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 last two years 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.

The nuclear policy is to be detailed during 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."⁶⁸⁷ 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.⁶⁸⁸ On 5 June 2016, Premier Lin Chuan stated that the reactors shutdown date would not be extended

⁶⁸⁴ 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 22 May 2016.

⁶⁸⁵ 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 22 May 2016.

⁶⁸⁶ *Taipei Times*, "GE files for arbitration in nuclear payment dispute", 12 December 2015, see <http://www.taipeitimes.com/News/taiwan/archives/2015/12/12/2003634631>, accessed 2 July 2016.

⁶⁸⁷ *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.htm>, accessed 2 July 2016.

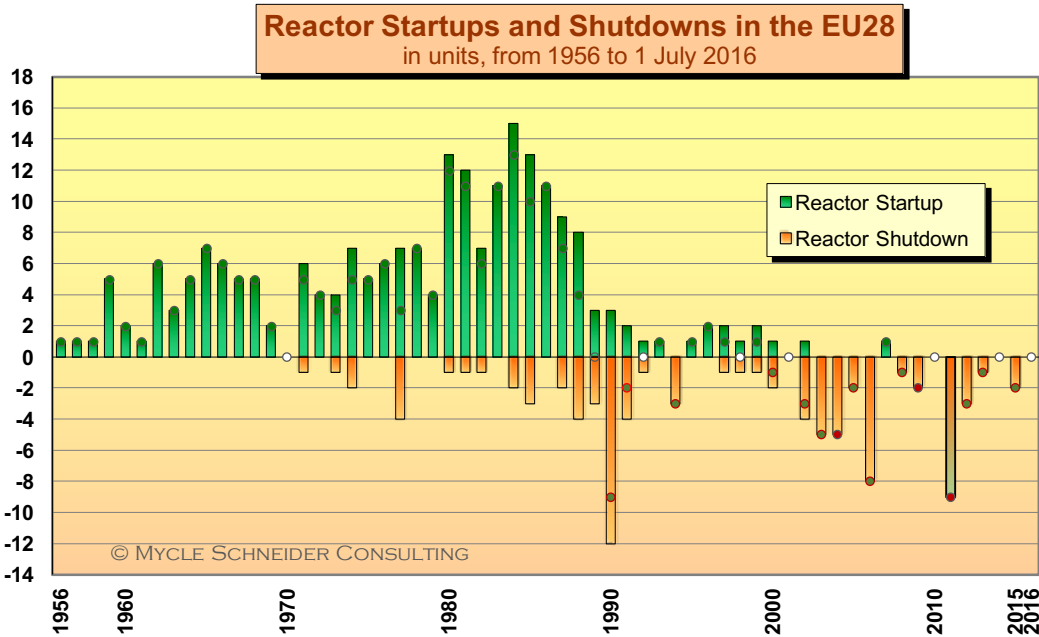
⁶⁸⁸ *Focus Taiwan*, "Economics minister reaffirms goal of nuclear-free Taiwan by 2025", 27 May 2016, see <http://focustaiwan.tw/news/aeco/201605270025.aspx>, accessed 2 July 2016.

beyond December 2018,⁶⁸⁹ 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 shortages⁶⁹⁰. Environmental groups have launched a court case against the potential restart of Chinshan-1, calling it the “most dangerous reactor in the world”.⁶⁹¹

European Union (EU28) and Switzerland

As shown in Figure 44 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).

Figure 44: Nuclear Reactors Startups and Shutdowns in the EU28, 1956–2016



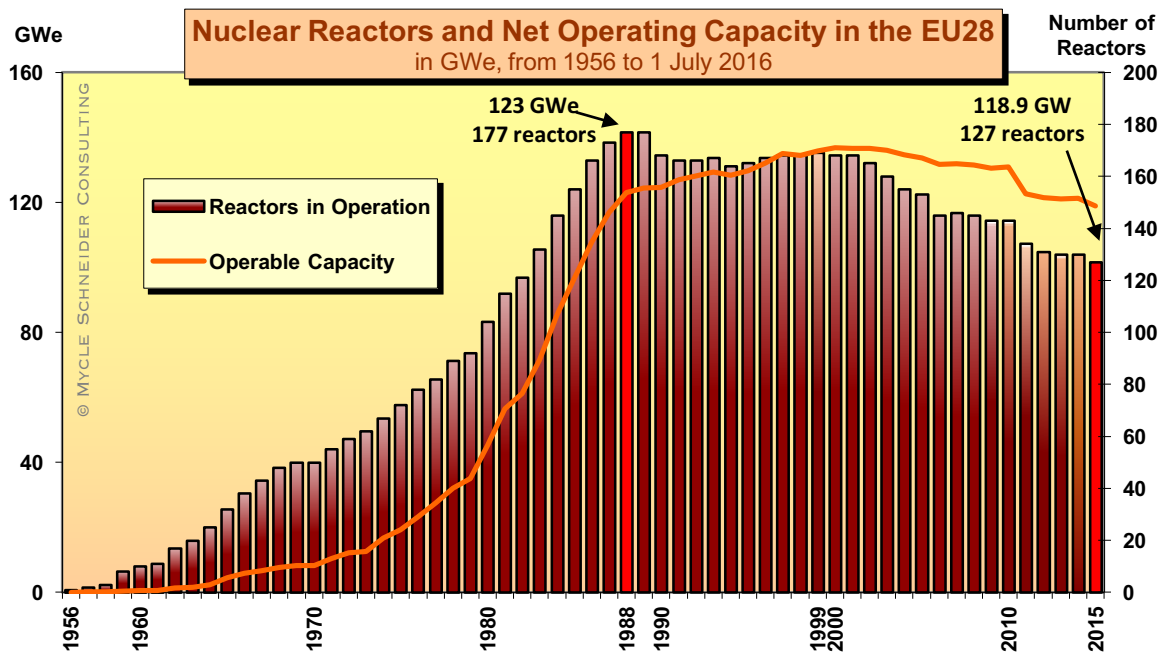
Sources: IAEA-PRIS, MSC, July 2016

The region has not had any significant building activity since the 1990s. Only two reactors were connected to the EU-grid since 2000. Two reactors were closed in 2015, Grafenrheinfeld in Germany and Wylfa-1 in the United Kingdom. Doel-1 in Belgium was shut down in February 2015,

⁶⁸⁹ Focus Taiwan, Premier considers reactivating long-closed nuclear reactor, 5 June 2016, see <http://focustaiwan.tw/news/aip/201606050006.aspx>, accessed 2 July 2016.
⁶⁹⁰ Focus Taiwan, “Restart of reactor a last resort: economics minister”, 6 June 2016, see <http://focustaiwan.tw/news/aeco/201606060019.aspx>, accessed 2 July 2016.
⁶⁹¹ Taipei Times, “Activists file suit over Jinshan reactor”, 31 May 2016, see <http://www.taipeitimes.com/News/taiwan/archives/2016/05/31/2003647555>, accessed 2 July 2016.

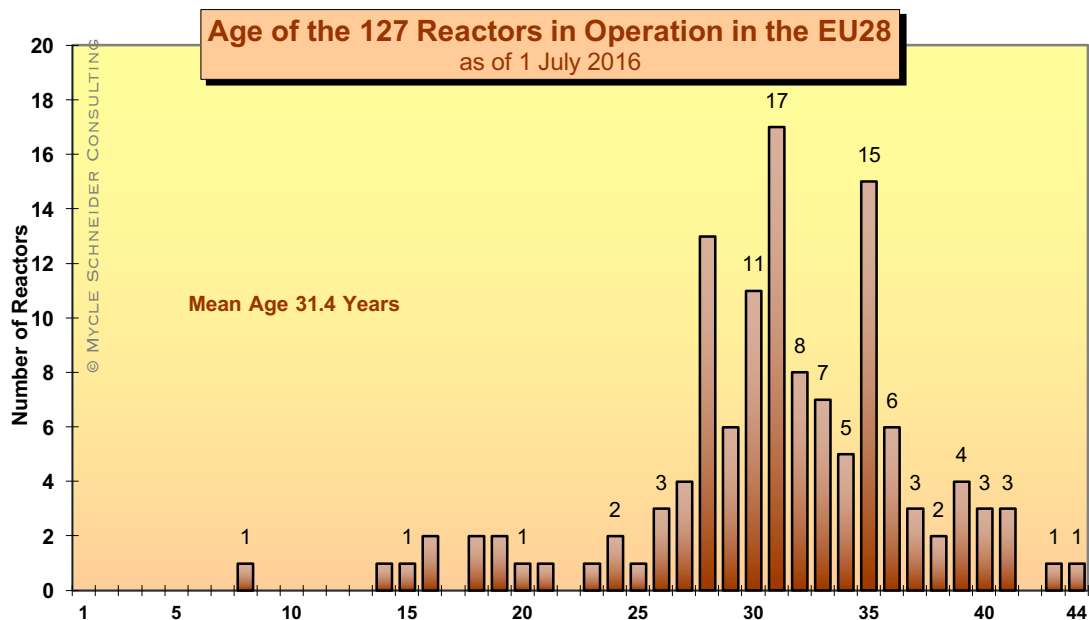
after its license had expired, but in June 2015, the Belgian Parliament voted a 10-year lifetime extension and the reactor was restarted on 30 December 2015.⁶⁹²

Figure 45: Nuclear Reactors and Net Operating Capacity in the EU28, 1956–2016



Sources: IAEA-PRIS, MSC, July 2016

Figure 46: Age Pyramid of the 127 Nuclear Reactors Operated in the EU28



Sources: IAEA-PRIS, MSC, July 2016

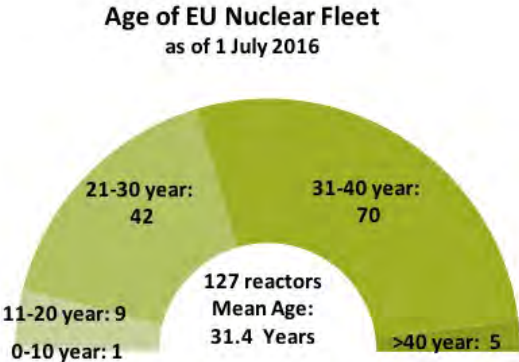
⁶⁹² On 18 June 2015, the Belgian Parliament voted legislation to extend the lifetime of Doel-1 and -2 by ten years. As the Doel-2 license had not yet expired, its operation was not interrupted. See also section on Belgium in Annex 1.

In July 2016, the 28 countries in the enlarged EU operated 127 reactors—about one-third of the world total—16 fewer than before the Fukushima events and 50 less than the historic maximum of 177 units in 1989 (see Figure 45). One reactor, Ringhals-2 in Sweden entered the LTO category, as it has not been generating power since 2014.

The vast majority of the operating facilities, 108 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.

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-2016 stands at 31.4 years (see Figure 46 and Figure 47). The age distribution shows that now 59 percent—75 of 127—of the EU’s operating nuclear reactors have been in operation for over 30 years.

Figure 47: Age Distribution of the EU28 Reactor Fleet



Sources: IAEA-PRIS, MSC, 2016

Western Europe

As of July 2016, 108 nuclear power reactors operated in the EU15, 49 units fewer than in the peak years of 1988/89. Two reactors were shut down in 2015, Wylfa-1 in the U.K. and Grafenrheinfeld in Germany, while Doel-1 was restarted at the end of the year, after its license was renewed (see Focus Belgium). As stated above, Ringhals-2 in Sweden entered the LTO category.

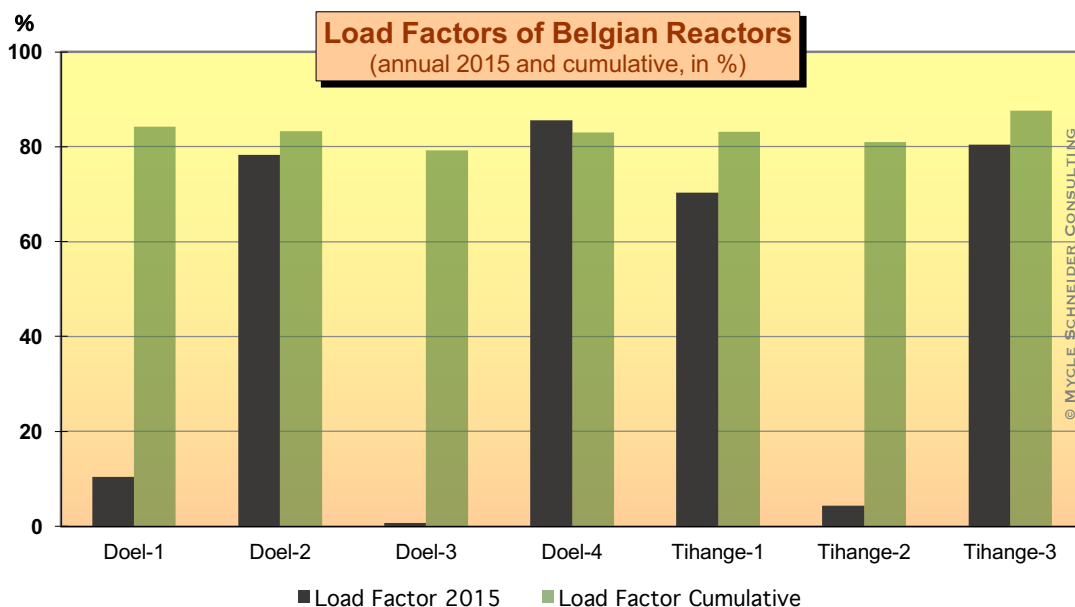
Two reactors are currently under construction in the older member states, one in Finland (Olkiluoto-3) and one in France (Flamanville-3). Both projects are many years behind schedule and billions over budget (details are discussed elsewhere in the report). Apart from the French projects and the Sizewell-B reactor in the U.K. (ordered in 1987), until the reactor project in Finland, no new reactor order had been placed in Western Europe since 1980. Despite numerous deadlines, the “Final Investment Decision” for EDF Energy’s Hinkley Point C project in U.K., as of early July 2016, has still not been taken.

The following section provides a short overview by country (in alphabetical order).

Belgium Focus

Belgium operates seven pressurized-water reactors and, for many years, had the world’s second highest share of nuclear in its power mix, behind France. Due to technical issues described below, it dropped to 47.5 percent in 2014—less than 50 percent for the first time since 1983⁶⁹³—and to 37.5 percent in 2015 (the maximum was 67.2 percent in 1986). The nuclear plants generated 24.8 TWh in 2015, another drop of 22.6 percent over 2014, and almost half of their highest output of 46.7 TWh in 1999. Load factors of individual reactors were obviously particularly low for the two units plagued by pressure vessel issues (see hereunder) and restarts only towards the end of the year, Doel-3 with 0.7 percent and Tihange-2 with 4.4 percent (see Figure 48).

Figure 48: Load Factors of Belgian Nuclear Reactors



Sources: IAEA-PRIS, MSC, 2016

Legally, the decision does not put into question the nuclear phase-out target of 2025: In January 2003, nuclear phase-out legislation required the shutdown of all Belgium’s nuclear plants after 40 years, so based on their start-up dates, plants would be shut down between 2015 and 2025 (see Figure 49). Practically, however, the new shutdown dates mean that five of the seven reactors would go offline in the single year of 2025.

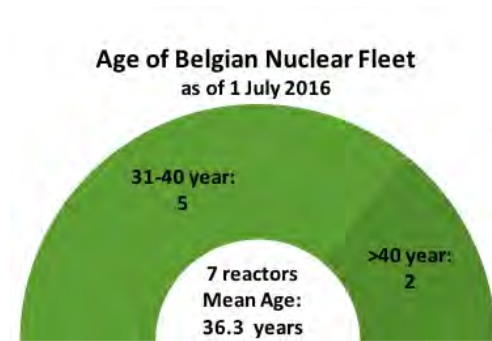
Following Fukushima, the phase-out legislation was left in place even though GDF-Suez (now Engie), that operates all seven PWRs in Belgium through its subsidiary Electrabel, was lobbying to postpone it via an extension of “at least 10 years”.⁶⁹⁴ In December 2013, the phase-out

⁶⁹³ World Bank, quoted in *Perspective Monde*, see <http://perspective.usherbrooke.ca/bilan/servlet/BMTendanceStatPays?langue=fr&codePays=BEL&codeStat=EG.ELC.NUCL.ZS&codeStat2=x>, accessed 25 May 2015.

⁶⁹⁴ Gérard Mestrallet, et al., “Nuclear in Belgium: recent developments”, GDF Suez, 4 November 2011.

legislation was finally amended for the first time,⁶⁹⁵ 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.⁶⁹⁶ The other shutdown dates were confirmed (see Table 16) and the law’s Article 9, which enabled continued operation in case of security-of-supply concerns, was deleted.

Figure 49: Age Distribution of Belgian Nuclear Fleet



Sources: IAEA-PRIS, MSC, 2016

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), asked the operator to carry out a specific test program prior to any restart decision. However, in late January 2013, AIB-Vinçotte, an international quality-control company based in Belgium working on behalf of the FANC, stated that “some uncertainty about the representativity of the test program for the actual reactor pressure vessel shells cannot be excluded”.⁶⁹⁷

An independent assessment concluded that “the restart of the two power plants has to be considered as hazardous”.⁶⁹⁸ However, in May 2013, FANC licensed restart⁶⁹⁹ in spite of serious concerns by several scientists. Then, on 25 March 2014, Electrabel announced the immediate shutdown of the Doel-3 and Tihange-2 reactors, declared as “anticipating planned outages”,

⁶⁹⁵ *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.

⁶⁹⁶ Melchior Wathelet, “Avec la réserve stratégique, Melchior Wathelet finalise l’exécution de son plan”, Energy Minister, 16 December 2013.

⁶⁹⁷ AIB-Vinçotte, “Synthesis Report Doel165”, 28 January 2013.

⁶⁹⁸ Ilse Tweer, “Flawed Reactor Pressure Vessels in Belgian Nuclear Plants Doel-3 and Tihange-2”, Materials Scientist and Consultant, Report commissioned by the Greens/EFA Group in the European Parliament, March 2013, see <http://www.greens-efa.eu/fileadmin/dam/Documents/Studies/Flawed%20Reactor%20Pressure%20Vessels.pdf>, accessed 18 June 2016.

⁶⁹⁹ 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.

respectively over one month and two months ahead of schedule.⁷⁰⁰ The decision was taken after one of the tests “related to the mechanical strength of a sample analogue to the composition of the concerned vessels did not deliver results in line with experts expectations”. FANC issued a statement:

The results of these tests indicate that a mechanical property (fracture toughness) of the material is more strongly influenced by irradiation than experts had expected. Additional testing and research are necessary to interpret and assess these unexpected results.⁷⁰¹

Table 16: Closure Dates for Belgian Nuclear Reactors 2022–2025

Reactor (Net Capacity)	First Grid Connection	End of License (Latest Closure Date)
Doel-1 (433 MW)	1974	10-year lifetime extension to 15 February 2025
Doel-2 (433 MW)	1975	10-year lifetime extension to 1 December 2025
Doel-3 (1006 MW)	1982	1 October 2022
Tihange-2 (1008 MW)	1982	1 February 2023
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

Sources: Belgian Law of 28 June 2015; Electrabel/GDF-Suez, 2014⁷⁰²

Additional inspections have raised the number of identified defects to over 13,000 in the Doel-3 pressure vessel (up to 40 per dm³, up to 18 cm long, down to a depth of 12 cm in the vessel wall) and to over 3,000 at Tihange-2.⁷⁰³ In April 2015, under the auspices of FANC, an International Review Board assessed the results of additional inspections and tests carried out by Electrabel. Some scientists involved in the research on the issue concluded that “meticulous inspections [are] needed, worldwide” (underlined in the original).⁷⁰⁴

⁷⁰⁰ Electrabel/GDF-Suez, “Anticipating planned outages of Doel 3 and Tihange 2 reactors”, 25 March 2014, see http://corporate.engie-electrabel.be/wp-content/uploads/2016/03/anticipation-scheduled-stops-reactors-doel3-tihange2_en.pdf, accessed 18 June 2016.

⁷⁰¹ FANC, “Doel 3 and Tihange 2 still temporally shut down until further notice”, 1 July 2014, see <http://www.fanc.fgov.be/GED/00000000/3600/3657.pdf>, accessed 2 July 2016.

⁷⁰² *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”, 6 July 2015, see http://www.ejustice.just.fgov.be/mopdf/2015/07/06_2.pdf, accessed 2 July 2016; and Electrabel/GDF-Suez, “News from the nuclear plants”, accessed 3 July 2014.

⁷⁰³ 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.

⁷⁰⁴ Walter F. Bogaerts, op.cit.

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, considered by Electrabel “totally safe”.⁷⁰⁵ Tihange-2 restarted on 14 December 2015. Doel-3 will need to permanently pre-heat a large amount (around 1,800 m³) of water for the case of emergency core-cooling water injection, in order to ease the stress of the thermal shock on the pressure vessel.⁷⁰⁶

In January 2016, independent material scientist Ilse Tweer concluded:

Keeping in mind that growth of the flaws in the RPV [Reactor Pressure Vessel] shells during operation cannot be excluded the authorized restart of the two nuclear power plants is not understandable.⁷⁰⁷

In an unprecedented move, on 20 April 2016, Germany's Environment Minister Barbara Hendricks called—in vain—for the provisional shutdown of Doel-3 and Tihange-2 “until open safety questions are cleared up”.⁷⁰⁸ Doel-3 restarted four days later.

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 to 2025.⁷⁰⁹ The law was promulgated on 28 June 2015, and went into effect on 6 July 2015.⁷¹⁰ 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 units⁷¹¹ 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. However, the list of works to be carried out is still under discussion, while the tax has been defined on the basis of the sole operator's estimate of the upgrading cost. The Belgian Conseil d'Etat had considered in an Opinion dated 16 November 2015 that the Electrabel-Government agreement contained indirect compensation insurances that could violate EU law and that in any case, the European Commission would have to be notified beforehand.⁷¹² The law has been amended on 2 June 2016, clarifying the conditions of the relationship between state and operator in the implementation of the legislation.

⁷⁰⁵ 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.

⁷⁰⁶ Chamber of Representatives of Belgium, “Compte Rendu Analytique–Sous-Commission de la Sécurité Nucléaire”, 2 December 2015.

⁷⁰⁷ Ilse Tweer, “Flawed Reactor Pressure Vessels in the Belgian NPPS Doel 3 and Tihange 2—Comments on the FANC Final Evaluation Report 2015”, Materials Scientist and Consultant, Report commissioned by the Greens/EFA Group in the European Parliament, January 2016.

⁷⁰⁸ BMUB, “Reaktorsicherheits-Experten sehen weiteren Untersuchungsbedarf für Tihange 2 und Doel 3—Hendricks: Solange Untersuchung läuft, sollten AKW vorübergehend vom Netz”, German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Press Release, 20 April 2016.

⁷⁰⁹ Marie-Christine Marghem, “Measures which intend to assure the security of supply in Belgium”, Minister of Energy, Environment and Sustainable Development (Belgium), Press Release, 5 March 2015, see <http://www.marghem.belgium.be/en/measures-which-intend-assure-security-supply-belgium>, accessed 2 July 2016.

⁷¹⁰ Moniteur Belge, op.cit.

⁷¹¹ Electrabel, “Sécurité d’approvisionnement et transition énergétique – Accord sur la prolongation de Doel 1 et Doel 2”, Press Release, 1 December 2015.

⁷¹² Chamber of Representatives of Belgium, “Projet de Loi modifiant la loi du 31 Janvier 2003 sur la sortie progressive de l’énergie nucléaire à des fins de production industrielle d’électricité – Avis du Conseil d’Etat”, 9 December 2015.

On 22 December 2015, FANC authorized the lifetime extension and restart of Doel-1 and -2.

Beyond the issues of lifetime extensions and restarts, FANC and his director Jan Bens made some headlines in Belgium over the past year.⁷¹³ An external, interview-based audit of FANC was carried out and the 70-page report leaked to the press in April 2016. The conclusions by the auditors of Whyte Corporate Affairs seriously undermine the credibility of the Belgian Safety Authority, as they identified a “toxic internal climate”, “lack of leadership”, “power struggles” and more.⁷¹⁴

Finland operates four units that supplied a record 22.3 TWh or 33.7 percent of its electricity in 2015 (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.

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 Siemens⁷¹⁵, is building a 1.6 GW EPR at Olkiluoto (OL3) under a fixed-price turn-key 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 and open to third-party investment. 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.⁷¹⁶ Responsibility for those liabilities remains unclear. An attempt by French Economy Minister Emmanuel Macron to accelerate the resolution of the pending international conflict opposing AREVA and TVO ended without apparent progress.

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 notes:

According to an announcement of the OL3 turnkey supplier, the delivery will be delayed from the original schedule according to which the power plant unit should have been in production as of 30 April 2009. In compliance with the supply contract the company is entitled to compensation in case the delay is due to the supplier. Additionally, because of the delay the company has incurred and will

⁷¹³ See for example a series of papers in *Le Soir*, “Prolongation du Nucléaire”, (in French), see <http://www.lesoir.be/tag/prolongation-du-nucleaire?page=3>, accessed 18 June 2016.

⁷¹⁴ *Le Soir*, 25 April 2016, extract quoted by Jean-Marc Nollet, “Un audit sème le doute sur la crédibilité de l’agence nucléaire”, Press Release, 25 April 2016, (in French), see <http://www.nollet.info/actualites/un-audit-same-le-doute-sur-la-credibilite-de-laagence-nucleaire>, accessed 18 June 2016.

⁷¹⁵ Siemens quit the consortium in March 2011 and announced in September 2011 that it was abandoning the nuclear sector entirely.

⁷¹⁶ *Le Monde*, “EDF pose ses conditions au rachat des réacteurs d’Areva”, 19 May 2015, 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.

incur direct and indirect expenses for which the company on the basis of the supply contract has claimed for compensation.⁷¹⁷

The TVO report states: “According to the schedule updated by the Supplier, regular electricity production at OL3 will commence at the end of 2018” and:

In July [2015], TVO and the Supplier, Areva Siemens Consortium, updated their claims in the International Chamber of Commerce (ICC) arbitration proceedings concerning the delay in the OL3 Project. The quantification estimate updated by TVO of its costs and losses is approximately EUR2.6 billion until December 2018. (...) In February 2016, the Supplier updated its claim in the arbitration proceedings concerning the delay in the OL3 Project. The Supplier's monetary claim is now approximately EUR3.52 billion in total.

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\$11.6 billion) for an original “fix price” estimate of “around €3 billion” (US\$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 2015.⁷¹⁸

In May 2015, credit-rating agency Standard & Poor’s downgraded TVO to BBB-, just one notch above “junk”, 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”.⁷¹⁹

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”.⁷²⁰ The decision was ratified by the Finnish Parliament on 1 July 2010. In May 2014, TVO requested a five-year extension on the time allowed to submit the construction license, with a subsequent revision of the estimated startup of the reactor to the “latter half of the 2020’s”.⁷²¹ The Government refused to grant the extension, and in May 2015, TVO announced that it had decided not to apply for a construction license during the validity of the decision-in-principle made in 2010.⁷²²

⁷¹⁷ TVO, “Report of the Board of Directors and Financial Statements 2015”, February 2016.

⁷¹⁸ NW, “Talks with TVO on Olkiluoto-3 ‘positive’ and ‘fast paced,’ Areva CEO says”, 3 March 2016.

⁷¹⁹ S&P, “Finnish Nuclear Power Producer TVO Downgraded T ‘BBB-/A3’; Outlook Negative”, 28 May 2015.

⁷²⁰ TVO, “Construction of a Nuclear Power Plant Unit at Olkiluoto—General Description—OL4”, August 2008.

⁷²¹ TVO, “TVO applies for an extension to submit construction license application of Olkiluoto 4 plant unit”, Press Release, 20 May 2014.

⁷²² 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 25 May 2015.

In parallel, Fortum Power has been planning a similar project, known as Loviisa-3. 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 and to being an EPR or ABWR. Startup was planned for 2020. Bids were received on 31 January 2012 from AREVA and Toshiba.⁷²³ In April 2013, to the general surprise of AREVA and Toshiba, Fennovoima invited Rosatom to direct negotiations over its 1200 MW AES-2006. Fennovoima stated that it will select the plant supplier “during 2013”.⁷²⁴ 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 disclosed⁷²⁵, 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. A construction license application had to be submitted by the end of June 2015⁷²⁶. It was—but without Fennovoima’s being able to demonstrate clearly that it met the requirement of being at least 60 percent owned by EU companies. In August 2015, Fortum announced that it taking a 6.6 percent share in the Pyhäjoki project, bringing the EU-company held shares to 65.1 percent. In September 2015, the Finnish Safety Authority STUK began assessing the project, which it stated would take until the end of 2017. No construction license could be issued prior to that date.⁷²⁷ However, site preparation work and rock blasting reportedly already began in January 2016.⁷²⁸

France Focus

France’s nuclear industry is seen to be a world leader and it is exceptional in many ways. But after four decades of continual public support for nuclear power, the Government under President François Hollande has initiated a significant shift in energy policy. On 17 August 2015, the National Assembly, the French lower house, adopted the Law Relative to the Energy Transition for Green Growth, a comprehensive 98-page document, that stipulates in particular the reduction of the nuclear share in France’s electricity generation mix from three-quarters to half and the capping of the currently installed nuclear capacity of 63.2 GW.⁷²⁹ However, unlike the German or Belgian nuclear phase-out plans, at this point, there are no precise dates for reactor shutdowns and, with the exception of the two oldest French reactors at Fessenheim that are under debate, no other reactor has been singled out. It is the Pluriannual Energy Program that will define the planning framework for the coming years to 2023. A recent draft, suggests not to decide on shutdowns before 2018—the Presidential elections are in 2017—but to rather prepare for lifetime extensions beyond 40 years for a “first batch” of 25 GW, in priority for the units that are

⁷²³ Fennovoima, “Fennovoima received bids for nuclear power plant”, Press Release, 31 January 2012.

⁷²⁴ Rosatom, “Fennovoima invites ROSATOM to direct negotiations”, Press Release, 5 April 2013.

⁷²⁵ Fennovoima, “Rosatom acquired 34% of Fennovoima”, Press Release, 27 March 2014.

⁷²⁶ 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.

⁷²⁷ 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.

⁷²⁸ PIE, “PIE's New Power Plant Project Tracker” February 2016.

⁷²⁹ 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.

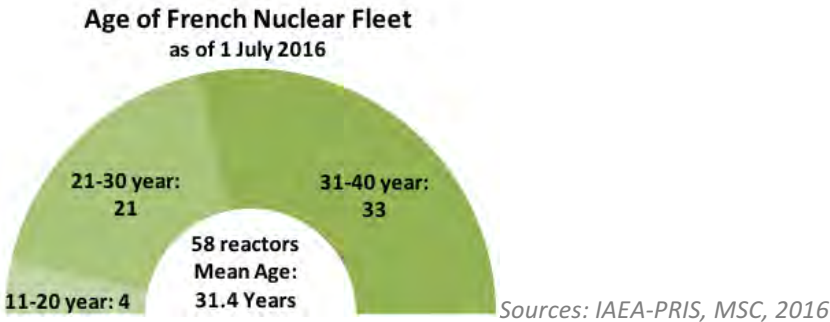
operating with plutonium-uranium (MOX) fuels. However, the French Nuclear Safety Authority has made it very clear that there is no guarantee that lifetime extensions will be granted. A general decision is indeed expected for 2018 and individual decisions starting in 2019. The French government and the nuclear energy establishment seem to be decided to gain time, rather than addressing the issues in the short term.

In 2015, France’s 58 reactors⁷³⁰ produced 419 TWh or 76.3 percent of the country’s electricity. In the peak year 2005, 431.2 TWh of nuclear electricity was produced, providing 78.5 percent of the total.

France is Europe’s largest electricity exporter with 61.7 TWh exported net in 2015,⁷³¹ followed closely by Germany with 60.9 TWh. France has profited in particular from the continued outage of two nuclear reactors in Belgium (see section on Belgium). 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. In other words: “In sum, it is no longer possible to consider borders separately, and indicators previously used for the France- Belgium and France-Germany borders have been replaced by France-CWE region indicators.”⁷³²

This is unfortunate as, contrary to the general perception, France remains a net *importer* of power from Germany, by 9.3 TWh in 2015, a 58 percent increase over 2014, and has been for a number of years, because German wholesale electricity generally undercuts French wholesale prices.⁷³³

Figure 50: Age Distribution of French Nuclear Fleet (by Decade)



The average age of France’s power reactors is 31.4 years in mid-2016 (see Figure 50). In the absence of new reactor commissioning, 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. 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, the shrinking client base, ferocious competitors, and the energy efficiency and renewable energy production targets set at both, the EU and the French

⁷³⁰ All pressurized water reactors, 34 x 900 MW, 20 x 1300 MW, and 4 x 1400 MW.
⁷³¹ Réseau de Transport d’Electricité (RTE), “2015 Annual Electricity Report”, March 2016.
⁷³² Ibidem.
⁷³³ RTE, “2015–Annual Electricity Report”, March 2016.

levels. It now looks plausible that EDF will attempt to extend lifetimes of some units, while others might be closed prior to reaching the 40-year age limit. But there is still no plan.

If the French Government and state controlled utility Électricité de France (EDF) in 2005 opted to proceed with the construction of a new unit, EDF would be motivated not by lack of generating capacity but by the industry's serious problem of maintaining nuclear competence. In December 2007, EDF started construction of Flamanville-3 (FL3). The FL3 site has encountered quality-control problems including basic concrete and welding similar to those at the OL3 project in Finland, which started two-and-a-half years earlier.

The Flamanville-3 project is now at least six years late—one year more since WNISR2015—and now expected to “load fuel and start up” until the fourth trimester 2018.⁷³⁴

In April 2015 the French Nuclear Safety Authority (ASN) revealed that the bottom piece and the lid of the FL3 pressure vessel had “very serious” defects.⁷³⁵ 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”.⁷³⁶ 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 is unclear, which of the four bottoms and lids have been manufactured by Creusot Forge, but likely at least the ones for Taishan-1, while, according to AREVA⁷³⁷ and media reports⁷³⁸, 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 is now 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 late 2015. 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”. In other words, AREVA will sacrifice two vessel heads that had already been manufactured for a never-built reactor project in the U.S. (Calvert Cliffs) and a maybe-built EPR at Hinkley Point in the U.K.

ASN added:

I would however remind you that rejection of the RPV closure head and bottom head further to the investigation cannot be ruled out. This is why I consider it necessary for you to study all alternative

⁷³⁴ EDF, “Rapport Annuel 2015”, February 2016.

⁷³⁵ *Usine Nouvelle*, “Le cri d'alarme de l'ASN sur le nucléaire français”, 20 January 2016, see <http://www.usinenouvelle.com/article/le-cri-d-alarme-de-l-asn-sur-le-nucleaire-francais.N374729>, accessed 11 June 2016.

⁷³⁶ 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 11 June 2016.

⁷³⁷ AREVA, “Taishan 1&2 - China—AREVA Supply Chain”, undated, see <http://www.aveva.com/EN/operations-2404/china-taishan-12.html#tab=tab5>, accessed 2 July 2016.

⁷³⁸ *Factwire*, “Made in China: critical component of Taishan nuclear plant manufactured in Guangzhou”, 27 May 2016, see <https://www.factwire.news/en/Taishan-nuclear-tech.html>, accessed 2 July 2016.

technical scenarios, such as replacement of the RPV bottom head and manufacture of a new closure head.⁷³⁹

At this point, the possibility that all three EPR pressure vessels containing parts forged in France will be rejected by the respective safety authorities and will have to be re-manufactured cannot be excluded. This then raises the question of the viability of the entire projects, since replacing the ends of the huge steel pressure vessels already installed inside the containment building appears not feasible.⁷⁴⁰

ASN inspections at the Creusot Forge plant in January 2016 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.⁷⁴¹

Following the detection of the manufacturing problems with the EPR pressure vessel, ASN requested an audit of the Creusot Forge plant. 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”.⁷⁴² The full list of pieces concerned has not been published. Apparently, about half of the total number has been manufactured for clients outside the nuclear industry.

The official cost estimate for Flamanville-3 stood at €8.5 billion (US\$11.6 billion) as of December 2012.⁷⁴³ In its annual report 2015, EDF updates the figure to €10.5 billion (US\$11.4 billion)⁷⁴⁴, equivalent to the current estimate for the Olkiluoto-3 EPR project in Finland, and 2.6 times the estimate at construction start.

In addition, there have been major difficulties with large investment projects—in particular in Italy, the United Kingdom, and the United States—all of which are taking a toll on the balance sheet and credit rating of France’s major nuclear companies. EDF has a €37.4 billion (US\$40.9 billion) debt, as of the end of 2015, and steadily rising operational costs.

⁷³⁹ ASN, Letter to the President of AREVA, 14 December 2016, (in English).

⁷⁴⁰ For a 4-page briefing on the issue see Yves Marignac, “Fabrication Flaws in the Pressure Vessel of the EPR Flamanville-3”, WISE-Paris, 12 April 2015, see <https://www.dropbox.com/s/njavhw7ihvkbyeu/WISE-Paris-Fabrication-Flaws-EPR-Flamanville-Latest.pdf>, accessed 18 June 2016.

⁷⁴¹ ASN, Letter to the Director General of AREVA NP, 9 May 2016.

⁷⁴² 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 11 June 2016.

⁷⁴³ *Usine Nouvelle*, “EDF a évité le pire sur l’EPR de Flamanville”, 7 December 2012, see <http://www.usinenouvelle.com/article/edf-a-evite-le-pire-sur-l-epr-de-flamanville.N187560>, accessed 18 June 2016.

⁷⁴⁴ EDF, “2015 Management Report—Group Results”, 13 May 2016.

The Hinkley Point C Saga – A French Perspective

WNISR has reported regularly about the developments around EDF Energy's (U.K. subsidiary of EDF Group) project to build two EPRs at Hinkley Point in the U.K.. Since the publication of the previous WNISR in July 2015, the issue made front page news on both sides of the channel. As the Final Investment Decision (FID) has been announced for many months, opposition inside and outside the nuclear establishment in France has reached unprecedented proportions. The traditionally ultra-pro-nuclear French trade unions in particular have come out strongly against the project. A little chronology:

- On 21 October 2015, EDF and China General Nuclear Power Corporation (CGN) sign a “non-binding” Strategic Investment Agreement for a joint investment in the construction of two reactors at Hinkley Point C (HPC) Under the agreement, EDF’s share in HPC should be 66.5 percent and CGN’s should be 33.5 percent.
- On 10 December 2015, the trade union representatives at EDF's Central Works Committee of EDF—unanimously and for the first time—launch an official “economic alert procedure” considering the “seriousness of the situation”. The economic circumstances of the HPC project are amongst the “most preoccupying facts”.⁷⁴⁵
- On 12 November 2015, the EDF employee shareholder association EAS calls on the EDF management “to stop this too risky project (...) that could well endanger EDF's existence”.⁷⁴⁶
- On 20 January 2016, the EDF branch of trade union CFE-CGC underlines that the entire debt of €25 billion (excluding financial costs) associated with HPC “will be fully consolidated in the accounts of EDF” and “solely on the EDF balance sheet”. The union also notes “this amount is higher than the Group's stock market valuation”. Amongst 15 questions to the EDF Board: “How, precisely, will EDF finance this project?”⁷⁴⁷
- On 1 February 2016, trade union FO states in a press release that HPC is a project that “a large majority of EDF staff, mid- and director levels included, consider risky as is, endangering the very existence of EDF”. The CFDT union would share all these concerns.⁷⁴⁸
- On 12 February 2016, CFE-CGC claims that “Macron is all wrong: Hinkley Point might well kill EDF”, and that the alternative of submarine cables to supply the U.K. with power would be ten times cheaper⁷⁴⁹
- On 27 February 2016, the British magazine *The Economist* asks “What's the (Hinkley) point?”, suggesting “it would be best if Britain's French nuclear partner threw in the towel”, stating that

⁷⁴⁵ CCE-EDF S.A, “Droit d'alerte des élus du comité central d'entreprise d'EDF sur la situation économique et sociale préoccupante d'EDF SA”, 10 December 2015.

⁷⁴⁶ EAS, “Hinkley Point ? Rien à gagner, tout à perdre”, 12 November 2015.

⁷⁴⁷ CFE-CGC, “EDF Employee Information – Hinkley Point C Project – 15 Questions to the Board of EDF”, 20 January 2016.

⁷⁴⁸ Force Ouvrière Énergie et Mines, “Projet nucléaire d'EDF au Royaume-Uni : Il est urgent d'attendre !”, 1 February 2016, (in French), see <http://www.force-ouvriere.fr/projet-nucleaire-d-edf-au-royaume-uni-il-est-urgent-d-attendre>, accessed 2 July 2016.

⁷⁴⁹ CFE-CGC, “Macron a tout faux : Hinkley Point risque de tuer EDF”, 12 February 2016, (in French), see www.miroirsocial.com/uploads/documents/CP_CFE_Energies_Hinkley_Point_EDF.pdf, accessed 2 July 2016.

“the projected costs are comparable to those of the Three Gorges [hydro] power station in China, which has about seven times the planned generating capacity—albeit non-nuclear”.⁷⁵⁰

- On 14 March 2016, RBC Capital Markets, one of the world's largest investment bank, declares EDF “uninvestible”. Analyst Martin Young states: “EDF’s management should not risk bringing the company to its knees, and should not proceed with Hinkley Point.”⁷⁵¹

- On 4 May 2016, Thomas Piquemal, EDF's former Chief Financial Officer who quit on 1 March 2016, is giving evidence to the French National Assembly. He leaves no doubt that his decision was intrinsically linked to the HPC project, as he did not wish to “caution a decision susceptible, in case of problems, to lead EDF to a situation close to that of AREVA”, that is technical bankruptcy.⁷⁵²

- On 9 May 2016, the four trade unions represented at the EDF's Central Works Committee (FNME-CGT, CFE-CGC, FCE-CFDT, FO-Energie et Mines) unanimously vote to commission an external expertise on the HPC project.⁷⁵³

- On 12 May 2016, EDF Group announces that the Chairman has engaged in an information and consultation process with the Central Works Committee. The same press statement indicates that The equity commitment contains a contingency margin and could raise the total cost of the project by 15 percent or £2.7 billion (US\$3.9 billion). Construction time would be 115 months (9.6 years) after FID until startup of the first reactor.⁷⁵⁴

- On 23 May 2016, the French Minister of Economics, Emmanuel Macron, writes a letter to U.K. “Members of Parliament” reaffirming: “I have every confidence that a final investment decision can be made rapidly after the end of the consultation of the Central Works Committee (...)”.

- On 24 May 2016, Vincent de Rivaz, CEO of EDF Energy, told the U.K. House of Commons' Energy and Climate Change Committee that “at the end of the consultation, the Works Council will be invited to give its advisory opinion, after which the chairman will present HPC to the board, and the board will make its decision. Last time I was here, I could not give a precise date for that decision, and that remains the case (...)” De Rivaz also told the Committee that the planned startup date 2025 “is certainly the date we would like to be able to confirm at the moment of the FID”. A Committee Member recalled that “Mr de Rivaz originally said that we would be cooking our turkeys with French energy in 2017”. Energy Minister Andrea Leadsom confirmed to the Committee that the government had not given any deadline to EDF for the FID.⁷⁵⁵

Power price increases, which should reach around 30 percent between 2012 and 2017 in order to cover the operating costs—a legal requirement—would prevent EDF from selling at loss and help funding necessary investments. But these tariff increases could also negatively affect EDF by

⁷⁵⁰ *The Economist*, “What's the (Hinkley) point?”, 27 February 2016.

⁷⁵¹ *Bloomberg*, “EDF Seen as 'uninvestable' as France Weighs Financial Help”, 14 March 2016.

⁷⁵² *Le Monde*, “EDF: le 'désespoir' de l'ex-directeur financier”, 5 May 2016.

⁷⁵³ CCE-EDF S.A., “Le CCE EDF SA vote une expertise sur le projet HPC”, 9 May 2016.

⁷⁵⁴ EDF, “Consultation of the EDF Central Works Council (Comité Central d'Entreprise) on the Hinkley Point C Project”, Press Release, 12 May 2016.

⁷⁵⁵ House of Commons, Energy and Climate Change Committee, “Oral evidence; UK New Nuclear: Status Update”, 24 May 2016.

resulting in a loss of market share, as alternative energy suppliers and resources, along with energy efficiency, will thereby become more competitive. With the completion of market liberalization and the end of regulated tariffs for non-residential customers as of 1 January 2016, EDF is rapidly losing big chunks of its client base. The number of non-residential clients that quit EDF exceeded 1.4 million (of a total of 4.9 million) by the end of the first quarter of 2016, an increase of over 45 percent in just three months. Residential clients also continue to move to another provider and their number increased by 157,000 (+4.2 percent) in the first quarter to reach over 3.8 million, about 12 percent of the total. By the end of the first quarter of 2016, EDF's competitors sold 47 percent (up over 15 percentage points in three months) of the power consumed by non-residential clients and 30 percent by households.⁷⁵⁶ The economic impact on EDF's results is yet to come, but it will be harsh. In April 2016, the French government decided to raise AREVA's capital (worth €1.2 billion as of 28 June 2016) by €4 billion by February 2017. The state is to inject €3 billion and €1 billion are sought from other investors.

EDF shares lost up to 89 percent of their peak value in late 2007. Credit-rating agencies had EDF on their watch lists for a couple of years. In May 2016, Moody's downgraded EDF to A2 from A1 with a negative outlook, citing prolonged low power prices and high exposure to market-exposed generation at times of high investment needs for nuclear upgrades, renewables and smart-meter rollout.⁷⁵⁷ Fitch Ratings downgraded EDF to A- (from A) on 7 June 2016 with a stable outlook, reflecting “the impact of the fall in power prices on an undiversified fuel mix, coinciding with the erosion of domestic business volumes”.⁷⁵⁸

The largest nuclear operator in the world is also struggling with a rapidly widening skills gap, as about half of its nuclear staff are eligible for retirement during 2012–17. EDF admitted that it will be faced with an extremely difficult period with a “forecasted doubling of expenditures between 2010 and 2020 (operation and investment)” and with “a peak of departures for retirement coinciding with a peak in activities.”⁷⁵⁹

AREVA, the self-proclaimed “global leader in nuclear energy”⁷⁶⁰, filed losses for the fifth year in a row—€2.8 billion (US\$3 billion) added in 2015—raising its cumulative losses over five years to about €10 billion (US\$10.9 billion). Debt reached €6.3 billion (US\$6.9 billion) for an annual turnover of €4.2 billion (US\$4.6 billion). Attempts to raise significant additional capital have failed in the past. In an ultimate salvation attempt, the French government decided to inject €5 billion into the bankrupt company, by the first quarter of 2017. However, the European Commission is yet to determine whether this injection is in accord with European Union competition rules.

⁷⁵⁶ Commission de Régulation de l'Énergie (CRE), “Marchés de détail – Observatoire des marchés de l'électricité et du gaz naturel—1^{er} trimestre 2016”, 18 June 2016, see <http://www.cre.fr/content/download/14533/172964/version/1/file/Observatoire-detail-T12016.pdf>, accessed 11 June 2016.

⁷⁵⁷ Moody's, “Moody's downgrades EDF's ratings to A2; outlook negative”, 12 May 2016, see https://www.moody.com/research/Moodys-downgrades-EDFs-ratings-to-A2-outlook-negative--PR_348764, accessed 18 June 2016.

⁷⁵⁸ Fitch Ratings, “Fitch Downgrades EdF to 'A-'; Stable Outlook”, 7 June 2016, see <https://www.fitchratings.com/site/pressrelease?id=1005684>, accessed 11 June 2016.

⁷⁵⁹ EDF, “Les grands chantiers du nucléaire civil—Le ‘grand carénage’ du parc nucléaire de production d'EDF”, 14 January 2014.

⁷⁶⁰ AREVA, see homepage www.areva.com, accessed 25 May 2015.

Credit agency Standard & Poor's (S&P) downgraded AREVA to "junk" (BB+) in November 2014⁷⁶¹, and by another two notches to BB-, deep into the speculative domain in March 2015.⁷⁶² Then, in December 2015, following further revelations on the extent of its financial problems, S&P's downgraded the stock further to B+, an investment class described as "highly speculative".⁷⁶³ By the end of June 2016, AREVA's share price had plunged to below €3.30 (US\$3.75) and had lost 95 percent of its peak 2007 value.

Beyond the capital injection, AREVA will have some income, estimated at €2.5 billion (US\$2.8 billion), from the sale of its reactor division AREVA NP to a holding that would be majority-owned by EDF. The scenario is not without risks as the takeover could turn out to exacerbate EDF's own difficulties: the two largely state-owned firms have long been intimately linked by transactions and dependencies, and the French state itself does not have infinite capacity to support long-term losses.

ASN Chief Pierre-Franck Chevet, in his presentation of the Annual Report 2015 to the media, stated that "the nuclear safety and radiation protection situation is of major concern" and requested "a significant increase in its resources".⁷⁶⁴ A call that, as of mid-2016, has not yet been heard. ASN wishes to increase the combined workforce of ASN and its technical backup, the Institute for Radiological Protection and Nuclear Safety (IRSN), by 140 to 150 people, while the government granted only an increase of 30 staff over the coming three years.

Renewable energy development has been slow in France and the biggest share remains large hydropower, but for the first time in 2014, new renewables (other than hydropower) generated more power than fossil fuels. Wind power capacity additions have accelerated with another GW in 2015 after 1.1 GW in 2014, to reach a total of 10.3 GW. Less than 1 GW of solar was installed in 2014 and 2015, and cumulated capacity reached 6.2 GW at the end of 2015. Over the past year, wind covered 4.5 percent of national electricity consumption versus a 1.6 percent contribution of solar photovoltaics.⁷⁶⁵

Germany's post-3/11 decision to shut down immediately eight of its 17 operating reactors and phase out the remaining nine until 2022 triggered comments around the world, from disbelief to certitude of failure. That 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, makes it virtually irreversible under any political constellation. This decision was based on a decades-long debate in German society with nuclear phase-out legislation in place since 2001, that had been amended only in September 2010 in order to allow

⁷⁶¹ S&P, "French Nuclear Group AREVA Downgraded To 'BB+/B' On Expected More Negative Cash Flows; Outlook Negative", 20 November 2014.

⁷⁶² S&P, "French Nuclear Group AREVA Downgraded to 'BB-' on Further Profit Challenges and Cash Burn; Outlook Developing", 5 March 2015.

⁷⁶³ *Reuters*, "S&P says Areva downgraded to 'B+' - RTRS", 22 December 2015, see <http://www.reuters.com/finance/stocks/AREVA.PAp/key-developments/article/3314652>, accessed 26 May 2016.

⁷⁶⁴ ASN, "The nuclear safety and radiation protection situation is of major concern. ASN is remaining vigilant", Press Release, 22 January 2016, see <http://www.french-nuclear-safety.fr/Information/News-releases/The-nuclear-safety-and-radiation-protection-situation-is-of-major-concern>, accessed 11 June 2016.

⁷⁶⁵ RTE, "2015 Annual Electricity Report", March 2016.

for lifetime extensions, before 3/11 triggered the decision to go back to the phase-out plan (see earlier WNISR editions for details).

Nuclear power plants still generated 86.8 TWh net in 2015—46 percent less than in their record year 2001—and provided 14.1 percent of Germany’s gross electricity generation, less than half of the renewables contribution and less than half of the historic maximum of 30.8 percent in 1997.

The nuclear sector was shaken by an inspection-protocol falsification scandal, apparently the first of its kind in Germany, when it came to light that three employees of a subcontractor company of operator EnBW had, in at least nine instances in late 2015, faked documentation for inspections of incident monitoring equipment at Philippsburg unit 2 that had not been carried out. In 15 further cases, dating irregularities were identified. The Environment Ministry of Baden-Württemberg, the nuclear safety authority in charge, ordered to keep the plant down until a thorough investigation had been carried out and procedures changed for such incidents not to occur again.⁷⁶⁶ The annual inspection period was extended to nearly two months until 1 June 2016, when the reactor came back online.

Germany power exports increased by 71.5 percent to a record 60.9 TWh net in 2015⁷⁶⁷, that is about 10 percent of the German electricity generation and just below the French power trade balance. The main driver for exports are bulk power prices, which were the second lowest in Europe behind Scandinavia. Nuclear operators in Germany, the traditional virtually integrated utilities, are struggling with low prices as their counterparts in other countries (for details on share-price developments and credit-rating see the Nuclear Finances Chapter). E.ON lost €6.4 billion and 36 percent of its market value in 2015, but started in-depth restructuring and reduced its debt by €5.7 billion (17 percent).⁷⁶⁸ RWE made a profit of €1.1 billion in a difficult market environment and reduced its debt load by almost 19 percent to €25.1 billion, but recorded dramatically reduced free cash flow (by 81 percent) and restrained from paying any dividends. Consequently, RWE shares lost 54 percent of their value over the year.⁷⁶⁹ EnBW filed a positive 2015 result, significantly supported by a boost of over 50 percent of renewable power sales. Net debt decreased by 15.6 percent to €6.7 billion. The EnBW strategy focuses clearly on the continued Solar photovoltaic systems cumulate about 40 GW installed capacity, which generated 38.4 TWh in 2015. Total installed wind capacity is now about 45 GW. Onshore wind turbines increased generation in an excellent wind-year by 42 percent to reach 79.3 TWh and offshore wind power generation took off, supplying 8.7 TWh that is six times more than in 2014.⁷⁷⁰

The use of renewables in the primary energy mix also continues to grow. While the consumption of all fossil fuels—with the exception of natural gas, which increased by 5 percent—declined, renewables contribution increased by almost 10 percent and contributes now 12.5 percent to the

⁷⁶⁶ Ministerium für Umwelt, Klima und Energiewirtschaft Baden Württemberg, “Vorgetäuschte Sicherheitsprüfungen im Kernkraftwerk Philippsburg 2 (KKP2)”, 27 May 2016, (in German), see <http://um.baden-wuerttemberg.de/de/umwelt-natur/kernenergie-und-radioaktivitaet/aktuelle-informationen/aktuelle-meldungen/vorgetaueschte-sicherheitspruefungen-kkp-2/>, accessed 13 June 2016.

⁷⁶⁷ Agora, “Die Energiewende im Stromsector: Stand der Dinge 2015”, 7 January 2016.

⁷⁶⁸ E.ON, “2015 Annual Report”, March 2016, see www.eon.com/content/dam/eon-com/ueber-uns/publications/EON_Annual_Report_2015_EN.pdf, accessed 2 July 2016.

⁷⁶⁹ RWE, “Annual Report 2015”, March 2016, see www.eon.com/content/dam/eon-com/ueber-uns/publications/EON_Annual_Report_2015_EN.pdf, accessed 2 July 2016.

⁷⁷⁰ Energibilanzen AG, “Energy Consumption in Germany 2015”, April 2015.

primary energy mix, more than lignite and about the same level as hard coal with 12.7 percent. Biomass contributes with 57 percent by far the largest portion to the renewables share, followed by wind with 19 percent and solar with about 10 percent.⁷⁷¹ Increase of the renewable capacity base that increased from 19.1 percent to 23.6 percent in 2015.⁷⁷² 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 €2.1 billion in spite of increasing sales.

Renewables were again the largest contributor to the power mix and supplied 30.1 percent of gross national electricity consumption—more than lignite with 23.8 percent, hard coal 18.1 percent, and natural gas 9.1 percent. While the contribution from all fossil fuel sources and nuclear energy declined, renewables increased by 20.5 percent to 195.9 TWh.

On 6 June 2011, the Government passed far-reaching energy transition legislation that passed the Bundestag on 31 July 2011 almost by consensus and came into force on 6 August 2011.

The seven-part new laws addressed many aspects of energy consumption and production. Key elements included:

- Nuclear operating licenses will expire once the production credit is used up and at the latest according to Table 17. This meant that the eight units that had been shut down after 3/11 lost their operating license with the coming into force of the legislation.
- The production credit can be transferred from older to newer plants.

In addition to these decisions, the German Government decided on 12 June 2014 to rule out for the future any loan guarantees for the export of nuclear facilities, new or existing.

On 27 June 2015, six months earlier than required by law, E.ON shut down the Grafenrheinfeld reactor. Refueling turned out uneconomic for the remaining license period.⁷⁷³

Germany also made notable progress in energy efficiency, and gross electricity consumption in 2014 was the lowest in 15 years. While the mild winter 2014-15 softened energy consumption in all European countries, the temperature sensitivity in France,⁷⁷⁴ for example, was 4.5 times higher than in Germany. In 2014, Germany's fossil-fueled power generation reached a 35-year low⁷⁷⁵,

⁷⁷¹ Ibidem.

⁷⁷² EnBW, "EnBW remains on course despite difficult conditions - renewable energies experience large boost in earning", Press Release, 21 March 2016, see https://www.enbw.com/company/press/press-releases/press-release-details_127552.html, accessed 13 June 2016.

⁷⁷³ E.ON, "Sicher bis zum letzten Tag: Nach 33 Jahren erfolgreichem Betrieb stellt das Kernkraftwerk Grafenrheinfeld die Stromproduktion ein", 28 June 2015, (in German), see <http://www.eon.com/de/presse/pressemitteilungen/pressemitteilungen/2015/6/28/sicher-bis-zum-letzten-tag-nach-33-jahren-erfolgreichem-betrieb-stellt-das-kernkraftwerk-grafenrheinfeld-die-stromproduktion-ein.html>, accessed 18 June 2016.

⁷⁷⁴ France has a high level of electric space heating in the housing sector, causing the highest temperature sensitivity in Europe. When the thermometer drops 1°C in winter, the capacity need increases by 2.4 GW. See RTE, "2014 Annual Electricity Report", 29 January 2015.

⁷⁷⁵ *Renewables International*, "Plummeting demand, renewables slightly up and fossil power generation at a 35 year low", 22 December 2014, see <http://www.renewablesinternational.net/plummeting-demand-renewables-slightly-up-and-fossil-power-generation-at-a-35-year-low/150/407/84355/>, accessed 18 June 2016.

and coal-fired generation fell back to the 2010–11 level despite the record power exports.⁷⁷⁶ In 2015, the trend persisted: while power generation increased by 3.8 percent—entirely covered by renewables—fossil fuel consumption in the power sector continued to decline for all sources—lignite, hard coal, natural gas and oil—while electricity exports soared.

Table 17: 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 ⁷⁷⁷	1976	
Isar-1 (BWR, 878 MW)	E.ON	1977	
Krümmel (BWR, 1346 MW)	KKW Krümmel ⁷⁷⁸	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 ⁷⁷⁹	1984	31 December 2017
Philippsburg-2 (PWR, 1402 MW)	EnBW	1984	31 December 2019
Brokdorf (PWR, 1410 MW)	E.ON/Vattenfall ⁷⁸⁰	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 ⁷⁸¹	1988	
Neckarwestheim-2 (PWR, 1310 MW)	EnBW	1989	

Notes: PWR=Pressurized Water Reactor; BWR=Boiling Water Reactor; RWE= Rheinisch-Westfälisches Elektrizitätswerk

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

⁷⁷⁶ Craig Morris, “Coal power down, renewables up in Germany”, *Renewables International*, 2 July 2015, see <http://www.renewablesinternational.net/coal-power-down-renewables-up-in-germany/150/537/88583/>, accessed 3 July 2015.

⁷⁷⁷ Vattenfall 66,67%, E.ON 33,33%.

⁷⁷⁸ Vattenfall 50%, E.ON 50%.

⁷⁷⁹ RWE 75%, E.ON 25%.

⁷⁸⁰ E.ON 80%, Vattenfall 20%.

⁷⁸¹ RWE 87,5%, E.ON 12,5%.

The **Netherlands** operates a single, 43-year-old 480 MW PWR that provided 3.9 TWh or 3.7 percent of the country's power in 2015, down from a maximum of 6.2 percent in 1986.⁷⁸² In June 2006, the operator and the Government reached an agreement to allow operation of the reactor until 2033.⁷⁸³ Greenpeace Netherlands has voiced concerns about the safety of Borssele, in particular since a near-by coal power station was shut down in late 2015 and power supply would lack redundancy. "If the power on the grid is unavailable for some reason, all power must come from there [the emergency diesel generators]", Joerien de Lege of Greenpeace stated.⁷⁸⁴

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".⁷⁸⁵ 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 2015 a 29 percent drop in equity value of its EPZ holding and practically a wipe-out of its income (-95 percent) compared to 2013.⁷⁸⁶ Dutch utility Delta that holds the majority 70 percent of EPZ is losing money and is undergoing fundamental restructuring.⁷⁸⁷

In June 2014, EPZ started the use of 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 is to consume all of the plutonium that is separated in as much as 40 percent MOX in the core.⁷⁸⁸

The Netherlands illustrates the significance of the European power market for the operational mode of national electricity generating capacities. The dramatic drop in wholesale power prices in Germany due to the rise in renewables, combined with low coal and relatively high natural gas prices, has led German utilities to shut down their gas-fired power plants in the Netherlands and import power from Germany. The Netherlands imported 16 TWh net from Germany in 2015.⁷⁸⁹

Spain operates seven reactors. Nuclear plants provided 54.8 TWh or 20.3 percent of the country's electricity in 2015 (with a maximum of 38.4 percent in 1989). Beyond the de-facto moratorium that has been in place for decades, the previous Premier Jose Luis Zapatero

⁷⁸² BP, "Statistical Review of World Energy", June 2014.

⁷⁸³ WNA, "Nuclear Power in the Netherlands", Updated 27 November 2014, see www.world-nuclear.org/info/inf107.html, accessed 2 June 2013.

⁷⁸⁴ *NLTimes*, "Greenpeace concerned about Borssele nuclear plant", 18 May 2016, see <http://www.nltimes.nl/2016/05/18/greenpeace-concerned-about-borssele-nuclear-plant-safety/>, accessed 2 July 2016.

⁷⁸⁵ DELTA, "DELTA puts off decision for a few years, no second nuclear plant at Borssele for the time being", Press Release, 23 January 2012.

⁷⁸⁶ RWE, "Annual Report 2015", March 2016.

⁷⁸⁷ Delta, "Annual Report 2015", 2016.

⁷⁸⁸ *NEI*, "Borssele moves to MOX", 11 March 2015, see www.neimagazine.com/features/featureborssele-moves-to-mox-4530062/, accessed 18 June 2016.

⁷⁸⁹ Agora Energiewende, "Die Energiewende im Stromsektor: Stand der Dinge 2015", 7 January 2016, (in German) see https://www.agora-energiewende.de/fileadmin/Projekte/2016/Jahresauswertung_2016/Agora_Jahresauswertung_2015_web.pdf, accessed 2 July 2016.

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 has stated that “there will be no new nuclear plants”.⁷⁹⁰ As of mid-June 2016, in the absence of an established new government, there is no clear visibility of national energy policy in Spain.

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.⁷⁹¹ 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 2016.⁷⁹² In February 2011, 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.⁷⁹³ Nevertheless, on 16 December 2012, Garoña was shut down permanently. The operator Nuclenor had calculated that further operation of the 446 MW plant would not be economic. The Cabinet of the Government elected in November 2011 approved in February 2014 a Royal Decree that would enable any recently shut reactors, in this case Garoña, to re-apply for their operating reactors within the next 12 months. In May 2014, Nuclenor applied for a new license to operate until 2031.⁷⁹⁴ However, there is still no official time schedule for restart. The Spanish parliament, with the support of most of the represented parties, including PSOE and Podemos, passed a motion against Garoña restart.⁷⁹⁵ Eleven mayors of towns in the vicinity of the plant have protested against the proposed restart and called for the closure of the unit to be confirmed.⁷⁹⁶

More recently, opposition has also been voiced in neighboring Portugal against the continued operation of the two aging 35- and 33-year-old reactors at Almaraz. According to two Members of the European Parliament (MEP), in a written question to the European Commission, on 29 April 2016, the Portuguese Parliament adopted a resolution “recommending that the government take all the necessary initiatives vis-à-vis the Spanish State and European institutions with the aim of ensuring that the Almaraz power plant is closed down”.⁷⁹⁷ The Portuguese

⁷⁹⁰ Reuters, “Spain Insists on Energy Saving, Not Nuclear Plants”, 21 January 2009.

⁷⁹¹ IEA, “Energy Policies of IEA Countries—Spain 2015 Review”, 2015.

⁷⁹² 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 2 July 2016.

⁷⁹³ 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 2 July 2016.

⁷⁹⁴ Nuclenor, “Nuclenor submits application to renew the operating licence of the plant Garoña”, Press Release, 27 May 2014.

⁷⁹⁵ Spanish News Today, “Greenpeace activists protest at Burgos nuclear power plant reopening plans”, 17 February 2016, see http://spanishnewstoday.com/greenpeace-activists-protest-at-burgos-nuclear-power-plant-reopening-plans_62450-a.html, accessed 2 July 2016.

⁷⁹⁶ EITB, “Mayors urge EU to monitor the possible re-opening of Garoña”, 17 June 2014.

⁷⁹⁷ Ana Gomes (S&D), Marisa Matias (GUE/NGL), “Subject: Almaraz nuclear power plant”, Parliamentary Questions, Question for written answer to the Commission, Rule 130, European Parliament, 12 May 2016, Updated 24 May 2016, see <http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+WQ+E-2016-003944+0+DOC+XML+V0//EN>, accessed 2 July 2016.

Environment Protection Agency Quercus has joined the calls for an Almaraz shutdown, as it constitutes “a potential danger to the border area”.⁷⁹⁸

Sweden operates eight reactors that provided 54.5 TWh—a 12.5 percent plunge over the previous year—or 34.3 percent of the country’s electricity in 2015, 7.2 percentage points down from 2014 and 18 percent points down from a maximum of 52.4 percent in 1996. Ringhals-2 did not generate any power in 2015 and entered the LTO category. Hydro power was the largest electricity source in 2015, providing 47 percent. Wind power generated a record 16.6 TWh—almost 45 percent more than in 2014—and contributed 10 percent to the national electricity production.

Sweden is a large power exporter. In 2015, net exports grew to historic maximum of 22.6 TWh or represented 17 percent of the electricity consumed in the country or 41.5 percent of the nuclear generation.⁷⁹⁹

Sweden decided in a 1980 referendum to phase out nuclear power by 2010. The referendum took place at a time when only six out of a planned 12 reactors were operating, with the other six still under construction. It was therefore effectively a “program limitation” rather than a “phase-out” referendum. 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.

On 5 February 2009, the parties of Sweden’s conservative coalition government signed an agreement on energy and climate policy that proposed ambitious renewable energy and energy efficiency targets and called for the scrapping of the Nuclear Phase-Out Act. In June 2010, the parliament voted by a tight margin (174–172) to abandon the phase-out legislation.⁸⁰⁰ 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 current ten. In January 2014, the state utility Vattenfall started a “decade-long public consultation” on the construction of new nuclear power plants.⁸⁰¹ The latest “traditional Swedish compromise”, according to Energy Minister Ibrahim Baylan⁸⁰², 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

⁷⁹⁸ *Portugal News Online*, “Portugal joins calls to shut down Almaraz nuclear power plant”, 28 April 2016, see <http://www.theportugalnews.com/news/portugal-joins-calls-to-shut-down-almazar-nuclear-power-plant/38075>, accessed 15 June 2016.

⁷⁹⁹ Swedish Energy Agency, “2015 var ett år med stor elproduktion och rekordstor export av el”, 11 February 2016, (in Swedish), see <http://www.energimyndigheten.se/nyhetsarkiv/2016/2015-var-ett-ar-med-stor-elproduktion-och-rekordstor-export-av-el/>, accessed 15 June 2016.

⁸⁰⁰ *NEI*, “Swedish Government Overturns Nuclear Ban”, 21 June 2010.

⁸⁰¹ WNA, “Nuclear Power in Sweden”, Updated April 2015, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Sweden/>, accessed 29 May 2015.

⁸⁰² *Financial Times*, “Boost to nuclear energy as Sweden agrees to build more reactors”, 10 June 2016, see <https://next.ft.com/content/b44e3214-2f13-11e6-bf8d-26294ad519fc>, accessed 2 July 2016.

nuclear energy, in the form of direct or indirect subsidies, can not be counted upon”.⁸⁰³ However, it removes the capacity tax on nuclear power within two years. Vattenfall's CEO Magnus Hall commented: “The abolishment of the nuclear capacity tax is an important precondition for us to be able to consider the investments needed to secure the long-term operation of our nuclear reactors from the 1980s”, but added: “Even with the abolishment of the capacity tax, profitability will be a challenge.”⁸⁰⁴ In the weeks prior to the energy compromise, Vattenfall had “threatened” that all remaining nine reactors would be closed in the early 2020s if the capacity tax was not removed.⁸⁰⁵

Vattenfall envisaged extending lifetimes of five of its seven units at Forsmark and Ringhals to 60 years. The previous objective for Ringhals-1 and -2 was a 50-year lifetime.⁸⁰⁶ However, in April 2015, Vattenfall decided “to change direction for operational lifetimes of Ringhals-1 and -2”⁸⁰⁷ 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 (Ringhals-3 and 4, Forsmark-1 to -3), the previously planned “at least 60 years of operational lifetime, until the beginning of 2040s, remains”. Following the energy agreement, 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.⁸⁰⁸

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, a 38 percent capacity increase was under way, but has been “indefinitely postponed” in June 2015.⁸⁰⁹ In March 2015, OKG had estimated that the modernization will be completed “before the turn of the year”, adding that “this is clearly a miscalculation compared with the original time estimate for these works, which were started in June 2013”.⁸¹⁰ Vattenfall had cancelled its planned 14 percent uprate for Forsmark-3 in November 2014, stating that the “profitability calculation for the power increase at Forsmark-3 has deteriorated since the issue was last discussed by the board about a year ago”.⁸¹¹ Indeed, in

⁸⁰³ Swedish Nuclear Society/Analysgruppen, “The Swedish energy policy agreement of 10 June 2016”, unofficial translation, undated.

⁸⁰⁴ WNN, “Sweden abolishes nuclear tax”, 10 June 2016, see <http://www.world-nuclear-news.org/NP-Sweden-abolishes-nuclear-tax-1006169.html>, accessed 15 June 2016.

⁸⁰⁵ *PiE*, “Sweden nuclear exit ‘in five years’”, 23 May 2016.

⁸⁰⁶ Vattenfall, “Vattenfall plans to provide nuclear power for up to 60 years”, Press Release, 22 May 2013, see <https://corporate.vattenfall.com/press-and-media/press-releases/press-releases-import/vattenfall-plans-to-provide-nuclear-power-for-up-to-60-years/>, accessed 18 June 2016.

⁸⁰⁷ Vattenfall, “Vattenfall changes direction for operational lifetimes of Ringhals 1 and 2”, Press Release, 28 April 2016, see <http://corporate.vattenfall.com/news-and-media/press-releases/2015/vattenfall-changes-direction-for-operational-lifetimes-of-ringhals-1-and-2/>, accessed 18 June 2016.

⁸⁰⁸ 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 18 June 2016.

⁸⁰⁹ 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.

⁸¹⁰ OKG, “Total safety modernisation of Oskarshamn 2 completed before the turn of the year”, 13 March 2015, see <http://www.okg.se/en/Media/Archive-2015/Total-safety-modernisation-of-Oskarshamn-2-completed-before-the-turn-of-the-year/>, accessed 18 June 2016.

⁸¹¹ 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 2 July 2016.

June 2015, E.ON, the majority owner of Oskarshamn-2, said it wanted to shut down the unit because it was unprofitable to operate, even though minority owner Fortum disagreed.⁸¹² Oskarshamn-1 is now scheduled to go offline as early as 2017.

In 2015, the **United Kingdom** operated 16 reactors, which provided 63.9 TWh or 18.9 percent of the country's electricity, down from a maximum of 26.9 percent in 1997. The U.K. nuclear power plant operators EDF Energy and Magnox Ltd. do not transmit load factor data to *Nuclear Engineering International (NEI)*. Data published in the IAEA-PRIS database indicate that the average load factor for the U.K. reactors in 2015 was 76.3 percent⁸¹³, up from 69.4 percent in 2014, but still well below its European counterparts.

The 11 first-generation Magnox plants, nine with twin reactors and two with four reactors, had all been retired by the start of 2015, except for Wylfa-1, which was closed at the end of 2015. 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 life of all the AGRs, and announced in January 2015 that it planned to seek a 5-year extension to 2024 for its Heysham-1 and Hartlepool plants and a 10-year extension to 2030 for its Heysham-2 and Torness plants.⁸¹⁴ The newest plant, Sizewell-B, is the only PWR in the U.K. and was completed in 1995.

In 2006, the Labour Government of Tony Blair started to organize the framework of a new-build program. In July 2011, the Government released the National Policy Statement (NPS) for Nuclear Power Generation.⁸¹⁵ 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.⁸¹⁶ Northern Ireland and Scotland⁸¹⁷ are not included.

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. Government⁸¹⁸ announced updates to the October 2013 provisional agreement of commercial terms of the deal

⁸¹² WNA, "Nuclear power in Sweden", Updated 17 June 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Sweden/>, accessed 2 July 2016.

⁸¹³ The IAEA calculates its load factors on the current rather than the design rating of the plant. Most of the U.K. reactors are unable to operate at design rating and actual capacity is 10 percent below design capacity. Calculating load factor on the basis of design rating, as would be more appropriate, would reduce the average to about 70 percent.

⁸¹⁴ 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 18 June 2016.

⁸¹⁵ DECC, "National Policy Statement for Nuclear Power Generation", July 2011.

⁸¹⁶ Bradwell, Hartlepool, Heysham, Hinkley Point, Oldbury, Sizewell, Sellafield, and Wylfa.

⁸¹⁷ 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.

⁸¹⁸ Department of Energy and Climate Change, "Hinkley Point C to power six million UK homes", 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.

for the £16 billion (US\$30 billion) overnight cost of construction of Hinkley C.⁸¹⁹ Since then, EDF has repeatedly announced its intention to make a Final Investment Decision but by mid-2016, no such decision had been taken, nor is one expected before September 2016. 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 between £89.5 and £92.5/MWh (US\$152.6–157.7/MWh), with annual increases linked to the retail price index. The completion date was put back from 2023 to 2025 with first concrete expected in 2019. 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 EDF claimed it expected to finance its part of the finance from equity (own funds), suggesting it would be “more efficient”.⁸²⁰ EDF announced in November 2015 its intention to sell non-core assets worth up to €10 billion to help finance Hinkley but by May 2016, no progress had been made with these sales.⁸²¹ By May 2016, it was not clear, whether this was a choice or whether it was forced on it by conditions imposed by the U.K. government it could not meet. The EDF CEO, Bernard Levy, wrote to EDF employees in March 2016 saying EDF would not go ahead with Hinkley “unless it gets more financial support from the French state.”⁸²² The type of financial support required was not specified, leaving the option that French loan guarantees were sought open.

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 and CNNC (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 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.⁸²³

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, Hualong One (or HPR-1000) at this site.⁸²⁴ It expects to submit the design to the U.K.’s Office for Nuclear Regulation (ONR) in 2016 for review under

⁸¹⁹ The 2013 and 2015 figures are all in 2012 money unless otherwise specified.

⁸²⁰ *The Telegraph*, “New nuclear plant at Hinkley Point to begin construction ‘within weeks’”, 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 2 July 2016.

⁸²¹ *Financial Times*, “EDF looks to sell €10bn of assets to boost balance sheet”, see <http://www.ft.com/cms/s/0/fcd6a462-7578-11e5-a95a-27d368e1ddf7.html>, accessed 4 July 2016.

⁸²² *Reuters*, “UPDATE 2-EDF says no new Hinkley Point reactors without more French state help”, 11 March 2016, see <http://af.reuters.com/article/energyOilNews/idAFL5N16J4TT>, accessed 18 June 2016.

⁸²³ *The Times*, “Chinese give Hinkley Point nuclear project a boost”, 9 May 2016.

⁸²⁴ CGN, “Agreements in place for construction of Hinkley Point C nuclear power station”, Press Release, 21 October 2016, see <http://en.cgnpc.com.cn/n1017152/n1017227/c1141640/content.html>, accessed 18 June 2016.

the Generic Design Assessment program, a process expected to take about 4 years.⁸²⁵ Plans are at an early stage and by May 2016, no timescales or even the number of reactors proposed had been announced.

The October 2013 announcement led to formal State Aid notification of the proposal to the European Commission, and on 18 December 2013, the Commission announced it was investigating the deal. On 8 October 2014, only days before he left office, Commissioner Joaquin Almunia announced the Commission's authorization of the state aid scheme.⁸²⁶ The decision is being challenged by the Austrian and Luxembourg governments and some renewable energy utilities. However, by May 2016, hearings on the challenge had not started.

Other new delays were triggered by EPR builder AREVA's 2015 technical bankruptcy, which not only makes it virtually impossible for AREVA to contribute 10 percent to the investment but is throwing the entire nuclear sector in France into great difficulty (see France Focus). Further uncertainties arose in April 2015, after “very serious” material defects were identified on the Flamanville EPR pressure vessel bottom and lid.⁸²⁷ According to the French regulator, the assessment of the safety implications will take at least until December 2016. As a result of the issues raised by the defective parts, the French safety authorities required AREVA to carry out an audit of quality control procedures. ASN reported that: “They revealed irregularities in the manufacturing checks on about 400 parts produced since 1965, about fifty of which would appear to be in service in the French NPPs. These irregularities comprise inconsistencies, modifications or omissions in the production files, concerning manufacturing parameters or test results.”⁸²⁸ By early July 2016, the implications of these failings were not clear but they could seriously affect the viability of the rescue of AREVA and of course, the Hinkley Point project (see also France Focus).

The delays with the Hinkley project mean that the two other consortia considering investment in new nuclear in the U.K. are now, on their own projections, close to overtaking the Hinkley project.

NuGen, in June 2014, finalized a new ownership structure with Toshiba-Westinghouse (60 percent) and GDF-Suez (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

⁸²⁵ ONR, “Assessing new nuclear reactor designs—Generic Design Assessment Quarterly Report (July-October 2015)”, Office for Nuclear Regulation, see <http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-jul-oct15.pdf>, accessed 18 June 2016.

⁸²⁶ European Commission, “Commission Decision of 08.10.2014 on the aid measure SA.34947 (2013/C) (ex2013/N) which the United Kingdom is planning to implement for Support to the Hinkley Point C Power Station”, 8 October 2014.

⁸²⁷ For a 4-page briefing on the issue see Yves Marignac, “Fabrication Flaws in the Pressure Vessel of the EPR Flamanville-3”, WISE-Paris, 12 April 2015, see <https://www.dropbox.com/s/njavhw7ihvkbyeu/WISE-Paris-Fabrication-Flaws-EPR-Flamanville-Latest.pdf>, accessed 4 July 2015.

⁸²⁸ ASN, “AREVA has informed ASN of irregularities concerning components manufactured in its Creusot Forge plant”, News Release, 4 May 2016, see <http://www.french-nuclear-safety.fr/Information/News-releases/Irregularities-concerning-components-manufactured-in-its-Creusot-Forge-plant>, accessed 18 June 2016.

to begin operating in 2024.⁸²⁹ However, the AP1000 design is not expected to be licensed before January 2017.⁸³⁰

Horizon Nuclear was bought by Hitachi from E.ON and RWE for an estimated price of £700 million (US\$1.2 billion). The company has submitted its ABWR 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.⁸³¹ The ABWR, planned for the Wylfa site, has passed the justification procedure at both Houses of Parliament in January 2015, the Generic Design Assessment (GDA) is even less advanced than that of the AP1000 and expected to be completed sometime by December 2017.⁸³² If everything did go according to plan, the reactor would start up in 2025.⁸³³

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 2015 was little different to that in 2014 (0.2 percent higher), the lowest consumption level in 17 years. How the U.K. Brexit decision will influence the prospects for nuclear new-build is highly uncertain, even if representatives of all U.K. projects were quick to ascertain that there would be no impact on their plans.

Meanwhile, renewables' share of electricity generation increased from 19.1 percent in 2014 to 24.7 percent in 2015,⁸³⁴ overtaking nuclear generation, and British renewable projects continue to demonstrate robustly lower market prices than the price guaranteed for 35 years to the largely French-state-owned owners of Hinkley Point C—a disparity bound to create increasing political tensions in the U.K.

Switzerland is the only non-EU Western European country that operates nuclear power plants. It operates five reactors that, in 2015, generated 22.1 TWh—a drop of 16.3 percent over the previous year—or 33.5 percent of the country's electricity, down from a maximum of 44.4 percent in 1996. The decline of the power generation is due to increased outage times,

⁸²⁹ *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 18 June 2016.

⁸³⁰ ONR, "Assessing new nuclear reactor designs—Generic Design Assessment Quarterly Report (November 2015-January 2016)", undated, see <http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-nov15-jan16.pdf>, accessed 11 May 2016.

⁸³¹ *Telegraph*, "Hitachi reluctant about UK nuclear reactor plan", 14 April 2013, see <http://www.telegraph.co.uk/finance/newsbysector/energy/9993564/Hitachi-reluctant-about-UK-nuclear-reactor-plan.html>, accessed 2 July 2016.

⁸³² ONR, "Assessing new nuclear reactor designs—Generic Design Assessment Progress Report, November 2015 to January 2016", see <http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-nov15-jan16.pdf>, accessed 2 July 2016.

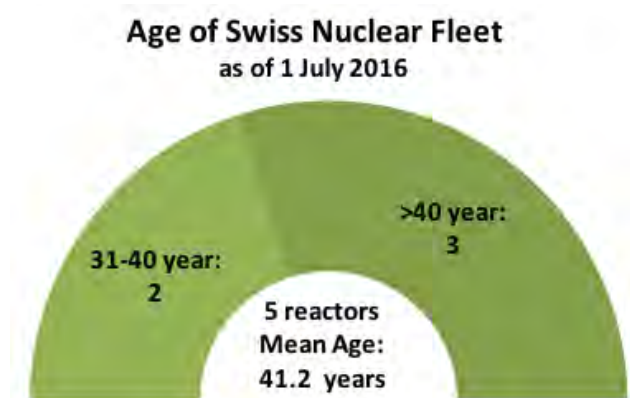
⁸³³ *WNN*, "Horizon clears justification hurdle", 28 January 2015, see <http://www.world-nuclear-news.org/NN-Horizon-clears-justification-hurdle-2801151.html>, accessed 2 July 2016.

⁸³⁴ DECC, "Statistics – Energy trends—Section 5 – Electricity", June 2016, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/511931/Electricity.pdf, accessed 2 July 2016.

especially for inspections and vessel head replacements at the two Beznau reactors, and load reductions due to high air and water temperatures during the summer 2015.⁸³⁵

With an average age of 41.2 years, Switzerland operates the oldest nuclear fleet and—with Beznau-1, age 46 and turning 47 in July 2016—the oldest reactor in the world. In a compelling 2014 report, Dieter Majer, former Director for Nuclear Facility Safety of the German Nuclear Regulator, recommended that especially the reactors Mühleberg and Beznau “should be shut down immediately”.⁸³⁶

Figure 51: Age of the Swiss Nuclear Fleet



Sources: IAEA-PRIS, MSC, 2016

Following the reactor pressure vessel problems identified at the Belgian Doel-3/Tihange-2 reactors (see Focus Belgium), inspections have been carried out at the two Beznau units. 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. At the pressure vessel of Beznau-2, 77 indications have been found with a maximum size of 20 x 50 mm.⁸³⁷ In November 2015, the Swiss Nuclear Safety Inspectorate (ENSI) established an International Review Panel to re-assess the integrity of the unit 1 pressure vessel. The unit remains shut down, while the Panel is working. After evaluation of the identified defects in unit 2, in December 2015, ENSI grants restart permission for the reactor.

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.”⁸³⁸ In January 2015, the federal regulator accepted the upgrades proposed by the operator in order to continue operating Mühleberg until

⁸³⁵ Swissnuclear, “En 2015, les centrales nucléaires suisses ont fourni environ un tiers de notre électricité”, Press Release, 26 February 2016.

⁸³⁶ Dieter Majer, “Risiko Altreaktoren Schweiz”, commissioned by Schweizerische Energie-Stiftung (SES), February 2014, see <http://www.energiestiftung.ch/energiethemen/atomenergie/risiken/risiko-altreaktoren/>, accessed 18 June 2016.

⁸³⁷ Christoph Pistner, “Beznau: Finding on the RPV”, Presentation at INRAG, 27 February 2016.

⁸³⁸ NIW, “Switzerland—News Briefs”, 1 November 2013.

2019.⁸³⁹ In December 2015, BKW officially began the closure procedure. According to current planning, the Federal Energy Department will take the formal shutdown decision by the middle of 2018⁸⁴⁰ and in March 2016, BKW communicated the date, when Mühleberg will be disconnected from the grid as the 20 December 2019.⁸⁴¹

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 billion in 2015. 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.⁸⁴² 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."⁸⁴³

Until 3/11, the nuclear phase-out option never gained a sufficient majority, but the "Swiss-style" referenda have maintained an effective moratorium on any new project over long periods of time. Fukushima had a very significant impact in Switzerland. On 8 June 2011, the Swiss parliament voted in favor of the phase-out of nuclear power in the country at the end of the projected lifetime of the last operating reactor in 2034.

Since then, a number of initiatives have attempted to modify the schedule, seeking either to accelerate or to slow down the process. While there seems to be a durable consensus in the country that any new-build initiative is off the table, the Government has initiated a process called Energy Strategy 2050 that does not fix any precise shutdown dates and aims to keep the existing reactors operating "as long as they are safe". On 26 January 2016, the Energy Commission of the Federal Assembly voted on the issue, in order to "eliminate divergences". A majority voted in favor of not limiting reactor lifetimes in the framework of the Energy Strategy 2050.⁸⁴⁴ A new nuclear phase-out initiative has been launched by various organizations and will lead to a national referendum on 27 November 2016. The initiative aims at the ultimate constitutional prohibition of the operation of nuclear power plants and a lifetime limitation of 45 years for the operating units, except for Beznau-1, that should be closed at the latest one year after the adoption of the constitutional change.⁸⁴⁵

⁸³⁹ ENSI, "Forderungen des ENSI für den Weiterbetrieb des Kernkraftwerks Mühleberg bis zur endgültigen Ausserbetriebnahme im Jahr 2019", 23 January 2015.

⁸⁴⁰ Office Fédéral de l'Énergie (OFEN), "Calendrier et explications—1er Procédure de désaffectation de la centrale nucléaire de Mühleberg", 4 April 2016.

⁸⁴¹ BKW, "Kernkraftwerk Mühleberg geht am 20. Dezember 2019 definitiv vom Netz", 2 March 2016, 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.

⁸⁴² Alpiq Public Affairs Konzept 2016, First Draft, see <http://www.pdf-archive.com/2016/03/19/alpiq-konzept/preview/page/1/>, accessed 21 June 2016.

⁸⁴³ Hans Wanner, "Umgang mit älter werdenden Reaktoren", ENSI, 21 March 2016, see www.energiestiftung.ch/files/pdf/20160321_npc_hans_wanner.pdf, accessed 18 June 2016.

⁸⁴⁴ Swiss Federal Assembly, "Pas de durée d'exploitation limitée pour les centrales nucléaires suisses", Press Release, 26 January 2016, (in French), see <https://www.parlament.ch/press-releases/Pages/2016/mm-urek-n-2016-01-26.aspx>, accessed 2 July 2016.

⁸⁴⁵ *SES-Magazin Energie & Umwelt*, "Die Bevölkerung muss sich vor den alten AKW selber schützen", April 2016, see http://www.energiestiftung.ch/files/pdf/e-u_2_2016_web.pdf, accessed 15 June 2016.

Central and Eastern Europe

In **Bulgaria**, nuclear power provided 15 TWh or 31.1 percent of the country's electricity in 2015, 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 currently licensed to operate until 2017 and 2021,⁸⁴⁶ but the operator has begun a relicensing program and plans 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 October 2015, Rosatom signed a contract for turbine generator upgrading to be implemented on unit 5 by May 2018. In January 2016, Rusatom Service and the Bulgarian company Risk Engineering signed an agreement for the assessment of the "technical condition and justification of the residual service life" of Kozloduy 6.⁸⁴⁷ In May 2016, it was reported that the technical work on the completion of the life-extension on unit 5 has been completed.⁸⁴⁸

There have been ongoing attempts since the mid-1980s to build another nuclear power plant at Belene in Northern Bulgaria including firms from Bulgaria, France, Germany, and Russia. The latest came to a halt in February 2013 when the Parliament finally confirmed the then Prime Minister's decision to abandon the plant. The Government and industry have now refocused their efforts on building another reactor at Kozloduy. In April 2012, the Government announced that an additional unit would be built "on market principles, that is, without government money or state guarantees."⁸⁴⁹ In December 2013, the Government approved a report from the Ministry of Economy and Energy to authorize the Bulgarian Energy Holding company—which would operate a new unit—to negotiate with Toshiba (owning 87 percent of Westinghouse) to become the strategic investor in the construction of an AP1000 reactor. Vendor Toshiba was to be asked to invest 30 percent of the final costs and help secure the remaining 70 percent from foreign lenders, specifically the Japan Bank for International Cooperation and the Export-Import Bank of the United States. The deadline for signing the agreement was 30 September 2014.⁸⁵⁰ The potential involvement of national export-import banks from the U.S. and Japan highlights the difficulties in building a reactor without state support. In early June 2014, Toshiba withdrew from the project and was replaced by Westinghouse as the strategic investor, and in August 2014, Westinghouse signed a "shareholder agreement" committing it to take a 30 percent stake in the project. Furthermore, US Vice-President Kerry offered that Washington could study ways in which it could

⁸⁴⁶ Republic of Bulgaria, "Sixth National Report under the Convention on Nuclear Safety", 2013 (although more recent press reports state that the license for unit 6 expires in 2019. See: *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 2 July 2016.

⁸⁴⁷ *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 2 July 2016.

⁸⁴⁸ *Reuters*, "Russia's Rosatom completes upgrade of Bulgarian nuclear reactor", 31 May 2016, see <http://uk.reuters.com/article/rosatom-bulgaria-idUKL8N18S28W>, accessed 2 July 2016.

⁸⁴⁹ *AFP*, "Bulgaria approves new reactor at nuclear plant", *Agence France Presse*, 11 April 2012.

⁸⁵⁰ *Sofia Globe*, "Bulgaria to begin talks with Westinghouse on new Kozloduy nuclear reactor", 11 December 2013, see <http://sofiaglobe.com/2013/12/11/bulgaria-to-begin-talks-with-westinghouse-on-new-kozloduy-nuclear-reactor/>, accessed 2 July 2016.

assist in financing.⁸⁵¹ Westinghouse was asked by the Bulgarian government to take a 49 percent stake in the project,⁸⁵² but it was reported in the Bulgarian press that Westinghouse had refused.⁸⁵³ In April 2015, the Bulgarian Government then announced it was dropping the deal with Westinghouse for financial reasons.⁸⁵⁴

In June 2016 the International Court of Arbitration ruled in favor of Atomstroyexport (ASE) over its claim for compensation after Bulgaria cancelled the Belene nuclear power plant. The press suggest that the Russian constructor was awarded about half of what it had asked for, receiving approximately US\$600 million.⁸⁵⁵

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 is suggested that Westinghouse may team up with State Power Investment Corporation (SPIC) to construct further units at Kozloduy.⁸⁵⁶ SPIC was recently established through the merger of China Power Investment Corporation and State Nuclear Power Technology Corporation, and is therefore a large state-owned enterprise under the administration of the Chinese central Government.

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 2015, nuclear plants generated 25.3 TWh or 32.5 percent of the electricity in the Czech Republic, that is over 3 percentage points down from record years 2013 and 2014. At the same time, the country was a net exporter of 12.5 TWh of electricity, equivalent to 57 percent of the nuclear output.

Three of the four Dukovany units were shut down in September 2015, following the detection by the State Nuclear Safety Office (SUJB) of faults in pipe welding and irregularities in the inspection practice by a subcontractor. Unit 3 restarted in December 2015, but was halted again in April 2016. Prolonged shutdowns are now expected at least for units 2 and 3. Unit 3 is not expected to be restarted before 19 October 2016. An extended outage of Unit 2 is planned to start on 16 September 2016 and last into 2017. In March 2016, the state regulator extended the operating license of Dukovany-1 indefinitely.⁸⁵⁷

⁸⁵¹ *NIW*, “Bulgaria, Energy Dependence on Russia Looks More Threatening”, 16 January 2015.

⁸⁵² EurActiv.com, “Bulgaria offers Westinghouse stake in new nuclear unit”, 27 March 2015, see <http://www.euractiv.com/section/energy/news/bulgaria-offers-westinghouse-stake-in-new-nuclear-unit/>, accessed 2 July 2016.

⁸⁵³ Mediapool, “‘Westinghouse’ refused to invest in block VII—Extend Talks to renegotiate the current price of U.S? ‘Maritsa East’ 1 and 3”, 31 March 2015, see <http://www.mediapool.bg/uestinghaus-otkazva-da-investira-v-v-blok-news232408.html>, accessed 2 July 2016.

⁸⁵⁴ *AFP*, “Bulgaria drops \$4 billion Westinghouse nuclear deal”, 2 April 2015.

⁸⁵⁵ *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 21 June 2016.

⁸⁵⁶ *NIW*, “Will SPI Team Up with Westinghouse in Bulgaria?”, 2 February 2016.

⁸⁵⁷ *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 2 July 2016.

The Dukovany units were started 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. 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.

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. In November 2012, the AREVA bid was excluded, since it had “not fulfilled some other crucial criteria defined in the tender”.⁸⁵⁸ 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.”⁸⁵⁹ CEZ Chief Executive Daniel Benes subsequently said: “If there is no certainty and a guarantee in legislation, it is impossible to decide about the construction at Temelín under the current market conditions.”⁸⁶⁰ Then 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”.⁸⁶¹ Czech news agency *České Noviny* said an investment of between CZK250 billion (US\$10.4 billion) and CZK300 billion (US\$12.4 billion) would be needed before the state could consider whether or not to provide guarantees for new nuclear power projects.⁸⁶² In these plans, new capacity is foreseen for both locations, Dukovany and Temelín, to maintain employment after the closure of existing reactors. In January 2016, the Government announced that it would make a new position of 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.⁸⁶³ In March 2016, CEZ signed a 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.⁸⁶⁴

⁸⁵⁸ CEZ, “Areva Failed to Comply with Public Contract Requirements Defined for Building Temelin NPP Units 3 and 4: CEZ had to Disqualify this Bidder”, 5 October 2012, see <http://www.cez.cz/en/investors/inside-information/1499.html>, accessed 2 July 2016.

⁸⁵⁹ Ceskenoviny, “Government won’t guarantee electricity prices for Temelin—PM Sobotka”, 6 February 2014.

⁸⁶⁰ Reuters, “Czech CEZ boss says prefers dividend predictability”, 31 March 2014.

⁸⁶¹ NIW, “Prague’s Vague NewBuild Plans”, 23 February 2015.

⁸⁶² WNN, “CEZ should fund new reactor projects, says government report”, 20 January 2015, see <http://www.world-nuclear-news.org/NP-CEZ-should-fund-new-reactor-projects-says-government-report-20011501.html>, accessed 29 March 2016.

⁸⁶³ NIW, “Czech Republic”, 29 January 2016.

⁸⁶⁴ 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.

Hungary has only one nuclear power plant, at Paks, where four VVER 440-213 reactors provided about 15 TWh or 52.7 percent of the country's electricity in 2015. 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, accompanied by a 20 percent increase in capacity. The first unit received permission to operate for another 10 years after a periodic safety review in 2013, the second unit in 2014.⁸⁶⁵

In March 2009, the Parliament approved a government decision-in-principle to build additional reactors at Paks.⁸⁶⁶ Even at this time, 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.⁸⁶⁷ But it was still a shock to nuclear vendors⁸⁶⁸ when in January 2014, an international financing agreement was reached between Hungary and Russia through direct negotiation between their heads of government for 80 percent of the value of the construction contract worth €12.5 billion (US\$13.2 billion). This was followed by an engineering, procurement, and construction and fuel contract in December 2014. It is said that was to be a “turn-key” contract, including a 20-year fuel contract and spent fuel return.⁸⁶⁹ The EU's EURATOM did not initially give its approval and it was only signed by all parties in April 2015 after changes on the diversification of fuel supply.

The loan deal has been criticized,⁸⁷⁰ because it was agreed just five days before a general election, and only a few of the crucial terms and conditions of the deal were made public.⁸⁷¹ According to a 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 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 years to 30. 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.”⁸⁷² The secrecy of the project has raised significant national and international protest as by keeping everything confidential, there will be little opportunity to keep track of costs. The project represents a U-turn for the ruling party, which had fiercely criticized previous socialist governments for failing to

⁸⁶⁵ WNN, “Paks unit 2 gets 20-year life extension”, 27 November 2015, see <http://www.world-nuclear-news.org/RS-Paks-unit-2-gets-20-year-life-extension-27111401.html>, accessed 29 March 2016.

⁸⁶⁶ John Shepherd, “Hungary's Parliament Paves Way to Build New Reactor Unit”, *NucNet*, 31 March 2009.

⁸⁶⁷ *Realdeal.hu*, “Hungary, Russia Seek to Resolve All Outstanding Issues in One Package, Says FM”, 21 January 2011.

⁸⁶⁸ *NIW*, “Newbuild: Hungary Ditches Tender in Favor of Rosatom Deal”, 17 January 2014.

⁸⁶⁹ *NIW*, “Newbuild, EPC Contract Signed for Russian VVER1200s at Paks”, 12 December 2014.

⁸⁷⁰ *NIW*, “Hungary: Secrecy, Political Risk Cloud Prospects for Paks Expansion”, 20 February 2015.

⁸⁷¹ *Politics.hu*, “Hungary signs EUR 10 billion Paks agreement with Russia”, 1 April 2014.

⁸⁷² *NIW*, “EU Hungary doubles down on Paks 2 secrecy”, 27 February 2015.

diversify away from reliance on Russian energy. Russia already provides about three-quarters of the country's oil and gas supplies.⁸⁷³

In September 2015 the European Commission notified the Hungarian authorities that the project meets the objectives of Article 41 of the EURATOM Treaty.⁸⁷⁴ However, on 23 November 2015, the European Commission opened an investigation into the Paks II project, with particular focus is the non-tendering of the project and the question, whether a private investor would have financed the project on similar terms, or if Hungary's investments constitutes State Aid.⁸⁷⁵ The government said, it takes "the view that the decision of the European Commissioner for Competition of 23 November 2015 and the summary published in today's edition of the Official Journal of the European Union contain a number of inaccuracies, misunderstandings, and unfounded and misleading claims".⁸⁷⁶ The Austrian government is pressing the European Commission to consider Hungary's support state aid. "We stand against any kind of support for the construction of nuclear power plants or the production of nuclear energy", said Economy and Energy Minister Reinhold Mitterlehner.⁸⁷⁷ However, there is also growing doubt over the wisdom of the project, both from the perspective that Russia may be unable to deliver on the financing and that, as Janos Lazar, head of the prime minister's office, told parliament that "Hungary's money market position has greatly improved lately and therefore Hungary is ready and able in the near future to replace the loan [from Russia] with capital obtained on the open financial market."⁸⁷⁸

The environmental impact assessment for the project is currently underway and is supposed to be finalized in the summer of 2016. Construction is planned to start in 2018 and commissioning in late 2023 or early 2024.⁸⁷⁹

The Presidents of Hungary and Russia re-confirmed their commitment to the project in February 2016, including President Putin saying Russia would make available up to 80 percent of the total cost, starting in 2016.⁸⁸⁰ However, as with other proposed Russian-financed projects, doubts have been raised about the ability of the vendor country to provide the necessary funds.

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 Rothchild & Cie for the Prime Minister's Office of the Hungarian Government in September 2015,

⁸⁷³ *Financial Times*, "Russia builds clout in eastern Europe with €10bn loan to Hungary", 14 January 2014.

⁸⁷⁴ *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 2 July 2016.

⁸⁷⁵ European Commission, "State Aid SA.38454 (2015/C) (ex 2015/N) – Hungary, Possible aid to the Paks nuclear power station", 23 November 2016.

⁸⁷⁶ Prime Minister's Office, "Inaccuracies and misunderstandings in European Commission's notification", Hungarian Government, 12 January 2016, see <http://www.kormany.hu/en/prime-minister-s-office/news/inaccuracies-and-misunderstandings-in-european-commission-s-notification>, accessed 18 June 2016.

⁸⁷⁷ *NIW*, "Briefs", 12 February 2016.

⁸⁷⁸ *Intellinews*, "Hungary eyes nuclear options as doubts grow over Paks deal", 20 June 2016, see <http://www.intellinews.com/hungary-eyes-nuclear-options-as-doubts-grow-over-paks-deal-100206/>, accessed 21 June 2016.

⁸⁷⁹ *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 2 July 2016.

⁸⁸⁰ *NIW*, "Briefs", 19 February 2016.

concluded that when making assumptions on the market price of power in the order of €65/MWh (which they describe 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.⁸⁸¹

This raises serious questions for the economics of the project as the operational costs are relatively low for nuclear power plants and the report states that investment cost can only be partially covered in their scenario, which make up a significant share of the cost of nuclear electricity. Furthermore, 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”.⁸⁸² The current market price for power (baseload future markets 2017) in Hungary is around €30-40/MWh.⁸⁸³

Credit-rating agency Standard & Poor’s, March 2016 confirmed Hungary’s BB+ (“junk”) commenting:

Downside risks to our base-case fiscal forecast could arise from further state acquisitions, an expansion of fiscal programs to support a slowing economy, electoral considerations, budgetary spending on large projects such as the PAKS nuclear power project (...).⁸⁸⁴

Romania has one nuclear power plant at Cernavoda, where two Canadian-designed CANDU reactors began operating in 1996 and 2007. In 2015, they provided 10.7 TWh or 17.3 percent of the country’s electricity, compared to 20.6 percent in 2009.

Construction started in the 1980s, with the initial intention of building five units. The first two units were partly funded by the Canadian Export Development Corporation, the second also partly by Euratom. Over the past decade, numerous foreign firms have been linked to the completion of the remaining Cernavoda units, including AECL and SNC-Lavalin (Canada), Ansaldo (Italy), AtomTechnoProm (Russia), CEZ (Czech Republic), Electrabel (Belgium), ENEL (Italy), GDF Suez—now Engie—(France), Iberdrola (Spain), KHNP (South Korea), RWE (Germany), and Arcelor Mittal (Luxembourg).⁸⁸⁵ In December 2013, Arcelor Mittal and ENEL sold back their shares in the project to the Romanian state.

The latest attempt involves China General Nuclear Power Group (CGN), which signed a letter of intent in November 2013 with the Societatea Nationala Nuclearelectrica (SNN) to complete the projects in 2019 and 2020. In March 2014, it was announced that an extension would be granted to the letter of intent, which was set to expire on 25 May 2014.⁸⁸⁶ In October 2014, SNN and CGN signed a binding agreement that made the latter the “selected investor”. This was followed in

⁸⁸¹ 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.

⁸⁸² Candole Partners, “NPP Paks II: Economic feasibility, impact on competition and subsidy costs”, Prepared for Greenpeace, May 2016.

⁸⁸³ PXE, “Price information from the Power Exchange Central Europe”, see <http://www.pxe.cz/>, accessed 8 June 2016.

⁸⁸⁴ S&P, “Hungary 'BB+/B' Ratings Affirmed; Outlook Stable”, 18 March 2016.

⁸⁸⁵ WNA, “Nuclear Power in Romania”, Updated December 2013.

⁸⁸⁶ *Telgraf*, “Construction of NPP units 3 and 4, the petty cash”, 22 March 2014.

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.⁸⁸⁷ 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.⁸⁸⁸

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 2015, these produced 14 TWh or 55.9 percent of the country's electricity—the third highest share in the world behind France and Ukraine. 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. However, 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, including from CEZ, Finland's Fortum, EPH—a Czech-Slovak energy investment group—and a Hungarian consortium of the utility MVM and Mol.⁸⁸⁹ In 2015, it emerged that CNNC was also interested in bidding. The Slovak State has also expressed interest in increasing its share⁸⁹⁰, but it has demanded from ENEL that Mochovce-3 and -4 be finished before a sale, in order to prevent further delays or even the cancellation of the project.⁸⁹¹ In December 2015, it was announced that EPH was the winner of the bid, with a preliminary price of €750 million (\$812 million). Under the deal, ENEL will get €150 million in the first stage, which will give EPH 33 percent in the company, the remaining share and final price will be agreed a year after Mochovce is completed.⁸⁹²

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\$2.6 billion). According to IAEA-PRIS, construction restarted in June 2009, and, at the time, the units were expected to start operation

⁸⁸⁷ 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 2 July 2016.

⁸⁸⁸ 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 2 July 2016.

⁸⁸⁹ Reuters, "ENEL expects four bids for Slovak utility stake-sources", 3 March 2015, see <http://www.reuters.com/article/2015/03/03/enel-ma-slovakia-idUSI6N00Z01620150303>, accessed 2 July 2016.

⁸⁹⁰ *Slovak Spectator*, "Finnish firm eyes Slovenské Elektrarne shares", 20 February 2015, see <http://spectator.sme.sk/c/20056311/finnish-firm-eyes-slovenske-elektrarne-shares.html>, accessed 2 July 2016.

⁸⁹¹ *Bloomberg*, "Enel to proceed with Slovak Sale in Face of Premier's Opposition", 26 March 2015, see <http://www.bloomberg.com/news/articles/2015-03-26/enel-to-proceed-with-slovak-sale-in-face-of-premier-s-opposition>, accessed 2 July 2016.

⁸⁹² Reuters, "Enel sells stake in Slovak power group, including nuclear plant, to EPH", 18 December 2015, see <http://www.reuters.com/article/slovakia-enel-eph-idUSL8N14657L20151218>, accessed 2 July 2016.

in 2012 and 2013.⁸⁹³ However, the project was beset with problems, and in 2013 the Slovak Government announced that the cost of completion had risen by €250 million (US\$260 million). Then in April 2014, at the Annual Shareholders meeting for SE, it was revealed that another €400 million (US\$424 million) would be needed to complete the units, taking the total costs of completion to €3.8 billion (US\$4 billion), with startup rescheduled for the end of 2014 and 2015.⁸⁹⁴ In June 2014, it was announced that the Russian Bank Sberbank would give SE an €800 million (US\$850 million) loan for 7.5 years; €300 million (US\$380 million) of the loan are to be spent on nuclear exports from Russia, including for the supply of nuclear fuel and for equipment for Mochovce.⁸⁹⁵ In May 2016, the Slovak press reported that estimated costs of completion had risen again and it was now expected to be €5.1 billion, with completion at the end of 2016/early 2017.⁸⁹⁶ According to SE, as of January 2016, unit 3 was over 90 percent complete and unit 4 over 70 percent.⁸⁹⁷

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 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 ENEL and 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.”⁸⁹⁸

The Slovak state owned utility JAVYS and the Czech utility CEZ started in 2009 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, the A1 reactor the two V1 reactors, as well as for Slovakia’s radioactive waste management. The so-called Bohunice NJZ (nová jadrová zdroj) 1200 MW 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 2014.⁸⁹⁹ Also later negotiations with China were fruitless. The Slovak ministry of environment approved the environmental impact assessment report in April 2016.⁹⁰⁰ The project is now likely to tender for technology.

⁸⁹³ ENEL, “ENEL Starts Site Works at Mochovce 3–4”, 3 November 2008, see https://servizi.enel.it/eWCM/salastampa/comunicati_eng/1594888-1_PDF-1.pdf, accessed 26 March 2016.

⁸⁹⁴ *Spectator*, “Shareholders approve additional funding for Mochovce plant”, 9 April 2014.

⁸⁹⁵ *WSJ*, “Sberbank to lend \$1.1 billion to Slovakia’s Largest Power Company”, 10 June 2014.

⁸⁹⁶ *Spravy Pravda*, “Additional money for Mochovce ? Ziza has no official information”, 11 May 2016, see <http://spravy.pravda.sk/ekonomika/clanok/392783-dalsie-peniaze-na-mochovce-ziga-nema-oficialnu-informaciu/>, accessed 2 July 2016.

⁸⁹⁷ SE, “Mochovce 3&4 Project Completion (01/03/2016)”, 3 January 2016, see <https://www.seas.sk/mochovce-3-4-npp>, accessed 25 May 2016.

⁸⁹⁸ *Reuters*, “Enel sells stake in Slovak power group, including nuclear plant, to EPH”, 18 December 2015, see <http://www.reuters.com/article/slovakia-enel-eph-idUSL8N14657L20151218>, accessed 2 July 2016.

⁸⁹⁹ *Radio Praha*, “ČEZ left with problematic Slovak nuclear joint venture after Rosatom talks die”, 7 March 2014, see <http://www.radio.cz/en/section/business/cez-left-with-problematic-slovak-nuclear-joint-venture-after-rosatom-talks-die>, accessed 2 July 2016.

⁹⁰⁰ *Energia*, “Nová atómka v Bohuniciach má zelenú od MŽP”, 19 April 2016, see <http://energia.dennikn.sk/dolezite/jadrova-energia/nova-atomka-v-bohuniciach-ma-zelenu-od-mzp/19850/>, accessed 23 March 2016.

Slovenia jointly owns the Krsko nuclear power plant with **Croatia**—a 696-MW Westinghouse PWR. In 2015, it provided 5.3 TWh or 38 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.⁹⁰¹

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 (Armenian-2) nuclear power plant, which is situated within 30 kilometers of the capital Yerevan. The unit provided 2.5 TWh—more than in any year since 1988, when two units were operating—or 34.6 percent of the country’s electricity in 2015, down from a maximum of 45 percent in 2009.

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. 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. The reactor is an early Soviet design, a VVER 440-230, and in 1995, a U.S. Department of Energy document stated: “In the event of a serious accident...the reactor’s lack of a containment and proximity to Yerevan could wreak havoc with the lives of millions.”⁹⁰² In October 2012, the Armenia Government announced that it would operate the Medzamor unit 2026. This led to the Turkish authorities’ calling for the immediate closure of the power station.⁹⁰³ In March 2014, the Turkish energy minister said of the plant: “The nuclear plant, which was put online in 1980, has had a lifespan of 30 years. This plant has expired and should be immediately closed.”⁹⁰⁴ In December 2014, an intergovernmental agreement was signed that would see the Russian Government finance a program of upgrading to let the reactor operate until 2026.⁹⁰⁵ An application for the life extension license will be launched in September 2016, with the upgrade work expected to be completed by 2019. The work is to be funded by a Russian state loan of US\$270 million and a grant of US\$30 million.

In March 2015, the European Commission released the “Implementation of the European Neighborhood Policy (ENP) in Armenia”, which stated: “The early closure and decommissioning

⁹⁰¹ 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 2 July 2016.

⁹⁰² Office on Energy Intelligence, “Most Dangerous Reactors: A Worldwide Compendium of Reactor Risk”, DOE, May 1995.

⁹⁰³ USAID, “Turkey renews demands for ‘immediate closure’ of Armenian nuke plant”, 5 November 2012.

⁹⁰⁴ *Hurriyet Daily*, “Turkey wants nuclear plant in Armenia to be shut down”, 22 March 2014.

⁹⁰⁵ *Diario Armenia*, “Armenia and Russia signed an agreement to extend the life of Medzamor nuclear power plant”, 27 December 2014, see <http://www.diarioarmenia.org.ar/armenia-y-rusia-firman-un-acuerdo-para-extender-la-vida-util-de-la-central-atomica-de-medzamor/>, accessed 2 July 2015.

of the MNPP [Medzamor Nuclear Power Plant] remain a key objective for the EU and under the ENP Action Plan. Since the power plant cannot be upgraded to meet current internationally recognized nuclear safety standards, it should be closed as soon as possible”.⁹⁰⁶ Armenia is currently carrying out a post-Fukushima stress test in cooperation with the European nuclear regulators group ENSREG.⁹⁰⁷

In December 2014, an intergovernmental agreement was signed for the Russian Government to finance a program of upgrading to enable the reactor to operate until 2026.⁹⁰⁸ However, in June 2015, the IAEA said that, following an Integrated Regulatory Review Service, it was concerned that no application for life extension had been received by the national regulatory authority, despite the operating license’s expiring in 2016.⁹⁰⁹

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. The plant was estimated by a U.S.-funded feasibility study to cost US\$5 billion.⁹¹⁰ In March 2014, the energy minister admitted that it was having difficulty in attracting funds to start construction.⁹¹¹ In July 2014, the energy minister said that Russia was expected to provide plant equipment worth US\$4.5 billion out of the total US\$5 billion.⁹¹² 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 2036.⁹¹³ It is unclear what triggered the shift, what the technology would be or where the financing would come from.

In **Russia**, nuclear plants provided 183 TWh of electricity, a record, an 8 percent year-on-year increase, primarily due to the commissioning of the Rostov-3 reactor. Nuclear energy contributed 18.6 percent to the country’s electricity mix, an identical level to the previous year’s historic maximum. A key construction question for 2016, will be if the Novovoronezh-2 unit—at least already six years behind schedule—will be finally connected to the grid.

According to the IAEA-PRIS database, Russia has eight reactors under construction, second only to China. 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

⁹⁰⁶ High Representative of the European Union for Foreign Affairs and Security Policy, “Joint Staff Working Document—Implementation of the European Neighbourhood Policy in Armenia—Progress in 2014 and recommendations for Actions”, European Commission, 25 March 2015, see http://eeas.europa.eu/enp/pdf/2015/armenia-enp-report-2015_en.pdf, accessed 2 July 2016.

⁹⁰⁷ ENSREG, “Armenia national stress test report open for public consultation”, European Nuclear Safety Regulation Group, 6 April 2016.

⁹⁰⁸ *Diario Armenia*, “Armenia and Russia signed an agreement to extend the life of Metsamor nuclear power plant”, 27 December 2014, see <http://www.diarioarmenia.org.ar/armenia-y-rusia-firman-un-acuerdo-para-extender-la-vida-util-de-la-central-atomica-de-medzamor/>, accessed 25 March 2015.

⁹⁰⁹ *NucNet*, “IAEA Expresses Concern Over Lack of Progress on Armenian-2 Licence Extension”, 12 June 2015, see <http://www.nucnet.org/all-the-news/2015/06/12/iaea-expresses-concern-over-lack-of-progress-on-armenian-2-licence-extension>, accessed 2 July 2016.

⁹¹⁰ NTI, “Armenia File”, Updated March 2016, see <http://www.nti.org/learn/countries/armenia/>, accessed 29 May 2016.

⁹¹¹ *Business New Europe*, “Armenia denies plans to abandon nuclear power plant project”, 28 March 2014.

⁹¹² Rosatom, “Russia and Armenia agree to unit 2 life extension”, Press Release, 24 December 2014.

⁹¹³ *NIW*, “Armenia”, 25 September 2015.

to the customer at the end of 2012.⁹¹⁴ The latest official start-up date is said to be 6 September 2016,⁹¹⁵ or the autumn of 2016 according to the Russian Deputy Prime Minister,⁹¹⁶ although other reports suggest the vessels will be launched only in 2019.⁹¹⁷ 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.⁹¹⁸

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. However, given the ongoing problems in electricity markets with low market prices and sluggish demand, there is little incentive for construction to restart. The Lithuanian Energy Minister, called for a boycott of power from the power plant should it be completed.

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 reports of the dropping from height of the control rod cluster assembly, cracking the walls and floor of the cooling pond, with a resultant possible six-month delay,⁹¹⁹ with completion of unit 1 now expected in 2018.⁹²⁰

Two VVER-1200 reactors are also under construction at Novovoronezh; one expected to be completed in 2016, and the second, according to the World Nuclear Association (WNA), in 2019.⁹²¹ Another reactor is being constructed at the Rostov nuclear power plant, expected to be completed in 2017.

In June 2016 the Russian regulator Rostekhnadzor granted a construction license for Unit 1 of Kursk II which was followed by and a construction permit from state nuclear corporation Rosatom. Russian press suggest that soil removal has now begun on the site.⁹²² 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 1.2 GW, Generation III+ design. The proposed start-up date of the first of two

⁹¹⁴ *NEI*, “KLT-40S nuclear barge project still afloat”, 9 March 2010.

⁹¹⁵ *WNN*, “Reactors installed on floating plant”, 1 October 2013.

⁹¹⁶ *Ok-inform-ru*, “Visit icebreaker “Arktika” and “Sibir””, 8 December 2015, see <http://ok-inform.ru/photoarchive/osmotr-ledokolov/osmotr-ledokolov-arktika-i-sibir-i-teploelektrostantsii-akademik-lomonosov-1-12641.html>, accessed 28 March 2016.

⁹¹⁷ *U.S.EIA*, “Russia”, 12 March 2014, see <http://www.eia.gov/countries/cab.cfm?fips=RS>, accessed 12 May 2015.

⁹¹⁸ *NTI*, “Floating nuclear reactors could fall prey to terrorist, experts say”, *Global Security Newswire*, 13 August 2010, see <http://www.nti.org/gsn/article/floating-nuclear-reactors-could-fall-prey-to-terrorists-experts-say/>, accessed 2 July 2015.

⁹¹⁹ *NIW*, “Briefs—Russia”, 24 July 2015.

⁹²⁰ *NIW*, “Briefs—Russia”, 7 August 2015.

⁹²¹ WNA, “Nuclear Power in Russia”, Updated March 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power/>, accessed 28 March 2016.

⁹²² *RussianConstruction.com*, “Builders of the second Kursk nuclear power station granted a license”, 3 June 2016, see <http://russianconstruction.com/news-1/23980-builders-of-the-second-kursk-nuclear-power-station-granted-a-license.html>, accessed 29 June 2016.

reactors at the site has been put back to 2023—“due to a revision of forecast energy consumption in the region”⁹²³— and is expected to cost RUB225 billion (US\$ 3.57 billion in 2016 conversion).⁹²⁴

A January 2015 report by Russia’s Audit Chamber found that seven out of then nine units under construction are 12–38 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.⁹²⁵ 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.⁹²⁶

All these delays, financial and technical problems have continually downgraded targets for the deployment of new units, as have the falling power demand and weaker prices, due to reduced economic output. In September 2006, Rosatom announced a target for nuclear power to provide 23 percent of Russia’s electricity by 2020 from 44 GW of capacity (compared to 24 GW in 2014). By July 2012, this had been scaled back to suggest that there would be 30.5 GW of nuclear in 2020. That would require just the completion of the eight reactors currently under construction, taking into account the expected closure of the first two RBMK units at Leningrad.

Therefore, a key issue for the industry is how to manage its aging reactors. There are three major 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, while the VVER1000s are expected to work for up to 50 years. As of the middle of 2016, 22 have operated for over 30 years, of which eight have run for over 40 years.

Russia is attempting to be an increasingly important player on the world nuclear power market, but serious questions have to be asked about the ability for Russia to finance its nuclear export plans. In September 2015, Kirill Komarov, the deputy head of Rosatom, said that the total order book over the last 10 years was worth US\$100 billion and that by 2020 this would rise to US\$150 billion, as in the next five years it intended to sign construction agreements for between 30-40 reactors.⁹²⁷ Russian finance is currently being used in reactors being built in Belarus, China, and India. However, finance has been pledged or is being negotiated for many other countries, including Armenia, Bangladesh, Finland, Hungary, Iran, Jordan, South Africa, Turkey, Ukraine, and

⁹²³ *NIW*, “Russia gears up for landmark Kursk project”, 20 May 2016.

⁹²⁴ Rosatom, “Rostekhnadzor has granted Rosenergoatom a construction license for Unit 1 of Kursk NPP Phase II, 9 June 2016, see <http://www.rosatom.ru/en/search/?q=kursk>, accessed 29 June 2016.

⁹²⁵ *NIW*, “Auditor Report Illuminates Rosatom’s Financial Challenges”, 23 January 2015.

⁹²⁶ 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 18 June 2016.

⁹²⁷ *Nucnet*, “Russia plans to sign contracts for 30-40 overseas reactors”, 25 September 2015, see <http://www.nucnet.org/all-the-news/2015/09/25/russia-plans-to-sign-contracts-for-30-to-40-overseas-reactors>, accessed 2 July 2016.

Vietnam. The importance of foreign sales has increased and it represents about half of all revenues for Rosatom, compared to 30 percent a decade ago,⁹²⁸ with the objective to increase this to 50 percent by 2030. However, there is doubts as to the viability of these contracts. Steve Kidd, formerly WNA's head of strategy, said: "Rosatom is pretty good at announcing \$100 billion of orders in 25 countries, but not an awful lot of these are firm contracts, they are just bits of paper."⁹²⁹

A large part of the funding for these projects comes from Russia's National Wealth Fund. A rough estimate of the funding Russia has pledged is US\$24 billion for plants now under construction and an additional US\$64 billion for future agreements—a total of US\$88 billion over the next decade or two.⁹³⁰ However, the National Wealth Fund is also being used for stabilizing the Russian economy. With falling oil and gas prices, the falling value of the ruble, and ongoing sanctions, the nuclear export program will be disrupted for political and economic reasons. The Russian Finance Minister was quoted as saying, "Our reserves volume will decrease by approximately 2.6 trillion rubles (US\$40.85 billion) — more than half. This means that 2016 is the last year when we are able to spend our reserves that way. After that we will not have such resources."⁹³¹ Funds for overseas nuclear development have also been secured from the Russian Bank for Development and Foreign Economic Affairs (Vnesheconombank or VEB), under a co-operation agreement signed with Atomstroyexport in 2006,⁹³² and resulted in subsequent loans to Belarus, in 2014, and proposed deals in Hungary and India. However, the VEB is now also under financial pressure, in part due to Western sanctions and has now stopped lending.⁹³³ Despite this, at the AtomExpo 2016, VEB and Rosatom agreed to develop their co-operation to "contribute to the growth of the Russian economy and the expansion of Russia's presence in the global nuclear energy market".⁹³⁴

The credit-rating agencies reflect these developments. In February 2015, Moody's downgraded Atomenergoprom—a 100 percent subsidiary of Rosatom, which as an integrated nuclear group also building reactors is comparable to the French AREVA—to "junk" (Ba1) and assigned a negative outlook.⁹³⁵ Then in March 2016, Moody's placed it on a further review for downgrade.⁹³⁶

⁹²⁸ *NIW*, "Russia", 6 November 2015.

⁹²⁹ *Reuters*, "Rosatom's global nuclear ambition cramped by Kremlin politics", 26 June 2016, see <http://internal.uk.mobile.reuters.com/article/idUKKCN0ZCOQZ>, accessed 29 June 2016.

⁹³⁰ Cheryl Rofer, "Can Russia Afford Its Reactor Exports?", *Nuclear Dinner*, 18 February 2015, see <http://nucleardiner.com/2015/02/18/can-russia-afford-its-reactor-exports/>, accessed 2 July 2016.

⁹³¹ *Market Watch*, "Weak oil prices deplete Russia's sovereign-wealth fund", 27 October 2015, see <http://www.marketwatch.com/story/weak-oil-prices-deplete-russias-sovereign-wealth-fund-2015-10-27>, accessed 2 July 2016.

⁹³² VEB, "Vnesheconombank signs agreement on cooperation with CJSC Atomstroyexport", 31 May 2006, see http://www.veb.ru/en/press/news/arch_news/index.php?id_19=3524&from_19=146, accessed 2 July 2016.

⁹³³ *Bloomberg*, "Putin's Bailout Bank Needs a Rescue; It's an \$18 Billion Whopper", 28 December 2015, see <http://www.bloomberg.com/news/articles/2015-12-28/putin-s-bailout-bank-needs-a-rescue-it-s-an-18-billion-whopper>, accessed 2 July 2016.

⁹³⁴ *WNN*, "Russia's Rosatom signs \$10 billion worth of deals at AtomExpo", 1 June 2016, see <http://www.world-nuclear-news.org/C-Russias-Rosatom-signs-10-billion-worth-of-deals-at-AtomExpo-01061601.html>, accessed 2 July 2016.

⁹³⁵ Moody's, "Rating Action: Moody's takes rating actions on six Russian utility and infrastructure GRIs; assigns negative outlook", 25 February 2015, see https://www.moody.com/research/--PR_319091, accessed 2 July 2016.

⁹³⁶ Moody's, "Credit Opinion: Atomenergoprom, JSC", 23 March 2016.

Ukraine has 15 operating reactors, two of the VVER440 design and the rest VVER1000s. They provided 82.4 TWh or 56.5 percent of power in 2015, a considerable rise in both output and percentage contribution over the previous year. Also rising was the income from electricity sales, which increased by 41 percent to 39.4 billion hryvnas (US\$1.6 billion). While on paper this suggests a positive economic situation, non-payment has meant that Energoatom is “crippled financially and must borrow from banks to pay its bills”,⁹³⁷ and during April 2016 their accounts were frozen by the courts.⁹³⁸

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 lifetime of the reactors for another 20 years. The proposal was accepted and now it is a core element of the energy strategy approved by the government. The programme is estimated to cost €1.45 billion (US\$1.62 billion) in total, of which the European Bank for Reconstruction and Development 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 and two units at South Ukraine for 10 years. Two units at Zaporizhzhya NPP are currently not operating to implement measures necessary for the license extension with the expected decision of the nuclear regulator in first half 2016. 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.⁹³⁹ Environmental groups in Ukraine have called upon European institutions to stop the support for “risk” life extension programmes.⁹⁴⁰

Two reactors, Khmelnytsky-3 and -4, are officially under construction. 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 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.⁹⁴¹ However, in September 2015, the Ukrainian

⁹³⁷ *NIW*, “Nuclear restart jeopardized by political crisis”, 26 February 2016.

⁹³⁸ *NEI*, “Ukraine nuclear utility in financial difficulty”, 27 April 2016, see <http://www.neimagazine.com/news/newsukrainian-nuclear-utility-in-financial-difficulty-4876101>, accessed 7 May 2016.

⁹³⁹ 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 2 July 2016.

⁹⁴⁰ 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 2 July 2016.

⁹⁴¹ Oda Becker, et al., “Khmelnytsky NPP, Construction of Units 3 and 4—Expert Statement to the Information and Analytical Survey of the Feasibility Study and the EIA Report of the FS”, Umweltbundesamt (Environment Agency Austria), Federal Ministry of Agriculture, Forestry, Environment and Water

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.⁹⁴² Ukrainian media reported in November 2015 that the president of Energoatom Yuri Nedashkivsky told a briefing in Brussels Press Club: “We have reached an agreement with the world-renowned Barclays bank, we will obtain funds for the completion of two units at Khmelnytsky NPP.”⁹⁴³ However, there is no mention of this agreement on Energoatom’s web site.⁹⁴⁴ As construction relies on the VVER-1000 reactors there are only limited choice of the companies able to complete the units. Once the contract with Russia was canceled, Energoatom and Skoda JS, which is owned by Russian OMZ Group, signed a Memorandum of Understanding.⁹⁴⁵

Management, 2013, see <http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0441.pdf>, accessed 2 July 2016.

⁹⁴² *United Press International*, “Ukraine scraps nuclear reactor deal with Russia”, 16 September 2015, see http://www.upi.com/Top_News/World-News/2015/09/16/Ukraine-scraps-nuclear-reactor-deal-with-Russia/9811442413199/, accessed 2 July 2016.

⁹⁴³ *Ukrinform*, “Energoatom reaches agreement with Barclays on completion of two units at Khmelnytsky NPP”, 4 November 2015, see <http://www.ukrinform.net/rubric-economics/1908661-energoatom-reaches-agreement-on-completion-of-two-units-at-khmenytsky-npp-with-barklays.html>, accessed 2 July 2016.

⁹⁴⁴ Energoatom, “Press Centre”, see <http://www.energoatom.kiev.ua/en/press/>, accessed 2 July 2016.

⁹⁴⁵ *WNN*, “Russia’s Atomstroyexport pulls out of Ukraine”, 18 June 2015, see <http://www.world-nuclear-news.org/C-Russias-Atomstroyexport-pulls-out-of-Ukraine-18061501.html>, accessed 2 July 2016.

Annex 2: Japanese Nuclear Reactor Status

Table 18 : Japanese Nuclear Reactor Status (as of 1 July 2016)

Operator	Reactor	MW	Grid year - Startup - Age (year)	Shutdown	Shutdown duration	NRA Guidelines Compliance		Status
						Application	Approval	
CHUBU	Hamaoka-3 (BWR)	1056	1987 -29,4	29/11/10	5,6	15/06/15[1]		
	Hamaoka-4 (BWR)	1092	1993 -23,4	13/5/11	5,1	14/2/14		
	Hamaoka-5 (ABWR)	1325	2004 -12,2	14/5/11	5,1	30/5/14		
CHUGOKU	Shimane-2 (BWR)	789	1988 -28	27/1/12	4,4	25/12/13		
HEPCO	Tomari-1 (PWR)	550	1988 -27,6	22/4/11	5,2	8/7/13		
	Tomari-2 (PWR)	550	1990 -25,8	26/8/11	4,8	8/7/13		
	Tomari-3 (PWR)	866	2009 -6,6	5/5/12	4,2	8/7/13		
HOKURIKU	Shika-1 (BWR)	505	1993 -23,5	1/3/11	5,3			
	Shika-2 (ABWR)	1108	2005 -11	11/3/11	5,3	12/8/14		
JAEA	Monju (FBR)	246	1995 -20,8	8/12/95	20,6			
JAPCO	Tokai-2 (BWR)	1060	1978 -38,3	21/5/11	5,1	20/5/14		
	Tsuruga-2 (PWR)	1108	1986 -30	29/8/11	4,8	5/11/15 ⁹⁴⁶		
KEPCO	Mihama-3 (PWR)	780	1976 -40,4	14/5/11	5,1	17/3/15		
	Ohi-1 (PWR)	1120	1977 -38,5	10/12/10	5,6			
	Ohi-2 (PWR)	1120	1978 -37,7	16/12/11	4,5			
	Ohi-3 (PWR)	1127	1991 -25,1	2/9/13	2,8	8/7/13		
	Ohi-4 (PWR)	1127	1992 -24	15/9/13	2,8	8/7/13		
	Takahama-1 (PWR)	780	1974 -42,3	10/1/11	5,5	17/3/15	20/6/16	
	Takahama-2 (PWR)	780	1975 -41,5	25/11/11	4,6	17/3/15	20/6/16	
	Takahama-3 (PWR)	830	1984 -	20/2/12		8/7/13	9/10/15	Shutdown
	Takahama-4 (PWR)	830	1984 -31,7	21/7/11	4,9	8/7/13	20/6/16	

⁹⁴⁶ 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 2 July 2016.

Operator	Reactor	MW	Grid year - Startup - Age (year)	Shutdown	Shutdown duration	NRA Guidelines Compliance		Status
						Application	Approval	
KYUSHU	Genkai-2 (PWR)	529	1980 -36,1	29/1/11	5,4			
	Genkai-3 (PWR)	1127	1993 -23	11/12/10	5,6	12/7/13		
	Genkai-4 (PWR)	1127	1996 -19,6	25/12/11	4,5	12/7/13		
	Sendai-1 (PWR)	846	1983 -	10/5/11		8/7/13	27/5/15	Restarted
	Sendai-2 (PWR)	846	1985 -	1/9/11		8/7/13	27/5/15	Restarted
SHIKOKU	Ikata-2 (PWR)	538	1981 -34,9	13/1/12	4,5			
	Ikata-3 (PWR)	846	1994 -22,3	29/4/11	5,2	8/7/13	18/5/16	
TEPCO	Kashiwazaki-Kariwa-1 (BWR)	1067	1985 -31,4	6/8/11	4,9			
	Kashiwazaki Kariwa-2 (BWR)	1067	1990 -26,4	19/2/07	9,4			
	Kashiwazaki Kariwa-3 (BWR)	1067	1992 -23,6	16/7/07	9			
	Kashiwazaki Kariwa-4 (BWR)	1067	1993 -22,5	16/7/07	9			
	Kashiwazaki Kariwa-5 (ABWR)	1067	1989 -26,8	25/1/12	4,4			
	Kashiwazaki Kariwa-6 (ABWR)	1315	1996 -20,4	26/3/12	4,3	27/9/13		
	Kashiwazaki Kariwa-7 (BWR)	1315	1996 -19,5	23/8/11	4,9	27/9/13		
TOHOKU	Higashidori-1 (BWR)	1067	2005 -10,8	6/2/11	5,4	20/6/14		
	Onagawa-1 (BWR)	498	1983 -32,6	10/9/11	4,8			
	Onagawa-2 (BWR)	796	1994 -21,5	6/11/10	5,7	27/12/13		
	Onagawa-3 (BWR)	796	2001 -15,1	10/9/11	4,8			

Notes:

(1) Grid connection year

(2) 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.

(3) NRA Draft Review Report on Sendai.

Comments

WNISR considers that the 10 Fukushima units are shut down and will never restart. All of the remaining 40 reactors (including Monju) fall under the criteria of the WNISR Long Term Outage (LTO) category since none of them has generated any electricity in 2014 nor in the first half of 2015.

All these units should also be included in the Long-term Shutdown (LTS) under the criteria set by the International Atomic Energy Agency (IAEA).⁹⁴⁷ However, the Japanese government and the IAEA have chosen to limit the LTS classification to only one reactor (Monju) and consider all of the other reactors as “in operation”.

In March 2015, five units were officially closed and thus taken off the list of units in LTO. These are Mihama-1 and -2 and Tsuruga-1 on 17 March 2015 and Genkai-1 and Shimane-1 on 18 March 2015.

In July 2013, the NRA established a three-step review process for any company planning a reactor restart, designed to ensure that facilities meet the new regulatory requirements. The three steps of this process, are summed up as: “Permission for change in reactor installation license”, “Approval of plan for construction works”, and “Approval of operational safety programs”.

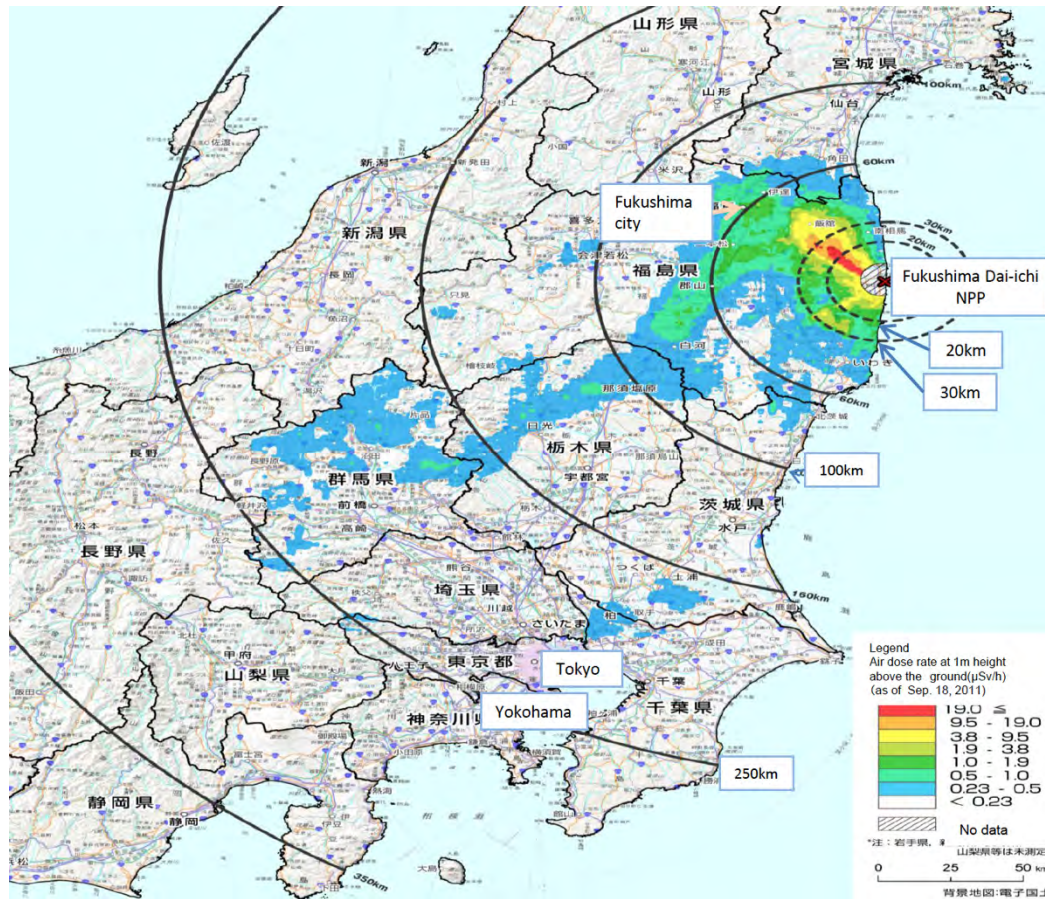
The NRA received Applications for Review for 25 reactors from 11 power companies. Half were submitted in July 2013, immediately after the regulation was first issued. As of 1 July 2015, only Sendai-1 and -2, on 27 May 2015, received Final Approval for Operation.⁹⁴⁸ Takahama-3 and -4, on 12 February 2015, passed the first of the three approval levels.

⁹⁴⁷ IAEA, Power Reactor Information System, “Glossary of Terms in PRIS Reports”, see <http://www.iaea.org/pris/Glossary.aspx>, accessed 6 June 2014.

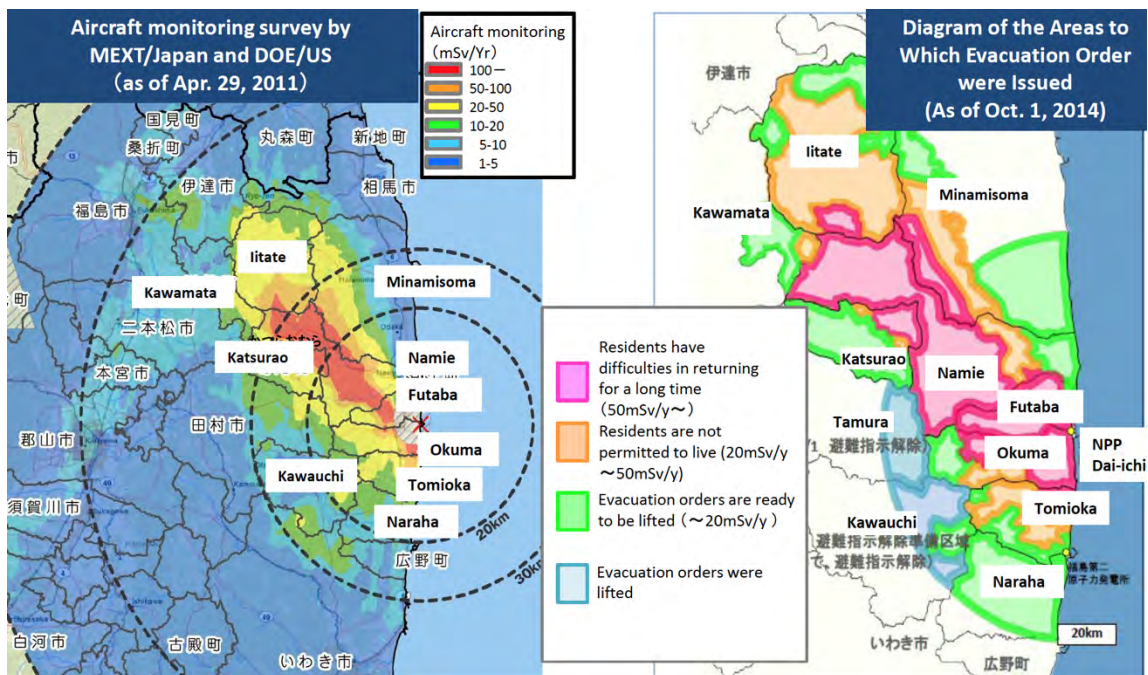
⁹⁴⁸ NRA, “Approval of Operational Safety Programs for Kyushu Electric Power Company’s Sendai Nuclear Power Station Units 1 and 2”, 27 May 2015, see <http://www.nsr.go.jp/data/000108443.pdf>, accessed 30 June 2016.

Annex 3 : Fukushima—Radioactive Contamination and Current Evacuation Zones

Figure 52: Fukushima: Radioactive Contamination and Current Evacuation Zones



Source: Ministry of Environment, "Progress on Off-site Cleanup Efforts in Japan", April 2015



- Notes:**
- Top:** Air dose at 1 m height above the ground (as of 18 September 2011)
 - Bottom left:** Aircraft monitoring survey by MEXT/Japan and DOE/US (as of 29 April 2011)
 - Bottom right:** Diagram of the areas to which evacuation orders were issued (as of 1 October 2014)

Annex 4: 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		High grade
Aa3		AA-	AA-	High grade		
A1		A+	A-1	A+	F1	Upper medium grade
A2		A		A		
A3	P-2	A-	A-2	A-	F2	Upper medium grade
Baa1		BBB+		BBB+		
Baa2	P-3	BBB	A-3	BBB	F3	Lower medium grade
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	Not prime	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		

Annex 5: Status of Lifetime Extensions in the U.S.

(as of 15 June 2016)

Table 19: Submitted and Expected Applications for Lifetime Extensions of U.S. Nuclear Power Plants

Plant	Grid Connection	Extension Application	Extension Granted
Calvert Cliffs 1, 2	1/75, 12/76	4/98	3/00
Oconee 1, 2, 3	5/73, 12/73, 9/74	7/98	5/00
Arkansas 1 (Ano-1)	8/74	2/00	6/01
Hatch 1, 2	11/74, 9/78	3/00	6/02
Turkey Point 3, 4	11/72, 6/73	9/00	6/02
Surry 1, 2	7/72, 3/73	5/01	3/03
North Anna 1, 2	4/78, 8/80	5/01	3/03
McGuire 1, 2	9/81, 5/83	6/01	12/03
Catawba 1, 2	1/85, 5/86	6/01	12/03
Peach Bottom 2, 3	2/74, 9/74	7/01	5/03
St Lucie 1, 2	5/76, 6/83	11/01	10/03
Fort Calhoun	8/73	1/02	11/03
Robinson 2	9/70	6/02	4/04
Ginna	12/69	8/02	5/04
Summer	11/82	8/02	4/04
Dresden 2, 3	4/70, 7/71	1/03	10/04
Quad Cities 1, 2	4/72, 5/72	1/03	10/04
Farley 1, 2	8/77, 5/81	9/03	5/05
Arkansas 2 (Ano-2)	12/78	10/03	6/05
Cook 1, 2	2/75, 3/78	10/03	8/05
Browns Ferry 1, 2, 3	10/73, 8/74, 9/76	1/04	5/06
Millstone 2, 3	11/75, 2/86	1/04	11/05
Point Beach 1, 2	11/70, 8/72	2/04	12/05
Nine Mile Point 1, 2	11/69, 8/87	5/04	10/06
Brunswick 1, 2	12/76, 4/75	10/04	6/06

Plant	Grid Connection	Extension Application	Extension Granted
Monticello	3/71	3/05	11/06
Palisades	12/71	3/05	1/07
Oyster Creek	9/69	7/05	4/09
Pilgrim	7/72	1/06	5/12
Fitzpatrick	2/75	7/06	9/08
Susquehanna 1, 2	11/82, 7/84	9/06	11/09
Wolf Creek	6/85	10/06	11/08
[Shearon] Harris	1/87	11/06	12/08
Indian Point 2, 3	6/73, 4/76	4/07	
Vogtle 1, 2	3/87, 4/89	6/07	6/09
Beaver Valley 1, 2	6/76, 8/87	8/07	11/09
Three Mile Island 1	6/74	1/08	10/09
Prairie Island 1, 2	12/73, 12/74	4/08	6/11
Cooper	5/74	9/08	11/10
Duane Arnold	5/74	10/08	12/10
Palo Verde 1, 2, 3	6/85, 5/86, 11/87	12/08	4/11
Hope Creek	8/86	8/09	7/11
Salem 1, 2	12/76, 6/81	8/09	6/11
Diablo Canyon 1, 2	11/84, 10/85	11/09	
Columbia	5/84	1/10	5/12
Seabrook	5/90	6/10	
Davis-Besse	8/77	8/10	12/15
South Texas 1, 2	3/88, 4/89	10/10	
Limerick 1, 2	4/85, 9/89	6/11	10/14
Grand Gulf	10/84	11/11	
Callaway	10/84	12/11	3/15
Sequoyah 1, 2	7/80, 12/81	1/13	9/15
Braidwood 1, 2	7/87, 5/88	5/13	1/16
Byron 1, 2	3/85, 2/87	5/13	11/15

Plant	Grid Connection	Extension Application	Extension Granted
Fermi 2	9/86	4/14	
LaSalle 1, 2	9/82, 4/84	12/14	
Waterford 3	3/85	3/16	
River Bend 1	12/85	Expected 1-3/17	
Comanche Peak 1, 2	4/90, 4/93	Expected 7-9/18	
Perry 1	12/86	Expected 10/19	
Clinton 1	4/87	Expected 1-3/21	

Sources:

- For grid connection dates: <https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US>
- For life extension dates: <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-reactor-license-renewal.html>, updated January 2016, accessed 16 June 2015 ; and <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>, reviewed/updated 14 April 2015, accessed 16 June 2015.

Notes:

- (1) Pairs of reactors marked † have significantly different designs.
- (2) The STARS Alliance of nuclear power plant owners has informed the NRC it will submit applications for life extensions for two unnamed units in 2016 and 2018. The Comanche Peak reactors are the only ones owned by STARS members that have not already applied for life extension or have had it granted, so it is assumed the application refers to these two units.
- (3) Nine Mile Point 2 applied for and received a license extension before its 20th birthday.
- (4) Kewaunee and Vermont Yankee facilities both applied for Lifetime Extensions which were granted in February 2011 and June 2011, before Kewaunee was shut down on 7 May 2013 and Vermont Yankee on 29 December 2014.
- (5) Crystal River's Unit 3 was first connected to the grid January 1977. An application for a lifetime extension was submitted in December 2008, then withdrawn on 6 February 2013. Crystal River-3 was permanently shut down on 20 February 2013.

Annex 6: 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.

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. Since 1992, she has maintained a world nuclear reactors database and undertakes data modeling work for the World Nuclear Industry Status Report. From 1983 to 2006, she worked in various positions at WISE-Paris, an independent information service on energy and environment issues that she co-founded. Starting in 1989, she developed the computerization of the library and electronic information products. Her responsibilities covered database development, specialized translation, and project management, as well as research activities for specific projects. She is a member of négaWatt (France). She develops EnerWebWatch in the framework of the Coopaname Co-op.

Ian Fairlie is an independent consultant on radioactivity in the environment living in London U.K. He has studied radiation and radioactivity since the Chernobyl accident in 1986. Fairlie has a degree in radiation biology from Bart's Hospital in London and his doctoral studies at Imperial College in London and (briefly) Princeton University in the U.S. concerned the radiological hazards of nuclear fuel reprocessing. He formerly worked as a civil servant on the regulation of radiation risks from nuclear power stations. From 2000 to 2004, he was head of the Secretariat of the U.K. Government's CERRIE Committee on internal radiation risks. Since retiring from Government service, he has been a consultant on radiation matters to the European Parliament, local and regional governments, environmental NGOs, and private individuals. His areas of interest are the radiation doses and risks arising from the radioactive releases at nuclear facilities.

Tomas Kåberger has a MSc in Engineering Physics, a PhD in Physical Resource Theory, a Docent degree in Environmental Science and has served as professor in International Sustainable Energy Systems at Lund University and currently is professor of Industrial Energy Policy at Chalmers University of Technology in Sweden as well as Overseas Distinguished Scientist at Zhejiang University in China. He is Editor in Chief of Energy Science and Engineering, a Wiley, open-access scientific journal.

Kåberger is a member of the boards of directors of Vattenfall, and Cleanergy. Since 2011, he spends a third of his time as executive board chairman of Japan Renewable Energy Foundation.

Previous to his current assignments he served the Swedish Government as Director General of the Swedish Energy Agency. In that capacity he headed the Swedish delegation to the International Renewable Energy Agency in Abu Dhabi, and was elected vice chairman of the Council of IRENA.

For 18 years he was on the board of the Swedish Bioenergy Association, six of which as chairman. He has chaired the Swedish Renewable Energy Council, serves on the Industrial Council of the International Solar Energy Society and on the Steering Committee of Ren 21. Professor Kåberger is elected member of the Royal Swedish Academy of Engineering Sciences and of the Swedish Association of Energy Economists.

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.

Fulcieri Maltini, graduated in Electrical Engineering, and holds a Doctorate in Electronics Engineering from the University of Rome, Italy, a Master in Nuclear Engineering and several European and U.S. management diplomas.

He started his industrial career with Westinghouse Electric and Framatome in the nuclear energy field and later with Gazocean and Alsthom-Atlantique in the industrial, marine and nuclear propulsion fields. In 1980 he moved to consulting activities in Switzerland, where he was a director of Société Générale pour l'Industrie and later with Elektrowatt Engineering mostly involved in world-wide project development of conventional and renewable energy, energy efficiency, environmental impact assessments, advanced telecommunications, technology transfer and venture capital.

In 1994, he joined the European Bank for Reconstruction and Development (EBRD) in London, where he was responsible for the Nuclear Safety Account. In 1997, he returned to independent consulting activities, advising Governments, International Institutions, the European Parliament and the European Commission and industry and developing and financing projects within an environmental framework on conventional and renewable energy, sustainable development, environmental sciences and energy efficiency. Major activities include the development and industrialization of innovative technologies and the establishment of spin-off companies from Universities and Research Centres.

M.V. Ramana received his Ph.D. in theoretical physics from Boston University. He is currently with the Nuclear Futures Laboratory and the Program on Science and Global Security at the Woodrow Wilson School of Public and International Affairs, Princeton University, U.S., where he has been assessing

nuclear power programs around the world. 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.

Steve Thomas is Professor of Energy Policy and Director of Research for the Business School, University of Greenwich. He holds a BSc (honors) degree in Chemistry from Bristol University and has been working in energy policy analysis since 1976. His main research interests are reforms of energy industries, economics and policy towards nuclear power, and corporate policies of energy industry companies. Recent clients include Public Services International, the European Federation of Public Service Unions, the Nonproliferation Policy Education Center (U.S.), Energywatch (U.K.), and Greenpeace International.

Annex 7: Abbreviations

ABWR	Advanced Boiling Water Reactor
AEA	U.S. Atomic Energy Act
AECL	Atomic Energy of Canada Limited
AES	[Rosatom Reactor Design]
AFP	Agence France Presse (French News Agency)
AGR	Advanced Gas-cooled Reactors
ALPS	Advanced Liquid Processing System
ANS	American Nuclear Society
APR	Advanced Power Reactor or Advanced Pressurized Reactor
ASE	Atomstroyexport , Russia
ASN	Autorité de Sûreté Nucléaire (French Nuclear Safety Authority)
ATMEA	[AREVA Reactor Design]
BATAN	National Nuclear Energy Agency, Republic of Indonesia
BBC	British Broadcasting Corporation
BKW	Bernische Kraftwerke (Power Production & Distribution Utility, Switzerland)
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
BN	[Rosatom Reactor Design]
BNDES	Brazilian National Development Bank
BNEF	Bloomberg New Energy Finance
BOO	Build-Own-Operate
BP	Beyond Petroleum
BWR	Boiling Water Reactor
CAD	Canadian Dollar
CANDU	CANadian Deuterium Uranium
CAREM25	Central Argentina de Elementos Modulares
CCE-EDF S.A	Comité Central d'Entreprise-Electricité de France S.A (Central Works Committee Electricité de France Corporation)
CEA	Commissariat à l'énergie atomique et aux énergies alternatives (Atomic Energy Commission, France)
CEO	Chief Executive Officer
CEZ	České Energetické Závody (Public Power Utility, Czech Republic)
CFD	Contract For Difference
CFE-CGC	Confédération Française de l'Encadrement-Confédération Générale des Cadres (Trade Union, France)
CFE-CGC	Confédération française de l'encadrement - Confédération générale des cadres (French Confederation of Management – General Confederation of Executives)
CFSI	Counterfeit, Fraudulent, Suspect Item
CGN	China General Nuclear Power Corporation
CGNPC	China Guangdong Nuclear Power Group
ChNPP	Chernobyl Nuclear Power Plant — Chernobyl Nuclear Power Complex
CNNC	China National Nuclear Corporation
CNSC	Canadian Nuclear Safety Commission
COLA	Combined Operating License Applications
CRE	Commission de Régulation de l'Energie (Regulatory Commission of Energy, France)
CSM	Concrete Storage Modules

CWE	Central West Europe
DEC	Department of Environmental Conservation, New York (USA) ; or Dongfang Electric Corporation
DECC	Department of Energy and Climate Change, U.K.
DOE	Department of Energy
DPP	Democratic Progressive Party, Taiwan
EAS	EDF Actionariat Salarié
EBRD	European Bank for Reconstruction and Development
EC6	Enhanced Candu-6
Edf	Electricité de France (French Electric Utility Company)
EGAT	Electricity Generating Authority of Thailand
EGH	Expert Group Health
EIA	Environmental Impact Assessment
EITB	Euskal Irrati Telebista (Basque Radio-Television)
EnBW	Energie Baden-Württemberg, Germany
ENEC	Emirates Nuclear Energy Corporation
ENEL	Ente nazionale per l'energia elettrica (National Entity for Electricity, Italy)
ENP	European Neighborhood Policy
ENSI	Eidgenössisches Nuklearsicherheitsinspektorat (Swiss Nuclear Safety Inspectorate)
ENSREG	European Nuclear Safety Regulation Group
ENSWDF	Engineered Near-Surface Solid Radioactive Waste Disposal Facility
ENTSO-E	European Network of Transmission System Operators for Electricity
EPDC	Electric Power Development Company, Japan
EPH	Energetický a průmyslový holding (Energy Group, Czech Republic)
EPR	European Pressurized Water Reactor (EU), or Evolutionary Pressurized Water Reactor (U.S.)
EPZ	Elektricitets Produktiemaatschappij Zuid-Nederland (Electricity Production Company South-Netherlands)
ERD	Economic Relations Division (Bangladesh)
EU28	European Union 28 Member States
EÜAS	State-owned electricity generating company, Turkey
EVN	Electricity of Vietnam
EWEA	European Wind Energy Association
FANC	Federal Agency for Nuclear Control, Belgium
FCE-CFDT	Fédération Chimie Énergie-Confédération française démocratique du travail (Energy Federation of the French Democratic Confederation of Labour)
FCM	Fuel Containing Material
FEPC	Federation of Electric Power Companies, Japan
FERC	Federal Energy Regulatory Commission, U.S.
FL3	Flamanville-3
FNME-CGT	Fédération Nationale des Mines et de l'Énergie-Confédération Générale du Travail
FO	Force Ouvrière
FS	Feasibility Study
FS	Frankfurt School
FY	Financial Year
GDF-Suez	Gaz de France
GDA	Generic Design Assessment
GDOS	General Directorate for the Environment, Poland
GDP	Gross Domestic Product
GE	General Electric
GmbH	Gesellschaft mit beschränkter Haftung ("Company with limited liability", Germany)

GPSC	Georgia Public Service Commission, U.S.
GUE/NGL	European United Left / Nordic Green Left, European Parliament Political Group
GWEC	Global Wind Energy Council
IAEA	International Atomic Energy Agency
IANs	Indo-Asian News Service
IAS	Information and Analytical Survey
ICC	International Chamber of Commerce
ICSRWM	Industrial Complex on Solid Radioactive Wastes Management
IDC	Interest During Construction
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IESO	Independent Electricity System Operator
IISS	International Institute for Strategic Studies
INDCs	Intended Nationally Determined Contributions
INES	International Nuclear Event Scale
INRAG	International Nuclear Risk Assessment Group
INSAG	International Nuclear Safety Advisory Group
IPCC	International Panel on Climate Change
IPFM	International Panel of Fissile Materials
IRG	International Review Group
IRP	Integrated Resource Plan
IRRS	Integrated Regulatory Review Service
IRSN	Institute for Radiological Protection and Nuclear Safety, France
ISF-1	Intermediate Spent Fuel storage building
ITAR/TASS	Information Telegraph Agency of Russia-Telegraph Agency of the Soviet Union, Russian News Agency
JAEC	Japan Atomic Energy Commission or Jordanian 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)
JESS	Jadrová energetická spoločnosť Slovenska, a.s.
JMA	Japan Meteorological Agency
JNFL	Japan Nuclear Fuel Limited
JSW	Japan Steel Works
KA-CARE	King Abdullah City for Atomic and Renewable Energy
KEPCO	Korean Electric Power Corporation
KGHM	Copper Mining and Smelting Industrial Complex, Poland
KHNP	Korea Hydro & Nuclear Power Co
KINS	Korean Institute of Nuclear Safety
KKNPP	Kudankulam Nuclear Power Project
KKP2	Kernkraftwerk Philippsburg 2 (Philippsburg 2 Power Utility)
KMT	Chinese Nationalist Party
LNG	Liquefied Natural Gas
LOCA	Loss-Of-Coolant-Accident
LRTP	Liquid Radwaste Treatment Plant
LRWTP	Liquid Radioactive Wastes Treatment Plant
LTEP	Long Term Energy Plan, Ontario, Canada
LTO	Long Term Outage

LTS	Long-Term Shutdown
MAFF	Ministry of Agriculture, Forestry and Fisheries, Japan
MBTU	million British thermal units
MEP	Members of the European Parliament
METI	Ministry of Economics, Trade and Industry, Japan
MHLW	Ministry of Health, Labour and Welfare, Japan
MISO	Midcontinent Independent System Operator, U.S.
MoSPI	Ministry of Statistics & Programme Implementation, India
MoU	Memorandum of Understanding
MOX	plutonium Mixed Oxide
MSC	Mykle Schneider Consulting
NB Power	New Brunswick Power Corporation, Canada
NCA	Nuclear Cooperation Agreement
ND	Not Detected
NEA	Nuclear Energy Agency, China
NEI	Nuclear Energy Institute or Nuclear Engineering International, U.S.
NGO	Non-Governmental Organization
NGS	Nuclear Generating Station
NIAEP	Open Joint-Stock Company Nizhny Novgorod Engineering Company «Atomenergoproekt»
NISA	Nuclear And Industrial Safety Agency, Japan
NIW	Nuclear Intelligence Weekly
NJZ	nová jadrová zdroj
NNEGC	National Nuclear Energy Generating Company, Ukraine
NPAD	New Politics Alliance for Democracy
NPCIL	Nuclear Power Corporation of India Ltd
NPP	Nuclear Power Plant
NPS	National Policy Statement
NRA	Nuclear Regulatory Authority, U.S. or Japan
NRC	Nuclear Regulatory Commission, U.S.
NSC	New Safe Confinement (at Chernobyl)
NSG	Nuclear Suppliers Group
NTI	Nuclear Threat Initiative
NW	Nucleonics Week
OCHA	Office for the Coordination of Humanitarian Affairs
OECD	Organization for Economic Development and Co-operation
OFEN	Office Fédérale de l'Énergie, Switzerland
OKG	Oskarshamns Kraftgrupp AB, Sweden
OL3	Olkiluoto 3, Finland
ONR	Office for Nuclear Regulation, U.K.
OPG	Ontario Power Generation, Canada
OPPD	Omaha Public Power District
OPR	[Korean Reactor Design]
PATRAM	Symposium of the Packaging and Transportation of Radioactive Materials
PEA	Pre-engineering Agreement
PFBR	Prototype Fast Breeder Reactor
PG&E	Pacific Gas & Electric Co, USA
PGE	Polska Grupa Energetyczna, Poland
PHWR	Pressurized Heavy-Water Reactor
PIE	Power in Europe
PJM	Pennsylvania-New Jersey-Maryland Interconnection LLC

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
PV	Photovoltaic
PWR	Pressurized Water Reactor
PXE	Power Exchange Central Europe — Prague Stock Exchange
RAPS-1	Rajasthan-1, India
RBMK	Reaktor Bolshoy Moshchnosty Kanalny or high-power channel reactor
RCP	Reactor Coolant Pumps
REN21	Renewable Energy Policy Network for the 21st Century
RTE	Réseau de Transport d'Electricité
RWE	Rheinisch-Westfälisches Elektrizitätswerk
S&D	Socialists & Democrats Party
S&P	Standard & Poor's
SCE&G	South California Electric & Gas
SE	Slovenské Elektrárne
SEA	Strategic Environmental Assessment
SES	Schweizerische Energie-Stiftung
SFPF	Spent Fuel Processing Facility
SFSA	Spent Fuel Storage Area
SIEAC	Seoul International Energy Advisory Council
SIP	Shelter Implementation Plan
SLWS	Temporary Solid and Liquid Waste Storage
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
SSE	State Specialized Enterprise, Ukraine
SSU	Security Services of Ukraine
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority, Finland)
SUJB	State Nuclear Safety Office, Czech Republic
SWPP	Solid Waste Processing Plant
SWU	Separation Work Unit
TACIS	Technical Aid to the Commonwealth of Independent States Programme, EU Commission
TEPCO	Tokyo Electric Power Company, Japan
TMMOB	Türk Mühendis ve Mimar Odaları Birliği (Chamber of Turkish Engineers and Architects)
TORCH	The Other Report on Chernobyl
TRM	Third-party Review Meeting
TVA	Tennessee Valley Authority, U.S.
TVO	Teollisuuden Voima Oyj
UAE	United Arab Emirates
U.K.	United Kingdom
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

UPI	United Press International
U.S.DOE	United States Department of Energy
VAE SPB	Visagino Atomine Elektrine
VEB	Vnesheconombank (Russian Bank for Development and Foreign Economic Affairs)
VVER	Vodo-Vodianoï Energueticheski Reaktor
WNA	World Nuclear Association
WNISR	World Nuclear Industry Status Report
WNN	World Nuclear News
WSJ	Wall Street Journal
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 8: Status of Nuclear Power in the World

Table 20: Status of Nuclear Power in the World (as of 1 July 2016)

Country	Nuclear Reactors			Under Construction (Reactors)	Power	Energy
	Operates (Reactors)	Capacity (MWe)	Average Age (Years)		Share of Electricity ⁹⁴⁹	Share of Commercial Primary Energy ⁹⁵⁰
Argentina	3	1 632	25.8	1	5% (=)	2% (=)
Armenia	1	375	36.5		34.5% (+)	?
Belarus				2		
Belgium	7	5 913	36.3		37.5% (-)	10.5% (-)
Brazil	2	1 884	25.1	1	3% (=)	1% (=)
Bulgaria	2	1 926	26.8		31% (-)	18.5% (-)
Canada	19	13 524	33.0		16.5% (=)	7% (=)
China	34	29 402	6.6	21	3% (=)	1.5% (=)
Czech Republic	6	3 930	25.0		32.5% (-)	15.5% (-)
Finland	4	2 752	37.3	1	33.5% (=)	20.5% (=)
France	58	63 130	31.4	1	76.5% (=)	41.5% (=)
Germany	8	10 799	30.1		14% (-)	6.5% (=)
Hungary	4	1 889	31.0		52.5% (=)	17.5% (=)
India	20	5 215	20.3	6	3.5% (=)	1.2% (=)
Iran	1	915	4.8		1.3% (=)	<1% (=)
Japan	3	2 522	32.0	2	0.5%	<1%
Korea	25	23 073	19.4	3	31.5% (+)	13.5% (=)

⁹⁴⁹ From IAEA-Pris, as of 24 June 2016.

⁹⁵⁰ BP, "Statistical Review of World Energy", June 2016.

Country	Nuclear Reactors			Under Construction (Reactors)	Power	Energy
	Operates (Reactors)	Capacity (MWe)	Average Age (Years)		Share of Electricity ⁹⁴⁹	Share of Commercial Primary Energy ⁹⁵⁰
Mexico	2	1 440	24.4		7% (+)	1.5% (=)
Netherlands	1	482	43.0		3.5% (=)	1% (=)
Pakistan	3	690	22.0	3	4.5% (=)	1.5% (=)
Romania	2	1 300	14.5		17.5% (-)	8% (=)
Russia	35	25 443	30.7	7	18.5% (=)	6.5% (=)
Slovakia	4	1 816	24.3	2	56% (=)	21.5% (-)
Slovenia	1	688	34.7		38% (=)	?
South Africa	2	1 860	31.6		4.5% (-)	2% (=)
Spain	7	7 121	31.4		20.5% (=)	9.5% (=)
Sweden	8	8 205	36.3		34.5% (-)	24.5% (-)
Switzerland	5	3 333	41.2		33.5% (-)	19% (-)
Taiwan	5	4 428	34.0		16.5% (-)	7.5% (-)
UAE				4		
U.K.	15	8 883	32.4		19% (+)	8.5% (=)
Ukraine	15	13 107	27.4		56.5% (+)	23.5% (+)
USA	100	100 353	36.2	4	19.5% (=)	8.5% (=)
EU	127	118 834	31.4	4	26% ⁹⁵¹ (-)	12% (=)
World	402	348 030	29.0	58	10.7%⁹⁵² (=)	4% (=)

⁹⁵¹ Eurostat, “EU-28 Electricity Production by Source, 2015”, May 2016, see [http://ec.europa.eu/eurostat/statistics-explained/index.php/File:EU-28_Electricity_production_by_source,_2015_\(in_%25\)_update.png](http://ec.europa.eu/eurostat/statistics-explained/index.php/File:EU-28_Electricity_production_by_source,_2015_(in_%25)_update.png), accessed 24 June 2016.

⁹⁵² BP, “Statistical Review of World Energy”, June 2016.

Annex 9: Nuclear Reactors in the World “Under Construction”

Table 21: Nuclear Reactors in the World “Under Construction” (as of 1 July 2016)

Country/Reactors	Units	MWe (net)	Construction Start	Planned Grid Connection	Delayed
Argentina	1	25			
Carem25			08/02/14	2018 (first power) ¹	?
Belarus	2	2 218			
Belarusian-1		1109	06/11/13	2018 (operation) ²	?
Belarusian-2		1109	03/06/14	2020 (operation) ³	?
Brazil	1	1 245			
Angra-3			01/06/10	5/2019 (commercial operation) ⁴	Yes
China⁵	21	21 500			
Fangchenggang-2		1000	23/12/10	2016	Yes
Fangchenggang-3		1000	24/12/15	2019	?
Fuqing-3		1000	31/12/10	2016	Yes
Fuqing-4		1000	01/10/12	7/2017	?
Fuqing-5		1000	07/05/15	2020 ⁶	Yes
Fuqing-6		1000	22/12/15	2020 ⁷	Yes
Haiyang-1		1000	24/09/09	2017 ⁸	Yes
Haiyang-2		1000	21/06/10	2017 ⁹	Yes
Hongyanhe-5		1000	29/03/15	2021 ¹⁰	?
Hongyanhe-6		1000	24/07/15	2021 ¹¹	?
Sanmen-1		1000	19/04/09	6/2017 ¹²	Yes
Sanmen-2		1000	17/12/09	End 2017 ¹³	Yes
Shandong Shidaowan		200	01/12/12	2/2017 ¹⁴	Yes
Taishan-1		1660	28/10/09	2017 ¹⁵	Yes
Taishan-2		1660	15/04/10	2017 ¹⁶	Yes
Tianwan-3		990	22/12/12	2/2018	?
Tianwan-4		990	27/09/13	11/2018	?

Country/Reactors	Units	MWe (net)	Construction Start	Planned Grid Connection	Delayed
Tianwan-5		1000	27/12/15	2021 ¹⁷	?
Yangjiang-4		1000	01/11/12	7/2017	?
Yangjiang-5		1000	18/09/13	11/2017	?
Yangjiang-6		1000	31/12/13	7/2019	?
Finland	1	1 600			
Olkiluoto-3			12/08/05	2018 ¹⁸	Yes
France	1	1 600			
Flamanville-3			03/12/07	2018 ¹⁹	Yes
India	6	3 907			
Kakrapar-3		630	22/11/10	2017 (completion) ²⁰	Yes
Kakrapar-4		630	22/11/10	2018 (completion) ²¹	Yes
Kudankulam-2		917	04/07/02	6/2016 (first criticality) ²²	Yes
PFBR		470	23/10/04	3/2017 (criticality) ²³	Yes
Rajasthan-7		630	18/11/11	2018 ("completion date") ²⁴	Yes
Rajasthan-8		630	30/09/11	2019 ("completion date") ²⁵	Yes
Japan	2	2 650		Notes ²⁶	
Ohma		1 325	07/05/2010	?	Yes
Shimane		1 325	12/10/2007	?	Yes
Pakistan	3	1 644			
Chasnupp-3 ²⁷		315	28/05/11	12/2016 (commercial operation)	?
Chasnupp-4 ²⁸		315	18/12/11	10/2017 (commercial operation)	?
K-2 (Karachi 2) ²⁹		1 014	20/08/15	late 2021 (commercial operation)	?
Russia ³⁰	7	5 473			
Leningrad-2-1		1085	25/10/08	2017 ³¹	Yes
Leningrad-2-2		1085	15/04/10	2019 ³²	Yes
Novovoronezh-2-1		1114	24/06/08	2016 ³³	Yes
Novovoronezh-2-2		1114	12/07/09	2019 ³⁴	Yes
Rostov-4		1011	01/01/83 ³⁵	06/2017 ³⁶	Yes

Country/Reactors	Units	MWe (net)	Construction Start	Planned Grid Connection	Delayed
Severodvinsk Lomonosov-1		32	15/04/07	31/12/19 (commercial operation) ³⁷	Yes
Severodvinsk Lomonosov-2		32	15/04/07	01/12/19 (commercial operation) ³⁸	Yes
Slovakia	2	880			
Mochovce-3		440	01/01/85	Early 2017 (first power) ³⁹	Yes
Mochovce-4		440	01/01/85	2018 (first power) ⁴⁰	Yes
South Korea ⁴¹	3	4 020			
Shin-Hanul-1		1340	10/07/12	04/2018 (commercial operation) ⁴²	Yes
Shin-Hanul-2		1340	19/06/13	02/2019 (commercial operation) ⁴³	Yes
Shin-Kori-4		1340	15/09/09	03/2017 (commercial operation) ⁴⁴	Yes
United Arab Emirates ⁴⁵	4	5 380			
Barakah-1		1345	01/07/12	2017	?
Barakah-2		1345	30/05/13	2018	?
Barakah-3		1345	24/09/14	2019	?
Barakah-4		1 345	30/07/15	2020 ⁴⁶	?
USA	4	4 468			
Virgil C. Summer-2		1117	09/03/13	mid 2019 ⁴⁷	Yes
Virgil C. Summer-3		1117	02/11/13	mid 2020 ⁴⁸	Yes
Vogtle-3		1117	12/03/13	mid 2019 ⁴⁹	Yes
Vogtle-4		1117	19/11/13	mid 2020 ⁵⁰	Yes
TOTAL	58	56 610	1983-2015	2016-2021	38

Sources: IAEA-PRIS, MSC, 2016, unless noted otherwise

¹ No startup date in IAEA/PRIS. CNEA indicates fuel loading in second half of 2017. Startup date from CNEA, “Proyecto CAREM – Cronograma”; Undated, see <http://www.cnea.gov.ar/carem-cronograma>, accessed 24 May 2016. First power from WNA, “Nuclear Power in Argentina”, updated May 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Argentina/>, accessed 24 May 2016.

² No startup date in IAEA/PRIS. Operation start “November 2018” from WNA, “Nuclear Power in Belarus”, Updated September 2015, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Belarus/>, accessed 24 May 2016; and 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 26 May 2016. WNISR previously used commercial operation date (2019) from WNA.

³ No startup date in IAEA/PRIS. Ibidem.

⁴ Delayed numerous times. Start-up estimate was 2018 in WNISR 2015. Commercial operation date of May 2019 from Brunswick, “Global Aspects and Contract Model of the Angra 3 Project”, Paper presented at the IAEA Technical Meeting, 10-12 February 2016, see https://www.iaea.org/NuclearPower/Downloadable/Meetings/2016/2016-02-10-02-12-NPES/5_Brazil_Brunswick_R1.pdf, accessed 24 May 2016.

⁵ Unless noted otherwise, dates are from 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.

⁶ CNNC states that expected construction of first Hualong reactor to be completed by June 2020. *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.

⁷ Additional delay follows from CNNC statement in March 2016, see previous note.

⁸ Delayed again. Original startup date 2014, one-year delay compared to WNISR2015, see WNA, “Nuclear Power in China”, updated June 2016, see <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>, accessed 26 June 2016.

⁹ Delayed again at least by several months, from planned startup date 9/2016 in WNISR2015. Ibidem.

¹⁰ WNN, “Construction Starts on Hongyanhe 5”, 30 March 2015, see <http://www.world-nuclear-news.org/NN-Construction-starts-on-Hongyanhe-5-3003154.html>, accessed 8 July 2016.

¹¹ Ibidem.

¹² Delayed again by more than a year since WNISR 2015. According to Sun Qin, chairman of the China National Nuclear Corporation “*We are forecasting that if everything goes smoothly, the first unit will go into operation in June 2017, and the second unit at the end of 2017*”, as quoted in *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 8 July 2016. Chief Engineer of State Power Investment Corporation Wang Jun stressed in April 2016 that Sanmen-1 would be operational by the end of the year 2016, see *Nuclear Street News*, “Engineer Confirms Sanmen AP1000 Start Up In 2016”, 7 April 2016, see https://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news/archive/2016/04/07/engineer-confirms-sanmen-ap1000-start-up-in-2016-040702, accessed 8 July 2016 ; but again, Westinghouse later said that fuel loading is expected by the end of 2016, see Westinghouse, “First Westinghouse AP1000® completes cold Hydro Test at Sanmen 1”, 26 May 2016, see <http://www.westinghousenuclear.com/About/News/View/first-westinghouse-ap1000%20ae-completes-cold-hydro-test-at-sanmen-1>, accessed 8 July 2016.

¹³ Delayed again, by a year and a half compared to WNISR 2015; see previous note.

¹⁴ Delayed. Originally planned for startup in 2016. In March 2013, the date was pushed back by one year. This date from WNA, “Nuclear Power in China”, Updated June 2016, see <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>, accessed 7 July 2016.

¹⁵ Delayed again. A further delay of about 2 years compared to WNISR 2015. Taishan reactors are at least three years behind schedule. Taishan-1 is now expected to be operating in the first half of 2017; *Bloomberg*, “China’s Areva-Designed Nuclear Reactors to Start Up in 2017”, 15 March 2016, see <http://www.bloomberg.com/news/articles/2016-03-15/china-s-areva-designed-nuclear-reactors-to-start-up-in-2017>, accessed 15 March 2016. See also *NW*, “2015 was a strong year for Chinese nuclear power development, industry says”, 14 January 2016.

¹⁶ Delayed again. A further delay of about 2 years compared to WNISR 2015. Taishan reactors are at least three years behind schedule. Taishan-2 is now expected to be operating in the second half of 2017. See previous note.

¹⁷ WNA, “Nuclear Power in China”, Updated June 2016, see <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>, accessed 26 June 2016.

¹⁸ Delayed. After numerous revisions of the original planned commissioning in 2009. the date refers to “commercial operation”. In 2013, TVO was preparing for the possibility that the start of regular electricity production of Olkiluoto 3 may be postponed until year 2016, see TVO, “Information About the Start-up of Olkiluoto 3 Nuclear Power Plant Unit”, 11 February 2013, see <http://www.tvo.fi/news/32>, accessed 11 February 2013. In 2014, TVO decided not to provide any new startup date; see TVO, “TVO Does Not Provide an Estimate of the Start-up Time of Olkiluoto 3 Nuclear Power Plant”, see <http://www.tvo.fi/news/190>, accessed 12 February 2014. AREVA, “Updated Schedule for Olkiluoto 3”, 1 September 2014, see <http://www.areva.com/EN/news-10288/updated-schedule-for-olkiluoto-3.html>; and TVO, “Olkiluoto 3 ready for electricity production in 2018, according to the plant supplier”, 1 September 2014, accessed 1 September 2014. In 2016, TVO sticks to this position: “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>, accessed 5 May 2016.

¹⁹ Delayed again by at least one year compared to WNISR2015. Delayed numerous times from the original planned startup date in 2012. EDF’s “Reference Document 2014”, April 2015, states: “In November 2014, the project schedule was revised, with the first marketable production scheduled for 2017”. Now the project is expected to “load fuel and start up” in the fourth trimester 2018. EDF, “Rapport Annuel 2015”, February 2016.

²⁰ In WNISR 2015, start-up was delayed two years from previous estimates. DAE (Department of Atomic Energy of India) indicated an anticipated completion date of 2017-2018 for Kakrapar 3 & 4. DAE, in Rajya Sabha, “Statement Referred to in Reply to Rajya Sabha Starred Question n°14 for Answer on 23.04.2015 by Shri K.C. Tyagi Regarding Generation of Power by Nuclear Plants”, 23 April 2015, see <http://www.dae.nic.in/writereaddata/parl/budget2015/rssq14.pdf>, accessed 1 May 2015.

²¹ In WNISR 2015, startup was delayed 3 years from previous estimates. DAE indicated an anticipated completion date of 2017-2018 for Kakrapar 3 & 4. DAE, in Rajya Sabha, “Statement Referred to in Reply to Rajya Sabha Starred Question n°14 for Answer on 23.04.2015 by Shri K.C. Tyagi Regarding Generation of Power by Nuclear Plants”, 23 April 2015, see <http://www.dae.nic.in/writereaddata/parl/budget2015/rssq14.pdf>, accessed 1 May 2015. Grid Connection (30 September 2015) and commercial operation dates deleted from IAEA/PRIS in August 2013. The expected commercial operation date of “December 2015” has been replaced by “under review” in NPCIL, “Plants Under Construction, Kakrapar”, Undated, see <http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=91>, accessed 27 June 2016.

²² Delayed numerous times. Construction at least seven years behind schedule. No IAEA/PRIS startup date. This “First Criticality” date - a further delay of 9 months compared to WNISR 2015 - from NPCIL, “Plants Under Construction, Kudankulam”, Updated May 2016, see <http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=77>, accessed 12 June 2016.

²³ Delayed numerous times. No IAEA start-up date. Criticality is now “expected” by March 2017. A further delay of one year compared to WNISR 2015. Lok Sabha - “Unstarred Question No.1762 - To be answered On 04-05.2016 -Fast Breeder Reactors, The Minister Of State For Personnel, Public Grievances & Pensions And Prime Minister’s Office (Dr.Jitendra Singh)” see <http://dae.nic.in/writereaddata/parl/budget2016/lsus1762.pdf>, accessed 29 May 2016.

²⁴ Delayed. Startup date (31 March 2016) was deleted from IAEA/PRIS. DAE indicates an anticipated completion date of 2018-2019 for Rajasthan 7 & 8. DAE, in Rajya Sabha, “Statement Referred to in Reply to Rajya Sabha Starred Question n°14 for Answer on 23.04.2015 by Shri K.C. Tyagi Regarding Generation of Power by Nuclear Plants”, 23 April 2015, see <http://www.dae.nic.in/writereaddata/parl/budget2015/rssq14.pdf>, accessed 1 May 2015. Expected date of Commercial operation still June 2016 according to NPCIL, “Plants Under Construction, Rajasthan”, see <http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=87>, accessed 12 June 2016.

²⁵ Delayed. Startup date (30 September 2016) was deleted from IAEA/PRIS. DAE indicates an anticipated completion date of 2018-2019 for Rajasthan 7 & 8. DAE, in Rajya Sabha, “Statement Referred to in Reply to Rajya Sabha Starred Question n°14 for Answer on 23.04.2015 by Shri K.C. Tyagi Regarding Generation of Power by Nuclear Plants”, 23 April 2015, see <http://www.dae.nic.in/writereaddata/parl/budget2015/rssq14.pdf>, accessed 1 May 2015. Expected date of Commercial Operation still “December 2016”, according to NPCIL, “Plants Under Construction, Rajasthan”, see <http://www.npcil.nic.in/main/ConstructionDetail.aspx?ReactorID=87>, accessed 12 June 2016.

²⁶ Although there remain major obstacles for both reactors, with little public information on the exact status and advancement of construction, even though no planned grid connection date has been communicated, considering that *some* construction work is reportedly ongoing, for the time being, WNISR reintegrates Shimane-3 and Ohma in its listing of reactors under construction.

²⁷ Dates were deleted from IAEA/PRIS. These dates from WNA, “Nuclear Power in Pakistan”, Updated May 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Pakistan/>, accessed 12 June 2016.

²⁸ Dates were deleted from IAEA/PRIS. These dates from WNA, “Nuclear Power in Pakistan”, Updated May 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Pakistan/>, accessed 12 June 2016.

²⁹ Construction start of “K-2” reactor on 20 August 2015 was retroactively introduced on the IAEA-PRIS website in 2016, IAEA-PRIS, see <https://www.iaea.org/pris/> (2015), accessed 11 May 2016. In IAEA-PRIS database, grid connection is 7/2020. This commercial operation date from WNA, “Nuclear Power in Pakistan”, Updated May 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Pakistan/>, accessed 12 June 2016.

³⁰ No dates for Russian reactors in IAEA/PRIS. All dates (“Start”) and other information from WNA, “Nuclear Power in Russia”, Updated June 2016, see <http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power/>, accessed 14 June 2016, unless otherwise noted.

³¹ Delayed many times from original startup date in October 2013 (see WNISR 2009). Previous date of 2016 startup from *NIW*, “Weekly roundup”, 20 February 2015. WNA indicates grid connection June 2017 and commercial operation in 2018.

³² Previous date of 2018 from *NIW*, “Weekly roundup”, 20 February 2015. WNA now says grid connection 11/2019, and commercial operation 2020.

³³ Delayed from original start-up date on 31 December 2012 (see WNISR2009).

³⁴ Previously announced to start up in 2016.

³⁵ Rostov 4 - Construction date: IAEA-PRIS considers construction start date to be 16 June 2010, but the Rostov-4 reactor was already listed as under construction with a construction start of 1983 in the IAEA, “Nuclear Power Reactors in the World”, April 1986 Edition.

³⁶ Delayed numerous times. WNA indicates June 2017 or 2019. No update from WNISR 2015

³⁷ Delayed several times. This estimate of 2019 from WNA Reactor Database, “Akademik Lomonosov 1”, see <http://world-nuclear.org/NuclearDatabase/reactordetails.aspx?id=27570&rid=E4152D64-0C6B-475E-86ED-BDADF73D9C19&country=Russian%20Federation>, accessed 8 June 2015. As of June 2016, WNA indicates 2017-2018, without providing any reason.

³⁸ Delayed several times. This estimate of 2019 from WNA Reactor Database, “Akademik Lomonosov 2”, see <http://world-nuclear.org/NuclearDatabase/reactordetails.aspx?id=27570&rid=A0D78EB7-B62A-48FF-9D78-21A8E4534D90>, accessed 8 June 2015. As of June 2016, WNA indicates 2017-2018, without providing any reason.

³⁹ Delayed numerous times. Latest IAEA/PRIS date was deleted. This estimate - a few month delay compared to WNISR 2015 - from WNA, “Nuclear Power in Slovakia”, Updated April 2016, see <http://world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovakia/>, accessed 29 May 2016.

⁴⁰ Delayed numerous times. Latest IAEA/PRIS date was deleted. This estimate - a few month delay compared to WNISR 2015 - from WNA, “Nuclear Power in Slovakia”, Updated April 2016, see <http://world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovakia/>, accessed 29 May 2016.

⁴¹ No IAEA startup date for any Korean reactor. Dates from KHNP (Korean Hydro and Nuclear Power Co).

⁴² Delayed a further year since WNISR 2015. KHNP, “Shin-Hanul #1,2”, 30 April 2016, see <http://cms.khnp.co.kr/eng/content/547/main.do?mnCd=EN03020303>, accessed 29 May 2016.

⁴³ Delayed a further year since WNISR 2015. KHNP, “Shin-Hanul #1,2”, 30 April 2016, see <http://cms.khnp.co.kr/eng/content/547/main.do?mnCd=EN03020303>, accessed 29 May 2016.

⁴⁴ Delayed an additional year since WNISR 2015, a three-year delay since WNISR 2014. KHNP, “Shin-Kori #3,4”, 31 March 2016, see <http://cms.khnp.co.kr/eng/content/546/main.do?mnCd=EN03020302>, accessed 1 May 2016.

⁴⁵ No IAEA startup dates. Dates for three reactors from Emirates Nuclear Energy Corporation (ENEC), “ENEC Submits Operating License Application to FANR for Barakah Units 1 & 2”, 26 March 2015, see <http://www.enec.gov.ae/media-centre/news/content/enec-submits-operating-license-application-to-fanr-for-barakah-units-1>, accessed 23 May 2015.

⁴⁶ This date from WNA, “Nuclear Power in the United Arab Emirates”, Updated April 2016, see <http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx>, accessed 7 July 2016.

⁴⁷ Delayed. This date is from USDOE, “Quarterly Nuclear Power Deployment Summary—April 2016”, April 2016, see http://www.energy.gov/sites/prod/files/2016/04/f30/DEPLOYMENT_SCORECARD_APRIL_2016.pdf, accessed 7 July 2016.

⁴⁸ Ibidem.

⁴⁹ Ibidem.

⁵⁰ Ibidem.